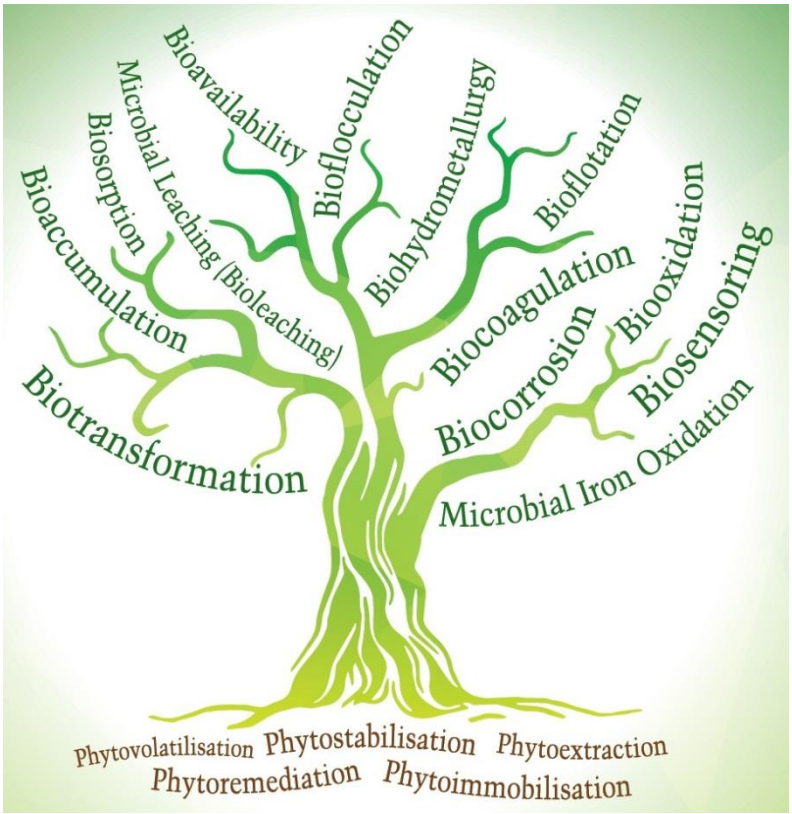
Ministry of Science and Education of Ukraine
National Technical University "Dnipro Polytechnic", Ukraine,
Technische Universität Bergakademie Freiberg, Germany,
under support of
GERMAN ACADEMIC EXCHANGE SERVICE (DAAD)

# PROCEEDINGS

of the International Conference

**"Applied Biotechnology in Mining"**

April 25-27, 2018




National Technical University "Dnipro Polytechnic"
Dnipro, Ukraine

UDC 602.4:622’17:622.88(062)

**Applied Biotechnology in Mining: Proceedings of the International Conference (Dnipro, April 25-27, 2018). – Dnipro: National Technical University “Dnipro Polytechnic”, – 2018. – 91 p.**

**ISBN**

The book contains abstracts on innovative approaches for biomining technologies including both phytomining and microbial technologies in mining, as well as environmental biotechnology and other environmental assessment technologies.

*The authors of the published materials are fully responsible for the selection, accuracy, reliability of the data, facts, quotations and other information.*

Edited by Prof. Dr. Hermann Heilmeier, Dr. Iryna Klimkina, Prof. Dr. Oleksandr Kovrov and others.

The Proceedings Book has been published under DAAD grant support in the frame of Program “Professionally Related Partnership with Universities of Developing Countries” and within the project “***Biotechnology in Mining – Integration of New Technologies into Educational Practice***” (2015 – 2018) due to cooperation between Technische Universität Bergakademie Freiberg (TU BAF), Germany, and National Technical University “Dnipro Polytechnic” (former National Mining University), Dnipro, Ukraine.

ISBN

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## CONFERENCE AGENDA

### Day 1: April 25, 2018, Wednesday

| Plenary Session | | Room 1/104 |
|---|---|---|
| **8.00-12.00** | Registration | |
| **09.30** | Welcoming Speech and Greetings | **Gennadiy PIVNYAK,** Rector NTU DP, Academician of the National Academy of Science of Ukraine<br>**Oleksandr SHASHENKO,** Prof. Dr. NTU DP, Vice-Rector on International Affairs<br>**Wolfgang MÖSSINGER**, Consul General, Head of Mission German Consulate General in Dnipropetrovsk, Ukraine<br>**Gisela ZIMMERMANN, Dr.** Head of the DAAD Information Centre in Kiev<br>**Hermann HEILMEIER,** Prof. Dr. TU BAF, Germany<br>**Oleksandr KOVROV,** Prof. NTU DP, Ukraine |
| **10.00** | The PCA of Phytomining: Principles, Challenges and Advances | **Hermann HEILMEIER,** Prof. Dr. TU BAF, Germany |
| **10.20** | Innovative Eco-Efficient Biohydrometallurgical Processes for the Recovery of Strategic and Rare Metals from Primary and Secondary Resources | **Michael SCHLÖMANN,** Prof. Dr. TU BAF, Germany |
| **10.40** | Use of Excavator Simulator for Education and Research | **Carsten DREBENSTEDT,** Prof. Dr. TU BAF, Germany |
| **11.00** | **Coffee break** | **Room 1/102** |

| Plenary Session | | Room 1/104 |
|---|---|---|
| **11.15** | Environmental Problems of Dnipropetrovsk region and Prospects for Application of Clean Technologies in the Industry | **Ruslan STRILETS**, Director Department of Ecology and Natural Resources of Dnipropetrovsk' Regional State Administration |
| **11.30** | Ash and Slag wastes of Thermal Power Plant as Technogenic Resource of Valuable Elements | **Tatiana ZAVGORODNIA** Manager, Department on Environmental Safety, LTD "DTEK Energy", Ukraine |
| **11.45** | Geomechanical Modeling of Mines and Dumps Using K-MINE to Minimize the Disturbed Lands Areas in Mining Operations | **Dmytro VINIVITIN** Deputy Head of Technical Department, FERREXPO POLTAVA MINING, Ukraine |
| **12.00** | CodelcoTech, Focused on a New Mining | **PATRICIO MARTÍNEZ BELLANGE** Director of Hydrometallurgical and Biotechnological Processes in CodelcoTech, Los Jardines, Huechuraba, Chile |

| | | |
|---|---|---|
| **12.15** | Modern Environmental Biotechnologies and Phytoremediation Techniques in Ukraine | **Oleksandr KOVROV,** Prof.<br>NTU DP, Ukraine |
| **12.30** | Second Generation Energy Crops Cultivation in Reclaimed Minelands | **Mykola KHARYTONOV,** Prof. Dr.<br>Dnipropetrovsk State Agrarian and Economics University |
| **12.45** | General photo | |
| **13.00** | **Lunch** | |
| **14.00-15.30** | • Round table for project coordinators and experts (room 1/102)<br>• For conference participants – excursions to the Folk Historical Museum named after Oleksandr Pol' and Geological and Mineralogical Museum of NTU DP | |
| **15.30-18.00** City Bus&Foot Excursion "**Katerynoslav-Dnipro: History and Modernity**" | | |

**Day 2: April 26, 2018, Thursday**

| **Conference Session 1** | | **Room 1/102** |
|---|---|---|
| **09.00** | A new "*Ferrovum*" species in a Schwertmannite-Producing Plant for Mine Water Treatment | **Michael SCHLÖMANN,** Prof. Dr.<br>TU BAF, Germany |
| **09.15** | BBS/BBF Encapsulated Microorganisms Technology for Solid Inoculation, the Next Step to Not Use Water in Bioleaching Processes with High Performance | **Patricio MARTÍNEZ BELLANGE**<br>Director of Hydrometallurgical and Biotechnological Processes in CodelcoTech, Los Jardines 927, Huechuraba, Chile |
| **09.30** | Siderophores for Selective Solid Phase Extraction of Strategic Elements | **Ringo SCHWABE,** PhD Student<br>TU BAF, Germany |
| **09.45** | Amphiphilic Siderophore Marinobactin for Froth Flotation Process | **Sylvi SCHRADER**, PhD Student<br>Helmholtz Institute Freiberg for Resource Technology, Freiberg, Germany |
| **10.00** | Leaching of Synthetic GaAs- and Indium- Bearing Sphalerite Ore with Help of "Reiche Zeche" Mine Water | **Danylo LYSENKO**, Master Student<br>NTU DP, Ukraine |
| **10.15** | Microbial Technologies in Mining: Prospects and Challenges in Ukraine | **Iryna KLIMKINA**, Dr.<br>NTU DP, Ukraine |
| **10.30** | **Coffee break and POSTER SESSION (room 1/102)** | |

| **Conference Session 2** | | **Room 1/102** |
|---|---|---|
| **11.15** | Bioavailability of Elements for Effective Phytoremediation and Phytomining: the Role of Rhizosphere Processes | **Hermann HEILMEIER,** Prof. Dr.<br>TU BAF, Germany |
| **11.30** | Genotypic Variation in the Accumulation of Rare Earth Elements (REE) in *Phalaris arundinacea* L. (Reed Canary Grass) | **Oliver WICHE**, Dr.<br>TU BAF, Germany |
| **11.45** | Short-Term Effect of Dispersion of Residual Sludge on the Soil *Eucalyptus camaldulensis* Dehnh, Tiaret (Algeria) | **Leila SOUDANI,** Dr.<br>Ibn Khaldun University, Tiaret, Algeria |

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|---|---|---|
| **12.00** | Reclamation Potential of *Robinia pseudoacacia* L. on Mining Rock within Steppe Zone of Ukraine | **Svitlana SYTNYK**, Dr.<br>Dnipropetrovsk State Agrarian and Economics University, Dnipro, Ukraine |
| **12.15** | Perspectives of Studying of Species of Family *Crassulaceae* dc. in Kryvyi Rih Area with Reference to Phytoremediation and Phytomining | **Olha KRASOVA**, PhD Student<br>Kryvyi Rih Botanical Garden of National Academy of Science of Ukraine |
| **12.30** | Evaluation of Antifungal Activity of Anaerobic Digestate and its Effect on Growth and Yield of Maize | **Nazia ZAFFAR**, Master Student<br>Quaid-i-Azam University, Islamabad, Pakistan |
| **12.45** | The Use of Coniferous Plants as Phytoremediators of Technosoil in Ukrainian Steppe | **Viktoriia LOVYNSKA,** Dr.<br>Dnipropetrovsk State Agrarian and Economics University, Dnipro, Ukraine |
| **13.00** | **Lunch** | |

| **Conference Session 3** | | **Room 1/102** |
|---|---|---|
| **14.00** | Vegetative reclamation of Damped Coal Waste Heaps in Novovolyn Mining Area | **Vasyl POPOVYCH**, Prof.<br>Lviv State University of Life Safety, Lviv, Ukraine |
| **14.15** | Remote-Sensing Methods of Indicator Estimations of Gardening Territories Placed by Mining Industry Waste | **Yuriy BUCHAVYY**, Dr.<br>NTU DP, Ukraine |
| **14.30** | Plant Cover Diversity of Technozemes of Reclamation Land at the Nikopol Manganese Ore Basin | **Kateryna ANDRUSEVYCH**, Dr.<br>Dniprovsko-Orilsky Nature Reserve, Dnipro, Ukraine |
| **14.45** | Comparison of the Soil Radioactive and Heavy Metals Pollution with Physiological Parameters of Test Plants at the Facilities of Sukhachevsky Industrial Site | **Olexandr VALYAEV,** PhD student<br>N.S. Polyakov Institute of Geotechnical Mechanics under the National Academy of Science |
| **15.00** | Phytoremediation Potential of Native Plants Growing on Reclaimed Coal Dumps | **Tatiana SOROKA**, 3-years Student<br>NTU DP, Ukraine |
| **15.15** | Technological and Environmental Aspects of Utilization of Hydrolysic Sulfuric Acid of Production of Pigment Titanium Dioxide | **Alona DERIMOVA**, Master Student<br>Ukrainian State University of Chemical Technology, Dnipro,Ukraine |
| **15.30** | **Coffee break and POSTER SESSION (room 1/102)** | |
| **16.00** | Justification of Mixture Composition for Reclamation of Lands Disturbed as a Result of Underground Coal Mining | **Ilya TKACH**, 3-years Student<br>NTU DP, Ukraine |
| **16.15** | Investigation of Phytoindication Effects due to Cadmium Contamination | **Ksenia TSUNIK**, Master Student<br>NTU DP, Ukraine |
| **16.30** | The Influence of Mercury Pollution on the Growth of Bio-Indicator Plants | **Katerina KALININA**, Master Student<br>NTU DP, Ukraine |
| **16.45** | Alternative energy sources: Electric Current from Living Plants | **Polina CHIRVA**, Master Student<br>Dniprovsky Transport and Economic College, Dnipro, Ukraine |
| **17.00** | End of the oral and poster sessions | **17.30 Dinner** |

**Day 3: April 27, 2018, Friday**

| Field trip | | Schedule |
|---|---|---|
| **8.00-19.00** | **FERREXPO POLTAVA MINING**<br><br>City of **Gorishni Plavni** (former Komsomol'sk), Poltava region, Ukraine, 39802 | 8.00 – Departure from the building 4 (Dmytro Yavornytskii Av. 19)<br>11.00 – Arriving to FERREXPO POLTAVA MINING<br>11.00 – 11.15 – Coffee Break<br>11.15 – 11.30 – Health Safety Briefing<br>11.30 – 14.30 – Plant excursion and visiting the Biological Engineering Costruction<br>14.30 – 15.30 – Lunch<br>15.30 – Departure to Dnipro<br>18.30 – 19.00 – Arriving |

**Poster Session**

| Posters | | Room 1/102 |
|---|---|---|
| **PS1** | Test of Microbial Transformation of Flotation Tailings to Construction Material | **Sabine KUTSCHKE,** Dr. Helmholtz-Zentrum Dresden- Rossendorf, Helmholtz Institute Freiberg for Resource Technology, Freiberg, Germany |
| **PS2** | Chronological Study of the Vegetation of Forest Massif of Sdamas | **Mohamed AZZAOUI**, Dr. Agricultural college Mostaganem, Algeria |
| **PS3** | Ecosystem Services and Ecological Structure of Technozems Vegetation within Nikopol Manganese Ore | **Kateryna MASLIKOVA**, Dr. Dnipropetrovsk State Agrarian and Economics University, Dnipro, Ukraine |
| **PS4** | The Phytotechnology of Iron-Ore Dumps Revegetation by Creation of Steady Plant Communities | **Mykola BARANETS**, PhD Student Kryvyi Rih Botanical Garden, National Academy of Sciences of Ukraine, Kryvyi Rih |
| **PS5** | Role of Plant Surface Lipids in the Process of Phytoremediation | **Oksana BERZENINA**, Dr. Ukrainian State University of Chemical Technology, Dnipro, Ukraine |
| **PS6** | Miscanthus Cultivation in Rocks with Different Geological Age | **Mykola KHARYTONOV**, Prof. Dr. Dnipropetrovsk State Agrarian and Economics University (DSAEU), Ukraine |
| **PS7** | Heavy Metal Accumulation in Roots of *Taraxacum officinale* Wigg | **Irina KOMAROVA**, PhD Student Kryvyi Rih State Pedagogical University, Ukraine |
| **PS8** | Using Plants for Greening of Tailing Ponds of Iron Ore Combines of Kryvyi Rih Area | **Ivan KORSHYKOV**, Prof.Dr. Kryvyi Rih Botanical Garden, National Academy of Sciences of Ukraine, Kryvyi Rih |
| **PS9** | Plants for Phytoremediation and Biofuel Production | **Maksym KULYK**, Dr. Poltava State Agrarian Academy, Ukraine |
| **PS10** | Ecological Features of Dendrofloras of Iron Dumps in Kryvorizhzhya (Ukraine) | **Liudmyla LYSOHOR**, Dr. Institute of Evolutionary Ecology, National Academy of Sciences of Ukraine, Kyiv |
| **PS11** | The Forest Land Reclamation after Lignite Open Pit Mining in the South of Ukraine | **Oleksandr MASYUK**, Dr. Oles Honchar Dnipro National University, Dnipro, Ukraine |
| **PS12** | The Prospects for Energy Trees Growing in Marginal Lands | **Mykola KHARYTONOV,** Prof. Dr. DSAEU, Ukraine |

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| **PS13** | Theoretical Model Integrating of Renewable Energy into the Mining Industry | **Kateryna ZHARAN**, PhD Student<br>Department of International Management and Environment, TU BAF, Germany |
| **PS14** | Greening Practice in Overburden Rock Dumps of the Iron Ore Quarries in Kryvyi Rih | **Ivan KORSHYKOV**, Prof.Dr.<br>Kryvyi Rih Botanical Garden, National Academy of Sciences of Ukraine, Kryvyi Rih |
| **PS15** | Mercury Contamination in Top Soil and Selected Plant Species in Area of Veľká Studňa Hg-Deposit (Malachov, Slovakia) | **Pavol MIDULA**, PhD Student<br>Matej Bel University in Banská Bystrica, Department of Biology and Ecology, Slovakia |
| **PS16** | Geochemical Soil Mapping, Phytoextraction of Critical Elements and Energy Plant Production in the Post Mining Area of Freiberg | **Precious Uchenna OKOROAFOR**, PhD St.<br>Institute for Biosciences, Biology/Ecology Unit, TU BAF, Germany |
| **PS17** | Application of Phytoremediation for Recovery of Salted Soils Located Near Coal Mining Ponds | **Valerii KOLESNIK**, Prof. Dr.<br>NTU DP, Ukraine |
| **PS18** | *Betula pendula* on the Iron Ore Dumps of the Kryvyi Rih | **Yuliya PETRUSHKEVICH**, PhD Student<br>Donetsk Botanical Garden, National Academy of Science of Ukraine, Kryvyi Rih, Ukraine |
| **PS19** | The Use of Pretreatment of Plant Seeds to Overcome the Phytotoxicity of Mine Waste Dumps During their Biological Reclamation | **Elina RUBAN**, Dr.<br>Institute of Chemical Technologies, Volodymyr Dahl East Ukrainian National University, Rubizhne, Ukraine |
| **PS20** | Taxonomic Structure of the Plant Communities of Tree Plantations at the Iron Ore Dumps in Kryvyi Rih City | **Nataliya SHEVCHUK**, PhD Student<br>Kryvyi Rih Botanical Garden, National Academy of Sciences of Ukraine, Kryvyi Rih |
| **PS21** | Viability of *Picea pungens* F. Glauca in the Kurtin Type of Kriviy Rih Plantations | **Elvira HUSEINOVA**, PhD Student<br>Kryvyi Rih Botanical Garden, National Academy of Sciences of Ukraine, Kryvyi Rih |
| **PS22** | Environment Assessment and Modelling of Salts Transfer in Four Land Restoration Schemes in the Coal Mining Region | **Mykola KHARYTONOV**, Prof. Dr.<br>Dnipropetrovsk State Agrarian and Economics University, Ukraine |
| **PS23** | Copper in Coal Mining Products of Vizeyska Lviv-Volyn Coal Basin Mine: Ecological, Geochemical and Toxicological Aspects | **Iryna KOCHMAR**, PhD Student<br>Lviv State University of Life Safety, Lviv, Ukraine |
| **PS24** | Biomonitoring of Ecological State of the Environment in the Zone of Influence of the "Chervonogradska" Mine of the Lviv-Volyn Coalfield | **Ulyana Ravlyk,**<br>Lviv State University of Life Safety, Lviv, Ukraine |
| **PS25** | Neutralization Effect of the Fly Ash and Coal Dump Wastes | **Tatiana SEREDYCH**, M.Sc.<br>NTU DP, Ukraine |
| **PS26** | Application of Biotechnological Methods of Vermicultivation for Ecological Restoration of Mining Sites | **Tetiana SKVORTSOVA**, Dr.<br>NTU DP, Ukraine |
| **PS27** | Phytorecultivation of Rock Mass Dumps with Application of Product of Utilization of Industrial Wastes as a Fertilizer | **Alona PASENKO**, Dr.<br>Kremenchug Mykhaylo Ostrogradskyi National University, Kremenchug, Ukraine |
| **PS28** | Research of the Vegetative Cover of Abandoned Coal Dumps | **Svitlana KULYNA**, Dr.<br>Chervonohrad Mining and Economic |

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| | | College, State Higher Educational Establishment, Chervonohrad, Ukraine |
| **PS29** | Selection of Lipids from Blue-Green Algae | **Karina DETSYURA**, Master Student Kremenchuk Mykhailo Ostrohradskyi National University, Kremenchuk, Ukraine |
| **PS30** | Prospects for Obtaining Valuable Products from Cyanobacteria Biomass | **Sergii DIGTIAR**, PhD Student Kremenchuk Mykhailo Ostrohradskyi National University, Kremenchuk, Ukraine |
| **PS31** | Ecologic Approach to the Restoration Process at Areas Degraded by Mining Operations | **Olga CHEPAK**, Dr. Donetsk National Technical University, Pokrovsk, Ukraine |
| **PS32** | Research of Secondary Biomaterials as Potential Energy Source for Mining Labour | **Svitlana LYSYTSKA**, Dr. NTU DP, Ukraine |
| **PS33** | Bioedagradation of Thermoplastic Polyurethanes | **Vladymyr SYTAR**, Dr. Ukrainian State University of Chemical Technology, Dnipro, Ukraine |
| **PS34** | Biotechnological Aspects Use of Waste in Ecological Safety | **Olena KHARLAMOVA**, PhD student Kremenchuk Mykhailo Ostohradskyi National University, Kremenchuk, Ukraine |
| **PS35** | Repeating Polyethylene Derivatives of the Low Dense of Hrybvovitsky Dump | **Uliana KHROMYAK**, Dr. Lviv State University of Life Safety, Ukraine |
| **PS36** | Cost-Effective Technology for Heat Power Stations Ashes Processing and Utilization | **Oleksandr BEREZNYAK**, Dr. NTU DP, Ukraine |
| **PS37** | Identification of Organic Components of Solid Waste on Satellite Imagery while Managing Environmental Safety | **Viola VAMBOL**, Prof. National University of Civil Protection of Ukraine, Kharkiv, Ukraine |
| **PS38** | Bioutilization of Waste Agroindustrial Complex for Receiving Biogas | **Svetlana GARMASH**, Dr. Ukrainian State University of Chemical Technology, Dnipro, Ukraine |
| **PS39** | Studying the Possibility of Using Red-Brown Clay for Reclamation of Coal Waste Dumps | **Nataliia PODPRIATOVA**, M.Sc. NTU DP, Ukraine |
| **PS40** | Recultivated Soil Heterogeneity: Ecological Aspect | **Kateryna ANDRUSEVYCH**, Dr. Dniprovsko-Orilsky Nature Reserve, Ukraine |
| **PS41** | Phase Dynamics of Phytocoenosis on the Damped Waste Heaps of Novovolyn Mining Area | **Vasyl POPOVYCH**, Prof. Lviv State University of Life Safety, Lviv, Ukraine |
| **PS42** | The Germanium Extraction from Technogenic Raw Materials by Microbiological Methods | **Iryna BLAIDA**, Prof. I.I. Mechnikov Odesa National University, Odesa, Ukraine |
| **PS43** | The Impact of Coal Waste Heaps on the Environment of Sokal District of Lviv Region | **Vasyl POPOVYCH**, Prof. Dr. Lviv State University of Life Safety, Lviv, Ukraine |
| **PS44** | Microbial Characterization of Abandoned Mining Area of Sidi Kamber North-East of Algeria | **Nabil CHARCHAR,** Dr. National Center for Biotechnology Research, Constantine, Algeria |

**CONTENT**

## Session 1.

# MICROBIAL TECHNOLOGIES IN MINING

# INNOVATIVE ECO-EFFICIENT BIOHYDROMETALLURGICAL PROCESSES FOR THE RECOVERY OF STRATEGIC AND RARE METALS FROM PRIMARY AND SECONDARY RESOURCES

**Michael Schlömann**
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The conventional pyrometallurgical route for winning of metals is increasingly confronted with a number of challenges which include the necessity to exploit more complex and deeper deposits, arsenic containing deposits, increased demands to protect the environment, and to use less energy. Biohydrometallurgical processes have been shown to be a good alternative for the winning of metals from poor and complex ores. On large scale they are performed mainly for the oxidative dissolution of sulfidic copper ores, but processes have also been developed for winning of zinc or cobalt from sulfidic ores, as well as for the biooxidation of gold ores. Due to the strategic importance of biohydrometallurgical processes TU Bergakademie Freiberg with support by the Dr. Erich Krüger Foundation in 2013 established the Biohydrometallurgical Center Freiberg (BHMZ).

The major focus of the BHMZ is on the winning of indium from sphalerite (ZnS) in regional ores. After initial experiments in batch cultures (shake flaks and bioreactors), currently a continuous leaching in a three-step bioreactor system is established. A moderately thermophlic mixed culture comprising *Leptospirillum ferriphilum*, *Acidithiobacllus caldus* and *Sulfobacillus thermosulfidooxidans* is being used, and efforts are directed at lowering the hydraulic retention times.

At the deposit Pöhla-Hämmerlein a sphalerite associated with chalcopyrite is especially rich in indium. Chalcopyrite so far usually is poorly bioleached, but can be chemically leached by high chloride concentration. Usually chloride is inhibitory for acidophilic iron-oxidizing bacteria. Therefore attempts are made to obtain chloride-tolerating iron-oxidizing bacteria and to use them for bioleaching of chalcopyrite and other ores.

In the longer run the most elegant way of winning metals from poor ores may be *in situ*-bioleaching. To investigate this approach in more detail, an experimental site for *in situ*-bioleaching was established in the research and teaching mine "Reiche Zeche". Here also, besides zinc, indium despite of its low concentration is the main valuable metal Using several methods, the permeability of the rock is increased by hydraulic stimulation and explosions.

Many ores in the ore omountain region contain arsenic, e.g. as arsenopyrite or tennantite. A special case is represented by the BiCoNi ores which contain cobalt and nickel in the the form of skutterudite ($CoAs_3$ or $NiAs_3$). Experiments are being performed to leach the metals from the BiCoNi ores.

In the "Theisen sludge" project bioleaching is performed on a secondary resource which resulted from dusts of copper smelters processing black-shale ores. This sludge contains a number of valuable metals. While these metals can be leached to a considerable extent, it was so far not possible to establish a selective leaching using set redox potential.

**Key words**: Indium, Cobalt, Continuous bioreactor leaching, *In situ*-bioleaching, Arsenides, Theisen sludge

# A NEW "*FERROVUM*" SPECIES IN A SCHWERTMANNITE-PRODUCING PLANT FOR MINE WATER TREATMENT

**Sophie Ullrich[1], Martin Mühling[1], David Holmes[2] and Michael Schlömann[1]**
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Mining activities for metals or coal often result in the development of acid mine drainage due to the oxidation of sulfidic minerals which get exposed to oxygen. The acidic mine waters are characterized by low pH, high concentrations of sulfate and ferrous iron, and possibly dissolved heavy metals or metalloids. Conventional treatment comprises neutralization and oxidation yielding a sludge of iron oxides/hydroxides. Since iron usually occurs in AMD in the reduced form, biological iron oxidation provides an alternative approach to remove iron and some sulfate from the waters. Thus, the company G.E.O.S. Freiberg has designed a plant yielding the iron hydroxysulfate schwertmannite ($Fe_{16}[O_{16}\,|\,(OH)_{10}\,|\,(SO_4)_3]*10\ H_2O$) as product of iron oxidation at ca. pH 3.

Investigation of the microbial community of such a plant revealed the dominance of members of the new, and still not completely described genus "*Ferrovum*" and of *Gallionella/Sideroxydans*-related acidophilic iron oxidizers. After obtaining several *Ferrovum* cultures contaminated not or only slightly with *Acidiphilium* strains, the cultures were investigated physiologically and genome sequences were obtained of strains JA 12, Z-31, and PN-J185. While strain Z-31 turned out to be fairly similar to the type strain P3G of "*Ferrovum myxofaciens*", strains JA12 and PN-J 185 showed considerable differences. While P3G and Z-31 appear to be diazotrophic and motile, PN-J185 and JA12 should be nonmotile and seem to be able to use a larger variety of fixed nitrogen sources ($NH_4^+$, $NO_2^-$, $NO_3^-$, urea). The second group of *Ferrovum* strains also has a smaller genome (only 1.9 to 2.0 Mb) which may be due to losses of some metabolic pathways. They also have a lower G+C content in their DNA, and genome–based phylogenetic indicators suggest that both JA12 and PN-J185 represent new species.

**Key words**: Acid Mine Drainage, Mine Water Treatment, Iron Oxidation, *Ferrovum*, Genome Sequencing

# BBS/BBF ENCAPSULATED MICROORGANISMS TECHNOLOGY FOR SOLID INOCULATION, THE NEXT STEP TO NOT USE WATER IN BIOLEACHING PROCESSES WITH HIGH PERFORMANCE

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Industrial hydrometallurgical processes using copper oxides and mixed oxide/sulfide exhibit high concentrations of several ions in their raffinates that hinder the treatment of copper ores with microorganisms because they are strongly affected by ionic impurities. On the other hand, water costs and hydric balance of processes in some mining sites, especially in desert areas, make it impossible to use fresh water for the dilution of toxic solutions and compatibility of the microbial activity in the bioleaching process. A strategy to address this in bioleaching applications has not been solved with an economical sustainable way.

CodelcoTech (Ex-BioSigma) has patented a new biomining microorganisms managing technology named BioSigma Bioleaching Seeds or BBS. This technology consists of encapsulated microorganisms using a natural matrix, conferring protection to cells and different additional advantages for the process.

Based in this technology a new strategy emerged, the use of BBS modified technology as a biofilter (BBF) for achieve 100% compatibility with raffinate solutions where BBS achieve just 75% for extreme toxic raffinate cases.

In order to demonstrate the potential for this integrated BBS/BBF technology, experimental columns using 100% raffinate solution with copper sulfide ore and encapsulated biomining consortium were established. The results show ferrooxidant activity (ORP over 600mV) past 100 days with 43% of copper recuperation in the BBS/BBF case, 16% more than the control without BBF that did not present ferrooxidant activity.

The data shows the remarkable advantages for the use of BBS/BBF technology in a complex bioleaching process, resolving water consumption in bioleaching, a critical variable in mining operations in northern Chile.

**Key words**: BioSigma Bioleaching Seeds Technology, Copper Sulfide Ore, Encapsulated Biomining Consortium

# SIDEROPHORES FOR SELECTIVE SOLID PHASE EXTRACTION OF STRATEGIC ELEMENTS

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All over the world, industrial mining is leaving contaminated areas and dumps that, although being full of valuable metals, have high concentrations of toxic heavy metals that pollute the environment. The development of sustainable alternative biomining and bioremediation processes offers the potential to fully exploit these unexploited mining sites.

To overcome metal limitation and metal stress bacteria have developed different strategies to inhabit such habitats. They excrete mixtures of low molecular organic acids and biomolecules with high metal affinity called metallophores, which allow them to dissolve and complex metals from minerals for a selective uptake of necessary trace elements through membrane pores or siderophore selective membrane receptors.

Interestingly, these molecules can be used for metal extraction processes of metals of industrial interest, and although these extremely strong metal-complexing molecules have been known for years, no industrial application in the field of biomining has been found yet, due to the challenging process of production and separation of these molecules, making this potential process too expensive.

Here we present a cost-effective way to exploit the high metal affinities of siderophores for the mobilization and extraction of metals from solid materials such as soils. Seven different bacterial strains were cultivated under iron-limiting conditions, the supernatant was extracted, and used in a 2-fold concentration for the following experiments. A complex soil matrix with natural levels of element mineralization from “El teniente” mine in Chile was employed as source of elements to study mobilization of the containing metals. After mobilization, metallophore-metal complexes were adsorbed on Amberlite XAD-16 resin and then eluted with a mixture of EDTA and acetic acid. As a reference, we used highly concentrated solution of the commercial metallophore desferrioxamine B (DFOB), EDTA and the culture media.

As a result, we obtained successful mobilization of especially iron, phosphorus and silicon, but also other metals / metalloids of interest as aluminium, molybdenum, manganese, copper, arsenic, zinc and vanadium. The extraction method with XAD shows about 80% recovery rate, dependent on the tested strain. Our results show that expensive purification processes are not necessarily needed to use siderophore for industrial purposes.

**Keywords:** Biomining, Bioremediation, Metallophores, Trace Elements, “El Teniente” Mine (Chile)

# TEST OF MICROBIAL TRANSFORMATION OF FLOTATION TAILINGS TO CONSTRUCTION MATERIAL

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The use and recycling of secondary raw materials increases resource efficiency. An interesting option would be the use of flotation tailings in the production of building materials. One of challenges is the content of mobilizable metals in the residues for ecological quality reasons of building material. Since flotation residues contain low metal concentration they are suitable for bioleaching approaches.

The aim is to bioleach base metals from flotation residues to match the raw quality parameters for building material. Quantitative chemical data of the feed material and pregnant liquor were acquired from all experiments by ICP-MS (Perkin Elmer ELAN 9000).

Flotation residues were taken from "Żelazny Most" (Poland). The used microorganisms are *Yarrowia lipolytica* (yeast)with a culture media containing (g/L): $KH_2PO_4$ 7; $Na_2HPO_4$ 2.5; $MgSO_4*7H_2O$ 1.5; $CaCl_2$ 0.15; $FeCl_3*6H_2O$ 0.15; $ZnSO_4*7H_2O$ 0.02; $MnSO_4*H_2O$ 0.06; yeast extract 0.5; glycerol 60, and *Thiobacillus thioparus* (bacterium) media with $(NH_4)_2SO_4$ 0.1; $K_2HPO_4$ 4; $KH_2PO_4$ 4; $MgSO_4*7H_2O$ 0.1; $CaCl_2$ 0.1; $FeCl_3*6H_2O$ 0.02; $MnSO_4*H_2O$ 0.02; $Na_2S_2O_3*5H_2O$ 10. The yeast was grown at 37°C and bacteria at 30°C.

The bioleaching was performed with a solid content of 5% in overhead shakers at 22°C for 7 days. Growing culture and culture broth were used as leaching agents.

Leaching the flotation residues with cultural broth of *Y. lipolyt*ica 5 to 20 times more metal, Cu and Pb, respectively, could be leached than with growing culture of *Y. lipolytica*. The results with *T. thioparus* show only a low mobilization. One reason for that observation may be the short incubation time.

The leaching results show the possibility to mobilize base metals from flotation residues. The quality requirements of construction material for Cu, Pb, and Zn could be matched after leaching with cultural broth of *Y. lipolytica*.

**Key words**: Secondary Raw Materials, Flotation Residues, Base Metals Bioleaching, *Yarrowia lipolytica*

# AMPHIPHILIC SIDEROPHORE MARINOBACTIN FOR FROTH FLOTATION PROCESS

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The consumption of metallic raw materials increased in the last years. The coverage of demand is getting more difficult, because both primary and secondary raw materials become more and more complex. To find a solution, some new ways have to go, like the combination of biotechnology with classic processes of processing methods.

The idea of this work is the biotechnological production of siderophores for the application in the classic froth flotation process. Siderophores are small organic molecules with a high affinity for binding Fe(III) and to form strong complexes also with other metals. They are produced by microorganisms (aerobic bacteria and fungi) and some plants to equalize the low bioavailability of iron in their environment. Especially the group of amphiphilic siderophores are very interesting. The hydrophilic part, carrying hydroxamate groups, is responsible for the binding of the metals. Flotation agents produced by the chemical industry with the same functional groups have already been applied successfully in this processing method. It can be suggested siderophores carrying the same functional groups, also work well as collectors. The fatty acid tail, that is representing the hydrophobic part, gets in contact with the bubble and spares additional chemicals and further working steps for making the target mineral particles hydrophobic.

This work includes on the one hand the biotechnological production of the marine siderophore marinobactin for the first time using a bioreactor and optimized conditions to make the production more efficient. On the other hand, the produced siderophore is tested in different froth flotation micro scale experiments like “Bubble-pick-up-test” and micro flotation in the Halimond Tube. These results show for the first time that amphiphilic siderophores are working in the froth flotation process and supply first concepts about the required concentration of siderophores in this processing process. In addition, the results also include interaction studies of different metals.

The application of amphiphilic siderophores as biochemicals in the froth flotation process can change the classic processing method in a more sustainable process – the bioflotation process. This will reduce the usage of other chemical agents and will make the process more purposeful and efficient.

**Key words**: Amphiphilic Siderophores, Marinobactin, Froth Flotation, Bioflotation

# MICROBIAL CHARACTERIZATION OF ABANDONED MINING AREA OF SIDI KAMBER NORTH-EAST OF ALGERIA

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The ecological importance of soil bacteria is not limited to their number or biomass, although these parameters contribute greatly. Indeed, their main asset lies in their great genetic and functional diversity. In this study carried out in the abandoned mine, located in Sidi Kamber (Oum Toub, Skikda, North-Est of Algeria) our objectives was to determine: a) contamination levels of this area by heavy metals b) heavy metal impact on bacterial communities and diversity c) possible risk on the ecological integrity of this area. Soil samples from three zones (Zone A upstream, Zone B at the center of the mine and Zone C downstream) were collected from the top layer (0–20 cm) of mining area. These samples were air-dried at room temperature and sieved through 2 mm mesh before further analysis according to standard methods. Soil pH was measured in a sample suspended in double-distilled water (at a sample: water ratio 1:2.5) with a pH meter, organic matter (OM%) and carbon content (C%) were determined using Walkey-Black method. Total nitrogen (TN) was measured using the Kjeldahl method, available phosphorus (P) was determined by Olsen method and cation exchange capacity (CEC) by titration method with $H_2SO_4$For contents of the heavy metals Lead (Pb), Copper (Cu), Zinc (Zn), Cadmium (Cd) and Nickel (Ni) 1 g of soil was digested with aqua regia method then filtered and diluted with de-ionized water. Heavy metals concentration (Pb, Cu, Cd, Zn and Ni) were determined by ICP-MS. Bacterial load (bacterial biomass) was estimated using plates counting methods. Individual distinct colonies were identified by their morphological and biochemical characteristics. Edaphic parameters of soils samples show that; the overall area was characterized by an acid pH, rates of OM%, C% were relatively low and TN contents were relatively high, resulting a low C/N ratio. The CEC was uniformly high, the content of available P was low. A Comparison of these edaphic parameters of the three sampling zones showed no significant variation for the pH values. However, zone A is characterized by the lowest values of C%, TN, OM%, CEC, C/N and the highest content of available P. Generally heavy metals contents were highest in zones B and C. The overall area was severely polluted with Cu, Cd, Pb, Ni and Zn, with a total concentration far exceeding international standard (CCME 2007; VROM, 2009; Baiz, 2000; Afnor, 1994). Heavy metal concentrations have shown significant variation between zones. According to bacteria biomass, we can classify the sites into two groups: group I includes zone B,C with a highest concentration of heavy metals and least load of bacteria and group II includes zone A and with a low concentration of heavy metals and high amount of bacteria. Zone A show the highest value of bacterial diversity with a high index of Shannon-Weaver, followed by Zone B and C respectively. The PCA analysis for soil characteristics indicates that organic matter and CEC positively affect the distribution of metallic trace elements in soil and also allowed us a clear separation of the studied zones. High levels of heavy metals have a negative impact on bacterial communities. Nonetheless, soil microorganisms have developed highly efficient systems for metal detoxification. Heavy metal contamination provides a strong pressure that selects for the recruitment of multiple resistance phenotypes that encode resistance to the predominant metals in the site.

**Key words:** Heavy metals, Mining Area, Sidi Kamber and Bacterial Diversity

# LEACHING OF SYNTHETIC GaAs- AND INDIUM-BEARING SPHALERITE ORE WITH HELP OF "REICHE ZECHE" MINE WATER

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The main goal of the experiment was to leach minerals using microbes. To accomplish this goal, the course dealt with the acquisition of adequate bacteria, by taking water samples in the underground mine "Reiche Zeche". Later leaching in stirred tank reactors was performed with two different substrates: synthetic GaAs and indium-bearing sphalerite ore. The leaching experiment was continuously monitored by the evolution of pH and redox potential. Samples were taken regularly in order to allow an evaluation of the actual leaching performance. The aim of the sampling part of the experiment was to establish a base for the following experiments. It was necessary to get some cultures likely able to leach sulfidic minerals. At the sampling points the pH and the redox potential were measured. In total, four samples were taken from several points. During sampling our group visited different location points in "Reiche Zeche" Mine. The Acid Mine Water (AMW) sample points were selected due to colour and measured pH of the water; aiming at the highest acidity. The common feature for all sample locations was dark brown colored water with a pH ranging between 2,4 and 3,3.

The taken samples were pre-cultivated and finally used for a leaching in stirred tank reactors with both GaAs and sphalerite for 15 days. Samples were taken regularly and pH and redox potential were measured; furthermore the concentrations of As, In, Zn, and Ga of the taken samples were measured by ICP-MS. The concentrations of arsenic and gallium were shown to increase until the addition of citric acid in all bioreactors; afterwards only the arsenic concentration kept on increasing.

To conclude the experiment, GaAs was leached quite fast and easily, if the cultures were growing actively. Nevertheless indium was not detectable, probably due to a too low In concentration in the ore material. It can also be inferred that the culture had advantages in changing conditions and the range of operation was wider than that of a pure culture because mixed culture can cover more pH conditions than pure cultures.

**Key words:** Synthetic GaAs and Indium Bearing Sphalerite Ore; Mixed Culture

# THE GERMANIUM EXTRACTION FROM TECHNOGENIC RAW MATERIALS BY MICROBIOLOGICAL METHODS

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The purpose of this work is the study and comparative analysis of germanium extraction and related valuable components of the sublimates from the burning of domestic power coals (product 1) and germanium sulfide materials, which are a waste of lead-zinc production (product 2), by traditional chemical methods (distillation of germanium in the form of tetrachloride from raw and preliminary burning source) and by microbial bioleaching of sulfur-oxidizing bacteria.

The efficiency of germanium tetrachloride extraction from products 1 and 2 was 78.50 and 19.52%, respectively. Such difference in efficiency of extraction is caused by germanium confinement as concomitant trace component to the basic phases of carriers. In sublimates germanium is a part of the acid-soluble compounds easily accessible (this includes the soluble form $GeO_2$, germanates of alkali metals, bivalent metals, iron and aluminum, insignificant quantities of elementary germanium). The share of acid-nonsoluble compounds (tetragonal $GeO_2$ and silico-germanates) in the product accounts for 21.5% of germanium.

The proportion between acid-soluble and acid-nonsoluble (silico-germanates, solid solutions of $GeO_2$ in $SiO_2$) germanium forms is 19.52 and 80.48%, respectively, in product 2. In connection with this we performed a preliminary heat treatment of raw material for germanium transfer to easily opening phases (fulfilled enough and often used method in the germanium technology). Our experiments have shown that implementation of restorative firing (with addition of 30-40% carbon at 1150 $^0$C) of sulfide product 2 considerably impacted on the extraction of germanium tetrachloride (91.76%) in comparison with its low extraction at straight distillation of hydrochloric acid (19.52%). The results are confirmed by a set of physical methods (infrared spectroscopy, electronic microphotograph, X-ray analysis).

We analyze the results of processing the same so-called hard phases material (product 2) with the help of microorganisms. The role of microorganisms which are present in initial germanium-containing raw materials and their influence on leaching metals processes has been studied and showed their high activity. In the sequel from products 1 and 2 strains of microorganisms as own microflora of raw materials were isolated. Their activity has been studied in comparison with typical and collection strains. All isolated strains of microorganisms leached metals from solid wastes approximately at 80–95%. The optimal parameters of bacteria's metals bioleaching process from wastes have been defined. Conversion kinetics from a solid phase in solution has been studied for such macroelements as iron, zinc and lead. It has been established that selected strains of bacteria are capable to extract from initial raw materials not only macrocomponents (iron, zinc, lead, manganese, aluminum, nickel), but also microimpurity of rare metals (gallium, germanium, zirconium). It is important that these metals were not extracted by traditional chemical methods (with application of aggressive conditions and heat) independently of the phase composition of the source.

The results have practical significance and can be the basis for developing a unified biotechnological method of technogenic waste processing with a purpose of their sterilization and detoxification with simultaneous obtaining concentrates of valuable metals.

**Key words**: Domestic Power Coals, Waste of Lead-Zinc Production, Germanium Tetrachloride Extraction, Microbial Bioleaching, Rare Metals, Sulfur-Oxidizing Bacteria

## Session 2.

## PHYTOTECHNOLOGIES IN MINING

# THE PCA OF PHYTOMINING: PRINCIPLES, CHALLENGES AND ADVANCES

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There is a number of commercially valuable elements whose concentration in the crust of the earth is too low for an economic mining with traditional approaches. However, phytotechnologies which take advantage of the capacity of certain plant species to take up these elements from the soil solution and accumulate them to large amounts in their biomass can be used for an economic winning of various metals and metalloids. This specific use of phytoextraction which has already been as one technology in the phytoremediation of contaminated sites is called "phytomining".

The aim of phytomining is to accumulate the elements of interest in high concentrations in the aboveground biomass of plants, from which, after harvest, these elements can be extracted for purification. The whole process consists of a number of individual steps, each of them related to a different scientific discipline and requiring specific methods. The main steps are the following:

(1) Growth of plants: Here usually (second generation) energy crops with a high biomass yield and some tolerance to adverse soil conditions are used. The high biomass gain allows for a large amount of elements to be accumulated in the biomass and an easy harvest of the plants.

(2) Increase of bioavailability of target elements in the soil and root environment (rhizosphere): Availability of the valuable elements can be increased by either induced phytoextraction by adding chelating agents like EDTA, organic acids or ammonium sulphate to the soil, or by growing plants with a high capacity for modifying their rhizosphere via e.g. organic acids or siderophores.

(3) Digestion of plant material: After harvest, the dried plant material can either be burnt and the target elements recovered from ash, or the fresh plant material can be digested for producing biogas as a second economically valuable product.

(4) Extraction of target elements from digestates: After fermentation (or ashing followed by chemical leaching) of the biomass, or alternatively after chemical or enzymatical digestation, the target elements can be extracted from the liquid phase via solid-liquid or liquid-liquid-separation.

(5) Re-use of digestates as fertilizer for plant growth: The residues from the digestation process still contain valuable nutrients, mainly phosphorous, which can be used as fertilizers.

Experiments were performed with various (second generation) energy crops (grasses, forbs) grown in pots and in the field, investigating their potential for accumulation of germanium (Ge) and rare earth elements (RREs). Forbs turned out to accumulate REEs, whereas grass species accumulated predominantly Ge. Whereas forbs accumulated Ge mainly in belowground organs, accumulation of Ge in grasses was highest in stems and leaves. Co-cultivation of oats with lupines increased concentration of REEs in above-ground organs of oats. Mixed cultures of rapeseed and lupine increased the concentration of available Ge in the soil and the concentration of Ge in rapeseed plants. The concentration of Ge and REEs in residues after fermentation could be increased up to 10-fold compared to the plant biomass of reed canary grass (*Phalaris arundinacea*).

It is concluded that grassy energy crops are good accumulators for Germanium, whereas forbs accumulate mainly rare earth elements. The amount of available elements in the soil solution can be increased by chelating agents released from plants with very active rhizosphere processes such as lupines. Digestion of plant biomass does not only yield biogas, but also residues in which target elements are concentrated with respect to the plant biomass. Therefore the investigated plant species are good candidates for an efficient extraction of valuable metal(loid)s from the soil via phytomining.

**Key words:** Phytoextraction, Accumulation, Biomass, Chelatants, Digestion, Fermentation

# BIOAVAILABILITY OF ELEMENTS FOR EFFECTIVE PHYTOREMEDIATION AND PHYTOMINING: THE ROLE OF RHIZOSPHERE PROCESSES

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The success of phytoremediation (especially phytoextraction) and phytomining depends heavily on the bioavailability of target elements, which, among others, is a function of soil mineral phases, soil organic matter, pH and redox potential. The use of soil additives which, e.g., change soil pH or increase the amount of chelating compounds, has been propagated in the past in order to desorb the target elements from the soil matrix. These additives, however, may have negative environmental consequences by causing leaching of toxic elements from the soil due to enhanced mobility in the soil solution. For this reason less dangerous alternatives are necessary which use the natural capacity of plants to increase availability of target elements in their root environment. Here we report on rhizosphere mechanisms of various plant species to increase bioavailability of germanium (Ge), rare earth elements (REEs) and also toxic elements for phytomining and phytoremediation.

Several species of forbs (e.g. *Lupinus albus, L. angustifolius, Fagopyrum esculentum, Brassica napus)* and grasses (e.g. *Hordeum vulgare, Panicum miliaceum, Phalaris arundinacea, Zea mays, Phragmites australis, Miscanthus giganteus*) were grown on various substrates, either without or with addition of organic acids, in mono- and mixed cultures both in the greenhouse and in the field. Plants were harvested, and the concentration of metals and metalloids was analyzed in the dried plant material via ICP-MS following micro-wave digestion with concentrated $HNO_3$ and HF. Germanium and REEs were also determined in different soil fractions after sequential extraction.

The addition of carboxylates (e.g. 1 and 10 mM citric acid) dramatically increased the mobility of Ge in soils (the amount of extractable Ge was increased up to 10-fold) and Ge contents in the plant material (ca. 50%). However it seems that this mobilization is restricted to very acidic conditions (pH < 4). The accumulation of Ge in aboveground plant material was by a factor of 10 higher in grasses than in forbs. In contrast, forbs accumulated higher concentrations of REEs than grasses. For those plants with a high capacity for lowering pH and releasing carboxylates from roots (e.g. genus *Lupinus*), which is a common strategy of plants to mobilize poorly available nutrients such as Fe, Mn and P in the rhizosphere, we could demonstrate that they were able to mobilize Ge and REEs.

Due to the chemical similarity between Si and Ge grass species, which accumulate Si in their shoots, are able to take up higher amounts of Ge than forbs. On the other hand, forbs which can release a high amount of organic acids from their roots and thus mobilize Ge in the soil, show only a limited capacity for Ge uptake, but a high capacity for accumulation of REEs. The mobilization of Ge and REEs seems to be restricted to the rhizosphere with its distinct pH and carboxylate gradients. Due to the higher reactivity of Ge in the soil, plant availability of Ge is lower compared to Si. This demonstrates that mobility of elements in the soil solution *per se* is not necessarily a good indicator for bioavailability of target elements in phytomining and phytoremediation.

**Keywords:** Bioavailability, Germanium, Rare Earth Elements, Phytoextraction, Rhizosphere

# USING PLANTS FOR GREENING OF TAILING PONDS OF IRON ORE COMBINES OF KRYVYI RIH AREA

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The tailing ponds of the iron ore-dressing combines occupy thousands of hectares in Kryvyi Rih area and create a serious ecologic problem in this region. If the surface of the tailing ponds dries up, it leads to dust storms, which often cover housing areas of the city as well as surrounding villages. To green these tailing ponds is one of the most reliable methods of dust suppression. However, the solving of this problem is fraught with a number of difficulties because very restricted quantity of herbaceous plant species can survive in the sludge substrate under conditions of the steppe zone of Ukraine. It is caused not only by low content of mineral nutrients and absence of organic substances, but primarily by excess in water-soluble salts; their concentration varies between 5 and 20 g/l. Only some of species reside in the sludge spontaneously, e. g. *Salsola tragus* L. s. str., *Kochia scoparia* (L.) Schrad., *Calamagrostis epigeios* (L.) Roth., *Lactuca tatarica* (L.) C.A. Mey., *L. saligna* L., *Phragmites australis* (Cav.) Trin. ex Steud., *Suaeda prostrata* Pall., *Tripolium pannonicum* (Jacq.) Dobrocz., *Scirpus tabernaemontani* C.C.Gmel., *Bolboschoenus maritimus* (L.) Pall., *Sonchus arvensis* L., *Atriplex micrantha* C.A.Mey., *Euphorbia virgata* Waldst. & Kit., but they occur very seldom in the some sites. The spontaneous establishment takes place at the site borders only. During last 30–40 years, different research organizations tried repeatedly to green the tailing ponds without covering with any fertile substrate. We developed two strategies: a) planting of herbaceous perennials which are able to grow in the salinity-affected, infertile, dense substrates and still to regenerate vegetatively, covering the surface of the tailing ponds; b) sowing of annual plant seeds. These species can survive under such conditions, their above-ground biomass serves as a block for dust spreading.

In 2016–2017, we used both approaches to green the tailing ponds of two large iron ore combines in Kryvyi Rih area. As a result, it was possible to make planting around 52 ha by using spring and autumn sowings and planting of plants with a closed root system. Our two-year-long testing of gramineous herbs showed that selected species have high viability in the dump conditions and provide their main function – they limit the spread of a dust. Advantage of gramineous herbs in process of growing composes in forming fibrille root system that fix the surface of a dump, the over-ground part serves as block for dust spreading. At spring plantings of container culture, vegetatively mobile gramineous herbs begin to settle in the vegetative period and, under relatively favourable conditions, even a few meters from the parent. Seeding of gramineous herbs using agrotechnical methods developed by us contributes to the dust retention already in the first months of their growth, as well as their dead and underground biomass at the end of the growing season. There is a kind of mulching of the surface of the sludge with the dead biomass of plants. Right at the moment of tillering gramineous herbs start to perform the function of dust retention. Vegetatively mobile plants colonize the entire surface of the heap including those local areas where the accumulated water periodically evaporates during the hot periods of the year. In addition, the greening of the tailing ponds is carried out once and, in subsequent years, any agrotechnical measures are not needed.

Greening by plants of the tailing ponds is more economically safe, than covering their surface with chemical reagents.

**Key words:** Kryvyi Rih, Tailing Ponds, Greening

# GENOTYPIC VARIATION IN THE ACCUMULATION OF RARE EARTH ELEMENTS (REE) IN *PHALARIS ARUNDINACEA* L

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Rare earth elements (REEs) represent a number of economically valuable elements whose increasing demand is closely associated with rapidly growing high-tech sectors such as high-tech electronics and "green energy technologies". In soils REEs are actually not rare but occur widespread with concentrations comparable to some essential plant nutrients (e.g. Zn). Thus, a promising chance to improve supply of these resources could be phytomining.

The aim of the present study was to explore effects of genotype and selected soil properties (organic matter content, pH) on the accumulation of REEs in plants of *Phalaris arundinacea*.

In a field experiment 12 different genotypes and 15 populations of *Phalaris arundinacea* (reed canary grass) were cultivated on four substrates with differing organic matter contents and pH-values in order to distinguish effects of genotype and soil properties. On each of the substrates each genotype was cultivated on plots (4 $m^2$ each) with three replications. After harvest REE concentrations in the shoots were measured by means of ICP-MS.

High contents of organic matter and low pH significantly increased ($p < 0.001$) the REE concentrations in all tested plants showing a strong impact of soil properties on REE availability. Compared to plants cultivated on the alkaline substrate (sums of REEs: 13 mg $kg^{-1}$), plants on the acidic substrate were characterized by concentrations that were a factor of roughly three higher (28 mg $kg^{-1}$) with maximum concentrations in those plants amended with compost (up to 78 mg $kg^{-1}$).

Considering all substrates we found substantial genotypic variation in the accumulation of REEs in shoots of the plants. For the acidic substrate REE concentrations between genotypes ranged from 10 mg $kg^{-1}$ to 80 mg $kg^{-1}$ with a low variability between the replications of a certain genotype. The substrates used in this study significantly affected the efficiency of the genotypes to accumulate REEs in the shoots indicating a high genotypic plasticity with regard to this trait. REE concentrations in the shoots correlated significantly positively ($r = 0.94$) with those of Fe suggesting a strong relationship between the accumulation of REEs and Fe acquisition in the rhizosphere.

It is concluded that accumulation of rare earth elements in *Phalaris arundinacea* heavily depends on the genotype. REE accumulation can be increased by application of organic substances to the soil and adjusting pH to acidic values. Uptake of REEs may be related to iron nutrition of plants.

These studies have been carried out in the framework of the Phalaris II project (Grant number FKZ 220 18913), financed by the Federal Ministry of Food and Agriculture, Germany. The authors are grateful to students and laboratory assistants contributing in the field work and sample preparation.

**Key words:** Phytomining, Plant-Soil Interactions, Nutrient Availability, Rhizosphere Processes, Uptake and Accumulation of Rare Earth Elements, Reed Canary Grass

# TESTING OF PHYTOMELIORATED DARK – GRAY SCHIST CLAY PROFILE WITH MISCANTHUS

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Renewable energy, especially from perennial grasses, can significantly affect the processes of solving global problems in the field of energy security. Among the extensive list of plants that can be used as energy crops, the most preferable are those that do not require intensive cultivation technologies, are unpretentious to environmental conditions and yield large harvests even on marginal, contaminated and disturbed soils. A promising plant in this regard can be miscanthus.

To study the potential of this crop when growing on marginal and disturbed soils a field experiment was established at Pokrov land reclamation station of Dnipropetrovsk State Agrarian and Economic University. The main attention was focused on the possibility of Miscanthus × giganteus growing on dark-gray schist clay (DGSC). Rhizomes of miscanthus were planted in lysimeters with geochemically active DGSC. The clay was taken from the experimental plot, which is in the stage of natural overgrowing for four decades. The required amount of rock was selected in three strata: 0–20 cm, 20–40 cm and 40–60 cm and has been poured into the lysimetric containers with a layer of 60 cm. Sand was used as underlying substrate. Morphometric parameters, biomass productivity and content of microelements in plant samples were studied.

Unlike other rocks dark-gray schist clay contains up to 1% pyrite. As a result of its oxidation in the presence of water the ferrous form of iron and sulfuric acid are formed. They, acidifying the soil solution in turn, detrimentally affect growth and development of plants. Similarly, sulfur oxide is harmful, which is a consequence from the pyrite oxidation without access of water. These chemical processes are accompanied by the release of heat, causing the dryness of rocks and scant content of organic matter. Thus, these rocks are harmful for most crops and without preliminary melioration unsuitable for their growth. On the territory of Pokrov reclamation station the piling of this clay onto the earth's surface took place about 50 years ago. So this substrate was under the influence of chemical and biological weathering. Data on pH (6.2–7.5) and electrical conductivity (90–1840 μS/cm) show that the dark-gray schist clay in the aeration zone is still under the influence of oxidation-reduction processes. At a depth of 20-60 cm, pH varies from slightly alkaline to slightly acidic. The lower layers are more salty. Such unfavorable factors affected the growth and development of miscanthus. Maximum height of plants in the first year of cultivation did not exceed 125–130 cm. The best values were noted for plants grown on the stratum 40–60 cm, the worst on the stratum 20–40 cm. The intensity of monocarpic shoot formation was also low and by the end of the year varied from 4 (stratum 0–20 cm) to 9 shoots per plant (stratum 20-40 cm). As a result, the productivity of dry biomass was small. The average dry weight of one plant grown on 20–40 cm and a 40–60 cm strata was almost identical – 201.8 and 213.4 g respectively. Plant productivity on the 0-20 cm stratum was significantly lower – 143.6 g. Accordingly in the first year Miscanthus × giganteus is able to produce a yield from 2 to 3 tons per hectare on dark-gray schist clay.

The content of microelements in the aboveground biomass of Miscanthus was as follows: for Zn 19.89-13.26 μg/g, Cu 3.21-1.91, Fe 369.86-134.45, Mn 30.53-15.38, Pb 2.71-1.67 μg/g. The relatively small content of trace elements in the above-ground mass can be explained by the effect of preferential accumulation of heavy metals in the roots.

Thus, the ability of Miscanthus plants to produce a stable yield and a small accumulation of heavy metals in the above-ground biomass suggests the prospects of this energy crop cultivation on phytomeliorated mining rocks.

**Key words**: Dark – Gray Schist Clay, Soil Profile, Phytomelioration, Miscanthus

# PHASE DYNAMICS OF PHYTOCOENOSIS ON THE DAMPED WASTE HEAPS OF NOVOVOLYN MINING AREA

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Nineteen non-recultivated waste heaps are found on the territory of the Novovolyn mining area (Lviv-Volyn coal basin), three of which are damping. The total area of disturbed lands is 116.7 hectares. An important role for optimization of disturbed objects is played by natural colonization by vegetation, since it indicates the state of the rocks the waste heaps are made of. Studying of phytocoenoses, which are formed during self-establishment, gives an opportunity to estimate the formed groups, considering their place and role in the vegetation cover of the region and predict their further development. On the waste heaps, where combustion is stopped, the phytomelioration process develops in two ways: a) the formation of phytocenoses cultures with the part of wood species (*Robinia pseudoacacia*, weeping birch, goat willow, Tartarian dogwood); b) natural colonization by zonal and synanthropic vegetation.

On the damped waste heaps there are three phases of vegetation cover formation: pioneer phase → simple phytocenosis → complex phytocoenosis. The analysis of the species composition at different stages of the vegetation colonization of the damped waste heaps has made it possible to reveal the following pattern: at the first phase of vegetation colonization the diversity of species is very low and, as a rule, these are ruderal species. At later phases, the number of species increases and the weeds content decreases. Certain species form aggregations (cluster of individuals) resulting in group arrangement of individuals in the population. In the pioneer phase vegetation colonization of damped waste heaps by aggregation is presented by *Plantago lanceolata*; in simple phytocoenosis – *Artemisia absinthium, Plantago lanceolata, Trifolium campestre*; in complex phytocoenosis – *Artemisia vulgaris, Arctium lappa, Trifolium pratense, Calamagrostis epigeios, Daucus carota*. Uniform distribution is inherent to phytocoenoses on recultivated waste heaps, particularly with *Robinia pseudoacacia.* Random distribution is inherent to a significant number of populations, in particular – *Tussilago farfara, Chamomilla suaveolens, Taraxacum officinale*.

As a result of the phytomelioration efficiency analysis of the waste heaps vegetation it was determined that low-growing vegetation prevails on the damped waste heaps, as shown by the low coefficient of phytomelioration efficiency $K_{FM}$ = 3.45. On the recultivated waste heaps, the phytomelioration efficiency coefficient ($K_{FM}$ = 6.2) is more closely related to the pine-oak complexed subor ($K_{FM}$ = 9.4), which indicates the dominance of high woody vegetation.

As a result of the calculations of the diversity index on the test areas it can be assumed that the species diversity index of the damped waste heaps is not high (by Whittaker – 3.23, by Simpson – 4.78, by Shannon – 0.67). The uniform distribution, calculated on the basis of the Simpson's and Shannon's methods, has a high index of 0.95–0.99, which indicates the suitability of the waste heaps for natural vegetation colonization and the regular distribution of vegetation on the waste heaps.

On the damped waste heaps with high content of heavy metals in rock refuse, a layer of soil mixtures must be applied before the afforestation. The most effective within the Small Polissya are carbonate loams. During vegetative reclamation of damped waste heaps areas, it is necessary to prepare the soil for planting. Gardening should be carried out on sites that are located on small plate-shaped tops and slopes of waste heaps.

**Key words:** Vegetative Reclamation, Damped Waste Heap, Phytocoenosis, Phase Dynamics

# MERCURY CONTAMINATION IN TOP SOIL AND SELECTED PLANT SPECIES IN AREA OF VEĽKÁ STUDŇA Hg-DEPOSIT (MALACHOV, SLOVAKIA)

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High concentrations of mercury represent a big risk to the environment due to the high toxicity of this metal. One of anthropic sources of up-ground environmental mercury contamination is mining industry. Analysis of the contamination and its prevention should be the essential part of the environmental policy for every company, dealing with this element.

The dump-field Veľká Studňa presents the rest of one of the most frequent mining activities in Slovakia for the last century. In the area of Malachov, where the dump is situated, Hg mine industry was well known in the past. The main source of mercury in this region is cinnabar (HgS), which was quarried in the locality centuries ago. The dump-field Veľká Studňa is situated in the site where the last attempt of mining was performed in early 1990s. The dump itself is approximately 20 years old with an area of 57,000 $m^2$. It is situated by a considerable distance from the urban area.

In the recent time, the dump-field presents the habitat for numerous plant species. Due to the fact that it is surrounded by woods and well developed ecosystems the succession at the field is quite fast. But a couple of anomalies in the plant growth is noticeable.

Our study was focused on Hg concentration in the soil substrate of the dump-field and accumulation by selected plants, which consisted of the representatives of gramineous, herbaceous and woody species. The study area was divided into several plots, based on physiognomic features of plant communities. In total 16 soil samples were taken from the field. In order to predict the Hg distribution for the whole study area, interpolation methods were used in GIS. The plant material consisted of 4 species: *Calamagrostis epigejos*, *Lotus corniculatus*, *Leontodon hispidus* and *Picea abies*. The samples were dried, grained, dissolved in $HNO_3$ and HCl solution and subsequently measured by inductively coupled plasma mass-spectrometry (ICP-MS).

The results show a widespread contamination of the dump-field environment by mercury. The values in soil vary from 11 to 910 mg $kg^{-1}$. The analyses of potentially bioavailable forms of mercury in the soil samples indicates, that only roughly 0.1 % of Hg content is potentially available for plants. However, the bioaccumulation potential of some plant species was significant. The Hg content in *Picea abies* reached 24 mg $kg^{-1}$. With regard to the presented data, the dump-field must be clearly considered as a risk for the local environment and its monitoring is essential to prevent environmental contamination in the future.

**Key words**: Mercury, Dump-Field, Contamination, Bioavailability, Plants

# APPLICATION OF PHYTOREMEDIATION FOR RECOVERY OF SALTED SOILS LOCATED NEAR COAL MINING PONDS

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The pond-storages of mine waters create a special danger for soil quality in the regions of coal mining. Their exploitation leads to the formation of sources of man-caused infiltration, which promotes the development of soil salinity processes and leads to changes in their physical and chemical properties. To restore salted lands, as well as to increase soil fertility, various methods of melioration have been analyzed, among which the most effective is their biological reclamation. Therefore, there is a need to find plants that are capable to efficiently and rapidly absorb salt from the soil, and also to increase the content of soil humus.

Preliminary selection of plants that could potentially be used in the climatic and edaphic conditions of the Western Donbas for desalinization of soils on the territory of coal-mining enterprises was carried out. The following plants were selected for phytoremediation: *Medicago sativa* L., *Onobrychis* spp., *Melilotus albus* and *Melilotus officinalis* (L.) Pall. To carry out the vegetation experiment, the soil samples were taken in the area adjacent to the pond storage of mine waters in the gully Svidovok (Western Donbass) at distances of 100, 500, 1000, 1500 and 2000 m in four cardinal geographic directions. The control soils were sampled on the territory of the Tsarichansk district in the Dnipropetrovsk region. The ability of plants to absorb salts from the soils was determined on the corresponding soil substrate, moisturized up to 70% where the seeds of the above-mentioned test cultures were sown. For the first few days the vessels with the samples under study were covered with glasses. Two to three times a day, the glasses were removed for 10-15 minutes of ventilation. On the fourth day, containers with planted seeds were placed in Phytotron, where they were kept for 14 hours under constant light and temperature 22–25ºC. The experiment was carried out in six replicates for each species. Experiments are performed from April to September.

Analysis of the data revealed that due to cultivation of *M. sativa* on saline soils, the total salt concentration decreased by 4.4%. The maximum absorption was observed for $SO_4^{2-}$, and the sulfate content decreased from 2.7 to 2.0 mg eq / 100 g of soil. Absorption by *M. sativa* L was up to 35% of $SO_4^{2-}$ and the increase in calcium content ranged from 1.03 to 1.21 mg eq / 100 g of soil (17.5%). The use of Onobrychis spp. reduced the salt content in the soil by 4.8%. The content of calcium and sulfates in the saline composition of the soil decreased on average by 10 and 25% respectively. Application of *M. albus* led to a decrease in the total salt concentration by 18.4%, which is quite a high value and indicates the effectiveness of the selected plant. Maximum absorption was observed with respect to $Na^+ + K^+$ and $Ca^{2+}$ ions. The sulfate content was reduced by 80%. *M. officinalis* reduced the salt content in the soil to 5%. There was an increase in the calcium content in the saline composition of the soil, as well as high $Na^+ + K^+$ and sulfate uptake rates. The use of *M. albus* led to the maximum effect of salt reduction in the soil while the humus content was decreased. *M. officinalis,* on the contrary, with a slight dissolving effect demonstrated high levels of increase in the content of organic substances. Therefore, the use of the investigated plants may be advisable according to the scheme: 50% of *M. albus* seeds + 50% of *M. officinalis* seeds. Under this scheme, the sustainable result of phytoremediation can be expected on the third year of cultivation. At the same time, the humus content may increase almost twice (by 93%).

Thus, it is possible to predict the expected reduction of the total salt content in the soil up to 0.2 % when using both *M. sativa* and *Onobrychis* spp. The average period of reclamation using these plants, depending on the initial salinity levels on the studied territories, may be from 2 to 5 years. Application of the proposed plants can stabilize the qualitative and quantitative salt composition of soils, increase the content of humus, as well as reduce the pH of soils. The proposed schemes with the use of *M. albus* and *M. officinalis* (50% + 50%) for the restoration of disturbed lands allow not only to normalize the salinity of the soil in about 3 years but also to improve the soil fertility.

**Key words**: Mine Waters, Soil Salinity, Phytoremediation

# *BETULA PENDULA* ON THE IRON ORE DUMPS OF THE KRYVYI RIH

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Ukraine is one of the richest countries in mineral deposits of the world: in its territory, which occupies only 0.4% of the world's land, 5% of the world's mineral resources are concentrated, 20 thousand deposits with 97 kinds of mineral resources were discovered, more than 9 thousands of which are open and estimated. Huge areas of disturbed lands and dumps of mining rocks and obsolete mining technologies have significantly worsened peculiar landscapes. The Krivorozhsky iron ore basin is the main raw material base of mining metallurgy in Ukraine, which provides about 40 % of foreign currencies to the state. In the location of mining and concentrating mills (mines) of Kryvyi Rih – North, Southern, Inguletsky and Central only 3700 hectares of useful area are occupied by external dumps of quarries and another one 1,000 hectares of adjoining territory are disturbed.

To improve the environment intensive planting of iron ore dumps in Kryvorizhya at the 2 part of the XX century was used. For more than half of a century, more than 100 species of woody plants and shrubs have been used for remediation, in the vast majority of introductions. For the last 20 years, the activity of greening the industrialized areas has significantly decreased due to the emergence of economic problems. From the planted plants at the time, the most stable and viable species were preserved in the dumps to our time. A special place among them is *Betula pendula* Roth, which has proven itself as a stable species in the conditions of technogenic landscapes.

The aim of the work is to study the morphometric parameters of *Betula pendula*, the ability to self-grow dumps and the possibility to form populations on the dumps of Kryvyi Rih.

The main research was made on the four dumps of Kryvorizhya. Vital state (VS) of trees was estimated on a 5-point scale V.A. Alekseev, height, diameter of a trunk area and volume of crown were measured according to the standard method. In each population, the number of self-seeding was counted, age and height were determined. Statistical processing was carried out in the MC Excel 2007 program.

As a result of the research, it was discovered that in the dumps trees grow individually, groups or rows, as well as stands of different size and density (from 1 to 51 individuals per 100 $m^2$) that arose as a result of a natural colonization. The population area reached from 0.08 to 2.79 hectares, depending on their location. The indicators of vital state varied from 86.5 to 100% and belonged to the category of "healthy". Age of plants ranged from 14 to 18 years, although some trees (maternal) reached 27 years. The mean height of *Betula pendula* varied from 4.5 ± 0.17 to 8.57 ± 0.54 m. The diameter of the tree trunk varied from 3.9 ± 0.45 to 8.74 ± 1.8 cm at the level of 1.3 m. The area and crown volume of the different trees populations fluctuated within 5.54 ± 0.7 – 13.92 ± 2.67 $m^2$ and 34.69 ± 7.99 – 113.42 ± 22.3 $m^3$, respectively. Most of the young, fast-growing trees, have already reached the generative age. This is confirmed by the presence of self-seeding in each population. In small isolated sections of iron-ore dumps, the Kryvorizhya trees of *Betula pendula* provide permanent coverage of the free area around themselves within a radius of 1-15 m of viable seeds. Reproduction occurs annually. The largest percentage of self-seeding was occupied by annual plants (10.4 % – 46.2 %), the height of which were in the range from 7.1 ± 0.2 to 10 ± 0.9 cm. The number of growth decreased with increasing age of plants. Obviously, not all individuals of the first year survive in such conditions; a certain part dies because of competition, or due to the influence of physico-chemical characteristics of the substrate.

Thus, *Betula pendula* is actively colonization on the technogenically disturbed landscapes of Kryvyi Rih and is capable of self-healing, so it can be considered perspective for the landscaping of technogenic landscapes without use of expensive remediation methods.

**Key words:** Kryvyi Rih, Dumps, *Betula pendula*, Self Seeding

# MISCANTHUS CULTIVATION IN ROCKS WITH DIFFERENT GEOLOGICAL AGE

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Recently, more and more scientists give to *Miscanthus* the leading part on supplying cellulose-rich feedstock for energy production and the chemical industry. In particular the *Miscanthus* biomass can be used as animal litter, biomaterial, or bioplastic.

During two years (2016–2017), an integrated study to identify the effect of different types of polymineral rocks and their mixtures on biometric parameters and the biomass of *Miscanthus* × *giganteus* was conducted. The research was carried out at Pokrov land reclamation station of Dnipropetrovsk State Agrarian and Economic University.

This site is located in the Dnipropetrovsk region in the steppe zone of Ukraine with moderately continental climate. Pokrov land reclamation station is located in the Nikopol manganese ore basin. The rocks of this ore basin are presented the holocene, postpliocene, neogen and paleogen deposits. These mining rocks are brought to the surface during manganese ore mining. The soil mass is taken off, piled up and heaped onto the land after the rock has been replaced.

Two experiment variants were established. In both variants the rhizomes of *Miscanthus* × *giganteus* were planted in lysimetric containers. In the first case, eight different models of rock substrata were used: 1) loess-like loam (LLL), taken from the board of the quarry (0–150cm); 2) a rocks mix (RM), which consists of loess-like loam and red-brown clay taken from the board of the quarry (0–150 cm); 3) red-brown clay (RBC) taken from the board of the quarry (0–150 cm); 4) green-grey clay (GGC) taken from the board of the quarry (0–150 cm); 5) black soil (BS) 0–50 cm + green-grey clay (50–150 cm); 6) black soil (0–50 cm) + red-brown clay (50–150 cm); 7) black soil (0–50 cm) + loess-like loam (50–150 cm); 8) black soil (0–150 cm).

The data obtained during the first experiment variant showed that the type of rock substrate affects biometric values. So, in the first year of growing, the difference in plant height between the models was up to 33 cm. The lowest values were noted in the variant with made layer of black soil (130 cm). In the second year of cultivation, this ratio has changed. The highest height was recorded for plants grown on red-brown clay with the addition of black soil (172.5 cm), and the smallest in the variant with green-grey clay (150.8 cm). It was shown that plants are added in growth from 2-3% (models BS+GGC and TM) to 20-30% (models BS+ LLL, BS and BS+ RBC) with age.

In the first year of cultivation, the *Miscanthus* plants form an average 8–13 monocarpic shoots per clump, depending on the type of rock substrate on which they grow. During the second growing season, the intensity of clump expansion was 70–120%. As a result, the stem number per 2-year-old plants ranged from 15 to 30 tillers.

The diameter of a monocarpic shoot depends little on the age of the plant, but environmental factors can influence its value. Here this indicator varied from 6.9 mm to 9.4 mm, depending on the rock substrate type on which the studied plants grew. The thickest strong shoots of *Miscanthus* develop on rocks mixture and on loess-like loam, and the weak ones on green-grey clay.

To determine the dry biomass yield (DM) of *Miscanthus*, the average weight of one plant was calculated. The conversion of yield per unit area was carried out from the calculation of the planting density (about 14,800 plants per ha). Thus, the yield of plants in the first year of cultivation was from 3.27 to 6.78 t DM $ha^{-1}$. The lowest productivity was shown by plants growing on green-grey clay; the greatest yield was recorded in specimens grown on loess-like loam. By the end of the second year the yield increased from 42.0 to 87.9%. The best result was shown by plants on loess-like loam and rocks mix.

**Key words**: Manganese Ore Mining, Rock Substrate, Melioration, *Miscanthus giganteus*

# THE USE OF CONIFEROUS PLANTS AS PHYTOREMEDIATORS OF TECHNOSOIL IN UKRAINIAN STEPPE

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In the process of coal mining, particularly under conditions of operation of mines, significant disturbance and pollution of land occurs, being especially relevant for agricultural lands. Arboreous vegetation that grows in poly-elemental man-made anomalies conditions primarily serves as a mechanical barrier for aerogenic migration of metals. Soil and plant objects are involved in all processes of transformation and migration of substances occurring in the biosphere. The state of assimilation apparatus of arboreous plants can be used as an object of environmental monitoring, which is associated with assessment of their environment stabilizing role as a mediator of pollutants spreading into the environment. The purpose of this research was studying peculiarities of accumulation of elements of the heavy metals group in assimilation apparatus of coniferous tree species, which grow under conditions of mining rock.

Sample plots for the research were established on the forest reclamation site of mine "Pavlohradska" in Dnipropetrovsk region, Steppe zone of Ukraine. Samples of vegetal material were taken from plants, which were growing on mine rock (technosoil). The object of the study was represented by foliage biomass (needles) of Crimean pine (*Pinus pallasiana* L.) trees.

Mine rock was defined as heavy loam, light and middle clays and characterized by adverse water-physical properties. The sulfur content in mine rocks indicated that the amount of pyrite was changing from 1.8 to 3.3%. Acidity (pH) was 4.8.

Determination of metals concentrations in mine rock and vegetal material was carried out by the method of plasma-optical emission spectrometry (ICP-OES) using Technologies 5100 (Agilent) spectrometer with inductively coupled plasma (University of Girona, Spain).

The comparative analysis of compliance with the maximum permissible concentrations (MPC) norms has demonstrated absence of excess for only one among the nine substances under research – Manganese. The results of analysis of other inorganic contaminants in mine rock have exceeded the MPC values for chemical substances in soil to various extent: Pb – 1.3; Zn – 2.5; Sb – 9.0; Cu – 9.2; Ni – 10.8; As – 12.9; Cr – 15.7; Sn – 20.3 times.

The studied chemical substances in the assimilating fraction of above-ground live biomass of investigated species were divided into 3 groups of concentration (mg/kg of dry mass): 1) substances with excess concentration (113.7–510.6) – *Mn*; medium concentration (41.5– 69.2) – *Pb, Zn*; low concentration (0.8–11.9) – *Sb, Cr, As, Cu, Ni, Sn*.

To characterize remediation potential for the investigated species, the coefficient of biological accumulation of metals by foliage fraction of their above-ground live biomass was calculated. Thus, the leaves fraction of the Crimean pine aboveground phytomass per unit area is able to accumulate the inorganic contaminants, ranging from 1.46 to 2134.35 $kg \cdot ha^{-1}$.

It was determined that the lowest accumulation in Crimean pine foliage biomass is characteristic for such metals as *Sb* and *As*. Translocation of manganese occurs most intensively. The second position in terms of gross content in foliage fraction is presented by lead and zinc, which are elements with synergistic action when accumulated in soils. An average content of lead included in this research is 209.11 $kg \cdot ha^{-1}$. For Crimean pine needles it was found that zinc is accumulated in lower quantities – 125.38 $kg \cdot ha^{-1}$. According to the results of our research it was found that for Crimean pine processes of translocation of such metals as *As, Sb, Ni* to assimilation apparatus are slowed down as compared to *Cr, Mn, Zn*.

Determination of content of heavy metals in mine rock and foliage biomass Crimean pine needles shows stabilization of content of heavy metals in the substrate. According to bioaccumulation coefficient, Crimean pine can be considered a hyperaccumulator of lead, which substantiates its use as a phytoremediation agent.

**Key words**: Coal mining, Coniferous Tree Species, Phytoremediation

# THE FOREST LAND RECLAMATION AFTER LIGNITE OPEN PIT MINING IN THE SOUTH OF UKRAINE

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Lignite mining in Kropyvnytsky region has been performed in the last few decades in Alexandria district in the watershed of the two rivers (Ingulets and Beska). Semenovske - Golodkywske mine is the pit associated with the open extraction of brown coal. Rocks located above the coal layer are carried to the earth's surface during the process of brown coal mining. These rocks are represented by loess-like loam, red-brown, quartz, glauconitic sands, kaolin and carbonaceous clays. The main method of restoring disturbed lands is the forestry reclamation. Standing timber is represented by pine, sucker, acacia, oak plantations, which are pure and mixed stand. They were formed due to the artificial cultivation of these trees.

The aim of study is to assess the state of the forest plantation of acacia (*Robinia pseudoacacia* L.) cultivated in different site-specific conditions which arose after the extraction of lignite and the technical stage of reclamation. 15 sample sites (SS) in Alexandria forestry reserve were formed. Sample area differed by age (5–25 years), stand composition (pure and mixed), the composition of the rocks. Rocks differed in texture – loess-like loam (LLL), clay (C) sandy (S), the condition of moisture and topographic features. The survey was carried out in accordance with the requirements of forest trees taxation. Great variety, depending on landscape conditions, was observed in the studied plantations of acacia. The impact of anthropogenic factors is observed throughout the section and appears in technogenic relief formation, re-formation of dumps, rocks removal to the Earth surface. Elevation alternates with depressions. This leads to a variety of land cover in fertility and moisture. Techno sols are represented by loamy sediments, which are admixtures of clay, sand and lignite. The range of technosol moisture provision varies from moist to wet condition. The height of the stand in such conditions were, respectively, 11–12 m, diameter 12–14 cm, wood stock 83–96 $m^3$/ha, density is 0.8, the taxation index is I–Ia. The average growth for the year was 3.32- 3.84 $m^3$. Acacia plantations aged 11 – 13 years is a significant part of the plots. The forest stand reaches a height of 6 m and diameter of 8 cm at this age. The variation of cover density is ranging from 0.75 to 0.85. This leads to differentiation of stocks of wood 25–28 $m^3$/ha and the fluctuation of the average growth of 1.92 to 2.55 $m^3$. Eight-year-old stands differed among the lowest taxonomic indicators: height – 3 m, diameter 4 cm, the supply of wood – 6 $m^3$/ha, density - 0.7, the average increase of 0.75 $m^3$ per year The stand has a third index taxation. Thus, in the initial stages of development (10 years) pure stands of acacia have a third index taxation. Improvement of the taxation indices to the first level occurs with age. The average growth reaches its maximum at the age of 20-25 years – 3.84 – 4.15 $m^3$, and the current (in 15–20 years) – 7.8–9,5 $m^3$. Mixed stands are represented by such combinations: pine and acacia – 47 %, maple and acacia – 33 %, poplar and acacia – 20 %. Planting with the composition of 6 acacia and 4 pine stand were formed in loamy sediments. Index taxation locust at 11 years of age – 2, timber reserves and 12 $m^3$/ha, density was 0.7. Locust had a height of 4 m, diameter – 6 cm, pine (*Pinus sylvestris* L.) is 3 and 4, respectively. Ten years worth of planting of acacia and poplar forest had the third degree index. The average height of acacia was 4 m, diameter – 6 cm, poplar (*Populus deltoides* Marsh.) 5 and 8, respectively. Ten-year planting consisting of seven acacia and three maple trees had the third taxonomic index. Thus, it can be noted that pure plantations of acacia on the reclaimed mine lands had higher rates of height, diameter and productivity.

Processes of self-regulation and restoration of fertility strongly inhibited biological development of reclaimed lands in the early stages. This significantly reduces the resistance of acacia stand, both the pure and the mixed. The increase in forest plantation parameters from the 3rd to the 1st valuation index occurs with age. Increasing the density from 0.6–0.75 to 0.85–0.9 is one of the ways of improving the productivity of acacia stand. This can provide an increase in timber resources by 30–35 %.

**Key words**: Lignite Mining, Forest Land Reclamation, *Robinia pseudoacacia* L.

# RECLAMATION POTENTIAL OF *ROBINIA PSEUDOACACIA* L. ON MINING ROCK WITHIN STEPPE ZONE OF UKRAINE

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Western Donbass is a powerful coal-mining region in the Steppe zone of Ukraine. In this region, large areas are damaged by coal mining. The mine rocks spread all over the coal district of Dnipropetrovsk region often contain toxic inorganic contaminants. In this regard using mine rocks for biological reclamation is nowadays an important environmental issue. Tree species can accumulate heavy metals from technosoils during the whole year and transfer these elements together with other nutrients to aboveground phytomass through the vegetation period.

The goal of the research was to study the features of the accumulation of heavy metals elements group by aboveground phytomass in a deciduous woody plant.

The object of the survey was Black locust (*Robinia pseudoacacia* L.) plantation of the Ukrainian Steppe zone within reclamation station in the minefield area of "Pavlogradskaya" coalpit (Dnipropetrovsk region, Ukraine). The Black locust sample trees were taken from reclamation plantation on the mine rock (technosoil). For the research structural compartments of the Black locust aboveground phytomass (assimilation apparatus, trunk wood, trunk bark, fruits) were used. Mine rock was defined as unfavorable in its texture properties with excessively large plasticity and significant shrinkage ability. Mine rock's water-physical properties areporosity – 34,8 %: specific mass density – 2.52 g/cm$^3$: volumetric density – 1.64 g/cm$^3$. Acidity of mine rock (pH) along one meter profile was ranging from 2.61 to 5.46.

The determination of metals concentration in the technosoil was conducted employing method of Inductively Connected Plasma Optical Emission Spectrometry (ICP-OES) by the spectrometer Technologist 5100 (Agilent). Samples of the Black locust leaves, trunk wood, trunk bark and fruits were crushed into the powder state and dissolved in acid solution. There after, acid solution was filtered and analyzed for the metals content. Analysis for the heavy metals was performed in the University of Girona, Spain. Features of Black locust trees development on the experimental forest reclamation plots were defined according to translocation of the inorganic contaminants. This is a quantitative measure of the transition of heavy metal from the technosoil to the plant. The accumulation is strongly affected by the chemical composition of the soil. In the same environmental conditions, heavy metals accumulation by functional plants' parts depends on soil contamination rate.

The monitoring data to reflect the content of studied metals from mining rock plot were (mg/kg absolutely dry matter): arsenic – 25.8 ±2.7; antimony – 1/5 ± 0.04; zinc – 56.5 ± 1.57; lead – 40.6 ± 4.58; chromium – 93.9 ± 2.21; nickel – 43.1 ± 2.53; copper – 27.5 ± 0.19; manganese – 164.5 ± 1.25; tin – 40.5 ± 1.4; cadmium – 5.3 ± 0.07; cobalt – 2.6 ± 0.03; mercury – 7.5 ± 0.04.

Excessive gross content and a significant concentration of mobile metals forms in a soil leads to their concentration in plant. Therefore, to establish the remediation potential of Black locust the biological accumulation of metals coefficient (BAC) was calculated.

Concentration of antimony was the maximum for all fractions of aboveground phytomass (BAC 0.533–1.167) with the greatest value in the leaves fraction. A slight translocation intensity ($1.0>BAC\geq0.1$) was determined for zinc, lead, cobalt and mercury. Such metals as chromium and tin showed the lowest accumulation rate in all fractions of aboveground phytomass ($BAC<0.01$). A comparative analysis of the accumulation abilities of the aboveground phytomass components showed that the inorganic contaminants are the most concentrated in the leaves fraction.

In general, *Robinia pseudoacacia* can be used for biological reclamation on the transformed areas after the coal mining. Also, this species can be used as an antimony accumulator on areas where there is soil contamination with this metal.

**Key words**: Mining Rock, Heavy Metals, Biological Reclamation, Black Locust, Aboveground Phytomass

# THE PHYTOTECHNOLOGY OF IRON-ORE DUMPS REVEGETATION BY CREATION OF STEADY PLANT COMMUNITIES

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Disturbed lands of mining landscapes remain a source of negative influence on environment for many years. Revegetation is one of the measures for overcoming such influence, renewing the productivity of these lands after technogenic disturbance and stabilizing their ecological state.

The aim of our work was to develop the revegetation (greening) technology of the iron ore dumps of Kryvyi Rih area by creation of the grassy herbs-fescue-feathergrass communities, which are similar to the zonal biogeocoenotic structures. The objects of our investigation are the herbaceous dominant species of the natural flora of the steppe zone and the species of other areas, which are promising for greening of disturbed lands.

As the result of investigation, we developed the method of iron ore dumps biological revegetation by creation of steady multicomponent grassy communities like natural steppe biogeocenotical structures. This phytotechnology excludes expensive stage with using of mining machinery, agricultural and agrochemical substrate improvement; also it includes seeding of gramineous grasses, dominants and subdominants of steppe ecosystems.

Different dump types are characterized by various rate of natural overgrowing; we developed relevant models of herbs-fescue-feathergrass communities for each of them. All these models are similar because they contain some gramineous grasses: firstly, species of *Stipa* L. (feathergrass), *Festuca* L. (fescue) or *Koeleria* Pers. (koeleria). Depending on the dump type, other herbaceous species are added. Such species as *Hyssopus officinalis* L. (hyssop) or *Crambe maritima* L. (sea kale) are promising to be included into the composition of the communities. These species are high-yield in the dumps; in the more unfavourable substrates, they can form even monodominant communities. The seeds of *Hyssopus officinalis* were sown at 1 ha 30 years ago; during this period, the species occupied over 3 ha. In some places, the density of *Hyssopus officinalis* reaches 500 individuals per $100m^2$; all the age groups are presented – from germs to subseniles. Generatively evolved plants are higher than 90 cm and show a good vitality. Mean-aged generative individuals have 20–70 generative shoots per plant; average production of these shoots is 160.2–181.6 flowers. The average seed production is 60% of theoretically possible one. *Hyssopus officinalis* demonstrates the qualities of a pioneer species but it can be displaced gradually by the firm-bunch grass, thus it does not threaten natural steppe species.

Implementation of such models allows excluding initial stages of self-overgrowing in the dumps and therefore to stimulate forming of steady multicomponent plant communities which are similar to the natural ones. When the plants enter the generative period, they become a seed source and expand into new areas due to self-seeding. Any supplementary measure is not needed.

Combination of vegetation cover forming technology at the different iron ore dump types and of process of natural overgrowing enables to significantly reduce the time of substrate consolidation (in loess-like loams – for 15–20 years; in quartzites and shales mixed with loess-like loams – for 30–40 years; in limestones – for 20–30 years); also it permits to achieve significant economic effects of the revegetation in a short time and to minimize relevant costs. Ecologic efficiency of the developed technology is proven at the iron ore dumps of the ore-dressing combines of Kryvyi Rih.

**Key words**: Phytotechnology, Revegetation, Dumps, Plant Communities, Kryvyi Rih Area

# THE EFFECT OF BIOPREPARATIONS TREATMENT ON POPLAR AND WILLOW SAPLINGS SURVIVAL IN THE RECLAIMED MINELAND

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The most appropriate for mineland reclamation is to search the bioenergy species, able to grow on marginal lands and give stable yields. Some species of the poplar (*Populus* L.) and willow (*Salix* L.) can be attributed to such plants. This is a fast-growing woody energy crops, enabling to create highly productive plantations with a long service life.

This research was carried out under Ukraine steppe zone conditions in the land reclamation area of Dnipropetrovsk State Agrarian and Economic University in the town of Pokrov for two years (2016–2017). In the spring of 2016, cuttings of 9 hybrid poplar and 2 local willow clones have been planted on experimental plots.

The plot substrate was a mixture of loess-like loam and red-brown clay, which had passed through a long-term phytomelioration stage. Four variants of the experiment were laid: treatment with vermicomposting extract (VCE), trichodermin, mycorrhiza and mixture of these three agents.

The survival percentage of 9 poplar clone saplings planted in 2016 was very different between varieties. The worst indicators were observed for the clone Heidemij – only 11%. Clones Tardif de Champagne, Ijzer-5 and Robusta showed a high level of survival (70, 80 and 95%, respectively). For the rest clones, this index varied in the range of 33-–5%. By the end of the year the average height of these plants was 80–93 cm, and some specimens reached 170 cm. Clone Dorskamp also showed good growth rates, but bad survivability does not give grounds for the expediency of its further cultivation on marginal soils. The clone Tardif de Champagne, despite the good sapling survival, showed a low growth rate and therefore also lacks a good potential.

According to the results obtained in the first year of cultivation, two clones - Ijzer-5 and Robusta – were evaluated as the most promising and selected for further research. Researches of the second year were devoted to the effect of biological agents on the survival and growth of these two clones. It was revealed that the sapling survival rate of both clones in the control, experiments with vermicomposting extract, mycorrhiza and a mixture of agents was practically the same and amounted to 87–93%. Treatment with trichodermin had a supressive action, as a result of which the survival of clones Ijzer-5 was 73%, and of clones Robusta was even lower – 66.7%. Treatment of clones Ijzer-5 with biopreparations promoted growth acceleration of all experimental specimens by 10–19%. The clone Robusta responded to the influence of biopreparations by growth intensification from 8.5 to 46%. Measurements of the annual shoot diameter showed that in the clone Ijzer-5 it is 22–30% higher than in the clone Robusta in the control plot and experiments with vermicomposting extract, mycorrhiza and trichodermin, and 4.5% less in the experiment with the mixture of agents. Treatment with biopreparations stimulated the activity of annual shoot lateral meristems in all experimental variants in both clones. The treatment with vermicomposting extract gave the best result for the clone Ijzer-5, and for clone Robusta in the experiment with a mixture of agents.

For clone Ijzer-5 an increase of the leaf area in all experiment variants was observed from 19.5 to 38%. The treatment with trichodermin had the greatest impact. In clone Robusta, quite the contrary, trichodermin caused a decrease in leaf area by 25% compared to the control. In other variants, an increase of this parameter was noted, but less intense than for clone Ijzer-5, only by 13.5–20.5%.

The treatment of the two willow clones root vermicomposting extract has provided greatest influence on the length and diameter of the shoots. In the arid summer of microbiological preparations did not exert additional effect.

**Key words**: Mineland, Fast-Growing Woody Energy Crops, Biopreparations

# GREENING PRACTICE IN OVERBURDEN ROCK DUMPS OF THE IRON ORE QUARRIES IN KRYVYI RIH

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At the territory of Kryvyi Rih, where from the end of the 20th century iron ore mining was performed in the open way, and in the following decades by underground method, dozens of decommissioned dumps and those in which the overburden rock is continuously backfilled are concentrated in a small area. The area of the largest dumps is close to 1000 hectares and their height to 100 m, these dumps create serious environmental problems for the region as dust blown from their surface spreads to residential areas of settlements. Reclamation of dumps, as a way of protection against wind and water erosion, is traditionally carried out in two stages: technical – alignment with the help of a heavy technique of the dump surface with subsequent soil application of 30–35 cm to create favourable conditions for the growing of plants, biological – planting of seedlings, in most cases *Robinia pseudoacacia* L., in this soil. Technical reclamation stage takes around 80% expenses on the dumps greening. Completely, it is possible to exclude this stage by using biological features of the plants, which are available to colonize the dumps after 10–15 years of rock backfilling. Herewith, not only herbaceous, but also woody plants grow on the dumps, seeds of which get into not only from the nearby plantations by anemochoric or zoochoric pathways. It is possible to actively assist to this elemental process with considerable time reduction for the dump greening. For this, previously, it is needed to estimate differentially the whole surface of a dump with respect to forest suitability and growth of leguminous plants as well. According to investigations (from 2005) of the iron ore dumps self growing of Kryvyi Rih there were some species found which successfully grow at the different places of the dump surface depending on mechanical and physical and chemical rock contents and also weathering stage.

Experience has shown that growth of herbaceous and woody plants is successful, which renew themselves due to seeds of local reproduction and demonstrate high vegetative mobility. We have elaborate ways and methods of the iron ore dumps greening by landing seedlings in the rock substrateds of these dumps. Species of woody plants were identified and tested, it has been established that they are much more stable, decorative and long-lived than *Robinia pseudoacacia*. A small number of species, which have reached the reproductive stage of development, could recover themselves due to own seeds in dump conditions. Depending on technogenic formations, there are some 3–6 species out of this group. As a rule, they are introduced species and they are able to form micropopulations in the dump conditions. There are also several herbaceous species of the local flora and introduced ones, which successfully develop and renew themselves in the dump conditions at the quite large areas. Steppe plants of natural flora penetrate the dumps, where they do not encounter competition with other species and form stable phytocoenoses. Among such species, vegetatively mobile cereals dominate, which are capable to form dense colonies with significant overground biomass. Dead biomass in the autumn period leads to the formation of a "cushion" of plant remains covering large areas (several hectares) with respect to the horizontal surfaces and slopes of the dumps. Assistance to the processes of natural colonization of iron ore dumps by woody and herbaceous plants is an effective and low-cost way of their greening.

**Key words:** Kryvyi Rih, Iron Ore Quarries, Dumps, Greening

# PERSPECTIVES OF STUDYING OF SPECIES OF FAMILY *CRASSULACEAE* DC. IN KRYVYI RIH AREA WITH REFERENCE TO PHYTOREMEDIATION AND PHYTOMINING

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To search plants-hyperaccumulators is one of the most promising directions of biological methods for removing of toxic compounds from ecosystems. Screening acquires special importance for species, which will be used to create phytocoenoses in large industrial centres of Ukraine. The results of model experiments in Kryvyi Rih Botanical garden revealed some arboreal and fruticous as well as ornamental plants, which are resistant to combined effect of heavy metal compounds; among them – *Sedum rupestre* L.

Given the relevance of further researches along this line, we paid attention to the members of the family *Crassulaceae* DC. In particular, this is because that *Sedum alfredii* Hance is one of the most effective absorbes of Cd, Zn and Pb among the 400 known hyperaccumulators species.

The family *Crassulaceae* is represented by over 30 genera and 1500 species of world flora. The most of its members grow in dry open places, often in rock cracks. The representatives of this family belong to the ecologic group of arid regions – succulent plants. All the representatives of this family are characterized by extraordinary ability to breed vegetatively. Easiness of forming of adventitious roots on the stalks, of buds on leaves, of new rosettes on creeping sprouts determines the outstanding viability of species of the family.

For Kryvyi Rih area, the native species are *Hylotelephium polonicum* (Blocki) Holub, *Sedum acre* L., *S. borissovae* Balk., *Sempervivum ruthenicum* Schnittsp. et C.B. Lehm. About 30 cultivars are used in landscaping; particularly, in Kryvi Rih Botanical Garden – 24 ones. In 1990s, the possibility to use plants of genera *Sedum* L. and *Hylotelephium* H. Ohba for reclamation of iron ore dumps was studied. The investigations were carried out in a dump of Pershotravnevyi quarry of Northern ore-dressing combine. In some sites, which had been backfilled by ferruginous quartzites, chlorite-biotite-amphibole and amphibole-kaoline shales, the seedlings of such species as *S. aizoon* L., *S. album* L., *S. hybridum* L., *S. kamtschaticum* Fisch., *S. pallidum* M. Bieb., *S. sexangulare* L., *S. spurium* M. Bieb., *Hylotelephium ewersii* (Ledeb.) H. Ohba, *H. spectabile* (Boreau) H. Ohba were planted. These plantings do not at present exist.

Instead of them, there are 3 species of *Crassulaceae* in technogenous landscapes of Kryvyi Rih area. *Sedum acre* occurs only in old dumps (Ternivsky, Burshchytsky) in small sites with stabilized small-rubbled substrates. *Hylotelephium polonicum* often prevails in petrophyte communities of 40–60-year-aged dumps; these communities are similar to natural ones. Monospecific "patches" of *Sedum rupestre* L. occupy enough great areas not only in rock substrates, but also in loams and limestones, however, they are limited to the dumps, which are adjacent to places where this species is cultivated, e. g. garden plots or cemeteries. Although the latter species is susceptible to natural invasion and therefore needs control over its distribution, the positive point is its high adaptive ability to survive under extreme ecotopic conditions.

Thus, aboriginal and cultured representatives of the family *Crassulaceae* may be of interest in the perspective of phytoremediation studies. Considering the fact that the rocks of the Kryvyi Rih iron ore suites, which fall into industrial waste dumps, contain rare metals – Ge, Mo, Nb, Pt, V, etc., the using of these plants for phytomining is not excluded.

**Key words:** Kryvyi Rih, *Crassulaceae* DC., *Sedum* L., Phytoremediation

# VEGETATIVE RECLAMATION OF DAMPED COAL WASTE HEAPS IN NOVOVOLYN MINING AREA

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During field studies in the Novovolyn mining area (Lviv-Volyn coal basin), recultivated and non-recultivated coal waste heaps were identified. Recultivated waste heaps were artificially afforested in the 80's of the twentieth century. Afforestation was preceded by the process of mining-engineering recultivation and reformation of waste heaps by 20–50 cm-thick-layer of soil mixtures pouring. Recultivated waste heaps are not burning. Waste heaps phytocoenoses that arose in the process of natural self-establishment are the result of a complex interaction between the climatopus and the ecotope: the more favorable they are for vegetation, the more typical phytocoenoses are formed. The floral composition of formed vegetative groups highly depends on site conditions, primarily edaphic factors. In general, there is less amount of species composition in phytocoenoses of damped waste heaps formed in the process of self-establishment compared with recultivated ones. The groups formed on such waste heaps are mostly single-typed and of less phytocoenotic variety of the vegetation cover. However, there are present certain resistant species from the vegetative groups of damped heaps – *Taraxacum officinale* Webb. ex Wigg., *Tussilago farfara* L., *Artemisia absinthium* L., *Artemisia vulgaris* L., *Arctium lappa* L., *Betula pendula* Roth., *Pinus sylvestris* L., *Carex pilosa* Scop. Waste heaps burning increases the temperature of the substrate and promotes the development of herbaceous vegetation (*Carex pilosa* Scop., *Daucus carota* L., *Artemisia absinthium* L., *Impatiens noli-tangere* L.) even in winter.

Since damped waste heaps are capable of self-growth, it is necessary to promote this phenomenon by moving the process to the formation of natural phytocoenoses. This method of technogenic landscapes cultivating will prevent the mining-engineering stage of recultivation and the destruction of the already developing vegetation. The species diversity of damped waste heaps should be expanded by oligotrophs, which can produce underground and aboveground mass, and enrich the edaphotope with nutrients.

On the waste heaps of the studied region, the following micro-associations are developing: *Populus tremula + Betula pendula + Calamagrostis epigeios; Betula pendula + Pinus sylvestris - Calamagrostis epigeios; Betula pendula + Populus tremula - Calamagrostis epigeios; Betula pendula - Taraxacum officinala - Plantago lanceolata + Polytrichum commune; Robinia pseudoacacia + Betula pendula + Pinus sylvestris + Salix caprea + Hieracium pilosella; Populus tremula + Betula pendula - Pinus sylvestris - Calamagrostis epigeios; Populus nigra + Fraxinus excelsior - Taraxacum officinale - Urtica dioica - Artemisia absinthium; Populus tremula + Robinia pseudoacacia + Arctium lappa - Daucus carota*. Extension of the phytocoenoses boundaries must be carried out by them. *Calamagrostis epigeios* and *Daucus carota* are developing on the hill-sides of waste heaps. They have the ability to fix the substrate. It is necessary to promote the development of these species by their seeding in preliminary prepared areas with nutrient soil mixtures in holes and landslides.

For vegetative reclamation of coal waste heaps of Novovolyn mining area the most promising are the following species: tree and shrub – *Betula pendula, Populus tremula, Populus nigra, Pinus sylvestris, Robinia pseudoacacia, Fraxinus excelsior, Salix caprea, Corylus avellana, Rubus idaeus, Rubus caesius, Rosa canina*; herbs – *Calamagrostis epigeios, Taraxacum officinale, Plantago lanceolata, Taraxacum hybernum, Crepis tectorum, Erigeron canadensis, Hieracium pilosella, Impatiens noli-tangere, Sambucus nigra, Stenactis annua, Urtica dioica, Artemisia absinthium, Arctium lappa, Daucus carota.*

**Keywords:** Vegetative Reclamation, Damped Coal Waste Heap, Phytocoenose

# SWITCHGRASS CULTIVATION ON RECLAIMED MINELAND WITH SOME AMENDMENTS

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Reclaimed mining rocks can be potential lands for biofuel feedstock production. Minelands are considered marginal because they often have low organic matter contents and adverse soil physical and chemical characteristics. Establishing perennial grasses such as switchgrass (*Panicum virgatum* L.) on these lands can be an economically viable option to produce cellulosic biomass with the addition of biological agents such as fertilizers, cinder and sewage sludge. To determine the effect of different amendments on the growth and development parameters of switchgrass plants growing on mining rocks a comprehensive study was conducted. The research was carried out at Pokrov land reclamation station of Dnipropetrovsk State Agrarian and Economic University during two years (2016–2017). The switchgrass seeds were sown on the experimental plot. Substrate was a mixture of loess-like loam and red-brown clay, which had passed through a long-term phytomelioration stage. The humus content in the substrate is about 1.5%. The ratio of humic and fulvic acids is 0.2–0.5, which indicates a weak humus accumulation and active destruction of the soil mineral part. The main minerals of rocks silty fraction consist of feldspar, calcite, illite, montmorillonite, chlorite and kaolinite. The near reserve of mobile phosphorus is represented by its medium-accessible forms. Five additive options were used: mineral fertilizer with a balance of nutrients $N_{60}$:$P_{60}$:$K_{60}$ kg.ha$^{-1}$; ash of sunflower husk and sewage sludge in amount 10 t.ha$^{-1}$; mixture of ash and sewage sludge (10 t.ha$^{-1}$); a double dose of sludge (20 t.ha$^{-1}$). All amendments were put into the soil once in spring in a dry form.

The year 2016 was rainier and more favorable for plant growth than 2017. The height of plants in this year varied from 105 to 120 cm. Addition of biologically active agents in the substrate had a positive effect on this morphometric parameter. The plant growth increased by 5% in the trial with mineral fertilizer and by 9.5% in the variant with sewage sludge. The addition of ash and a double dose of sludge had the greatest effect, the growth rate enhanced by 14.3%. In 2017 relatively long periods of drought, accompanied by high air temperatures, had a depressing effect on the growth and development of switchgrass plants. Their height did not exceed 90–110 cm. Nevertheless, the addition of tested amendments improved this index from 10% (ash) to 25.6% (sewage sludge). The greatest effect was due to a double dose of sewage sludge (41.3%). In the first years of cultivation, the dry biomass yield of switchgrass plants grown on a mixture of mining rocks was in the range of 4.5–5.9 DM t.ha$^{-1}$. Addition of amendments caused an increase in productivity. The least effect was obtained by the application of ash (+8.2%), the largest in the trial with a double dose of sewage sludge (+99.3%). Thus, it is possible to obtain biomass yields of up to 9 DM t.ha$^{-1}$ even in dry climate on minelands. To determine the effect of amendments on the uptake of trace elements with the switchgrass vegetative mass, the contents of copper and zinc in all experimental samples have been determined. The addition of ash and a mixture of ash and sewage sludge increased the copper content by 15% and 54%, respectively. Other variants of additives had no effect on this element absorption. The ash application increased the uptake of zinc with biomass by 4.5 times. At the same time, in the trial with sewage sludge, the zinc content was less by 10% than in the control. Thermal degradation of above-ground biomass from switchgrass specimens occurs within a temperature ranging between 30$^{o}$C and 600$^{o}$C. The main pyrolysis process proceeds in a range from approximately 200$^{o}$C to 380$^{o}$C. The application of mixture of a ash and sewage sludge, a double dose of sludge and especially mineral fertilizer increase the biomass reactivity of thermal decomposition of hemicellulose and cellulose.

**Key words**: Switchgrass, Mineland, Amendments, Heavy Metals, Biomass, Pyrolysis

# ECOLOGICAL FEATURES OF DENROFLORAS OF IRON DUMPS IN KRYVORIZHZHYA (UKRAINE)

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Plant individuals are very sensitive to changes in environmental parameters, as they are a fairly labile component of ecosystems. Each plant species has a specific range of environmental conditions in which it can exist – the tolerance amplitude of the species.

For today, the amplitude scales of 3300 flora species inUkraine, in which amplitude characteristics of species are reflected (Didukh, 2011). In these ecological scales, the characteristics of most of the alien species are not presented, which we have supplemented based on comparative analysis.

The analysis of the technogenic landscape dendrofloras was carried out by us on seven model dumps – Petrivskyi, Pershotravnevyi avtomobilnyi, Pershotravnevyi zaliznychnyi, Leninskyi, mine «Bilshovyk», «Stepovyi», «Inhuletskyi». We ascertained the species composition of dendrofloras dumps, which includes 65 species belonging to 46 genera, 25 families. The adventive fraction is represented by 43 species. The investigated plants species compound 12.6% of the total amount of the adventitious fraction of flora of Right-banks steppe Pridneprov'ya (Kucherevsky, 2004).

The eco-groups by the relation of trees species to soil water regime are represented by mesophytes (plants adapted to existence in ecotopes with a full soaking of the root-bearing layer of the substrate) – 53.1 % – *Ligustrum vulgare* L., *Lonicera tatarica* L., *Padus serotina* (Ehrh.) Borkh., *Rosa corymbifera* Borkh., *Tilia cordata* Mill. and others; sub-mesophytes (plants adapted to existence in ecotopes with moderate soaking of the root-bearing layer of the substrate) – 31.3%; hygropytes – 6.3% – *Populus alba* L., *P. tremula* L., *Salix alba* L., *Ulmus laevis* Pall.; sub-xerophytes – 9.3% – *Chaenomeles japonica* (Thunb.) Spach, *Mahonia aquifolium* (Pursh) Nutt., *Malus domestica* Borkh., *Padellus mahaleb* (L.) Vassilcz.

As regards to the soil acidity we defined 3 ecological groups: neutrophiles – plants, which grow on acidulous and neutral (pH = 6.5–7.1) soils – 57.8%; sub-acidophiles (soil with pH of 5.5–6.5) – 37.5%; acidophiles (plants adapted to the existence on substrates having an acidic reaction (pH 4.5–5.5, for example, *Betula pendula* Roth, *Sambucus racemosa* L., *Sorbus aucuparia* L.

The presence of accessible forms of nitrogen limits the growth of many species. We highlighted groups of trees plants to nitrogen content in soil: hemi-nitrophiles – 50%, nitrophiles – 40.6 %; sub-anitrophiles (plants which grow on poor on mineral nitrogen oligotrophic soils) – 4.7 % – *Betula pendula*, *Hippophae rhamnoides* L., *Pinus sylvestris* L.; eunitrophiles (plants which grow on soils well provided with mineral nitrogen) – 4.7% – *Corylus avellana* L., *Fraxinus excelsior*, *Swida sanguinea* (L.) Opiz.

The range of total salt regime in the dumps soil fall within the limits from 2–9 points to 9–14 points. On these criteria the following eco-groups are highlighted: semi-eutrophes – 45.3%; mesotrophes – 29.7%; eutrophes – 23.4 % and sub-glycotrophes – 1.6% (*Elaeagnus angustifolia* L., which can grow on soil with salt excess of $HCO_3^-$). According to our observations *Elaeagnus angustifolia* is a pioneer of overgrowing open cut measures calciferous.

By a vegetation cover it is possible to give an integral estimation of environment factors, which are characterized by significant changes in space and time. Many researchers point at the need for correcting presenting ecological scales and supplementing them with values for new species.

**Key words:** Environmental, Plant Species, Dump, Eco-Groups

# TAXONOMIC STRUCTURE OF THE PLANT COMMUNITIES OF TREE PLANTATIONS AT THE IRON ORE DUMPS IN KRYVYI RIH CITY

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The development of woody-shrub vegetation in dump ecotopes for a long time was considered as the perspective of phytorecultivation problems. As a result of preliminary studies of the Department of Optimization of Technogenic Landscapes of the Kryvyi Rih Botanical Garden of National Academy of Sciences of Ukraine, it has been established that optimal conditions for its development are created in the dump ecotopes, firstly, at a certain level of moisture and mineral nutrition, which corresponds to a range of a number of hygrotopes: from dry to fresh (clays), from dry to wet (loams), from wet to very wet (sands), from raw to wet (gravel and screes) and wet (pebbles and gravel). Secondly, the formation of spontaneous wood and shrub phytostructures is determined by local ecotopic conditions, which are created by the accumulation of large stone blocks in all components of the relief, and also due to the presence of rock fragments in microdepressions. At the present stage of floristic development, the application of the structural and comparative method of studying flora gives a possibility to fully identify the patterns of the organization and functioning of floristic systems and their elements, to model and predict their changes. We studied the taxonomic structure of plant communities of spontaneous woody vegetation on five iron ore dumps in Kryvyi Rih: dumps № 3 and № 7 of Hleyuvatsky quarry, the one of the mine «Bolshevik», the dump «Eastern wall», the dump of Pershotravnevyi quarry PJSC «Northern Mining Enrichment Plant». 208 geobotanical releves were made in accordance to the generally accepted methods. Species names of higher plants are given in accordance to the nomenclature checklist of S.L. Mosyakin and M.M. Fedoronchuk [1999]. The analysis of the floristic composition of woody plant groups developing spontaneously on the iron ore dumps of Kryvyi Rih allowed to ascertain that the species composition of vegetation on five iron ore dumps varies insignificantly. The largest number of species, families and genera in the groups of tree plants was noticed on the dump of the «Pershotravnevyi of PJSC» Northern Mining Enrichment Plant» (115, 90 and 35, respectively), and the smallest – on the dump «Eastern wall» (78, 62 and 25, respectively). Considerable number of species on the dump of Pershotravnevyi quarry can be explained by large number of ecological niches, which are caused by long-term formation and variety of conditions, the presence of localities of moisture on the bench slopes and sites of uplands. The analysis of dominating families allowed us to ascertain that the Asteraceae family has «absolute leadership» (19.1-29.8%) in the systematic spectra. At the studied dumps, the Poaceae family is one of the sub-dominant groups and occupies the second position in the rating of leading families – 7.8-12.8%. The anatomical and morphological features of the Poaceae family representatives give them a wide range of adaptive opportunities, which contributes to their survival in unfavorable conditions of the technogenically disturbed environment. In addition, the representatives of this family are very plastic in choosing of their survival strategies; when environmental factors change, they respond quickly to this situation by changing of adaptive strategies, so the same types of plants while changing the conditions of existence they have different coenobiotic types. This gives the gramineous plants a wide range of opportunities in a fierce competition for existence. The third to sixth place in the spectrum is occupied by the families Rosaceae, Fabaceae, Brassicaceae and Scrophulariaceae. The family of Apiaceae (6.4%, 5 species) occupies the seventh place in the spectrum of leading families, on the dump of the Pershotravneviy this place takes the Lamiaceae family (8.7%, 10 species) and on the dump № 7 of Hleyuvatsky quarry and the mine «Bolshevik» it is the family Salicaceae (5.1-5.6%, by 5 species according).

Thus, the distribution of species by the dominating families of plant groups of woody plantations of the iron ore dumps is somewhat different from the zonal vegetation, which is due to the specificity of the ecotopic conditions at different locations.

**Key words:** Taxonomic Structure, Plant Communities, Dump, Kryvyi Rih

# PHYSIOLOGICAL AND BIOCHEMICAL MARKERS IN THE PROCESS OF RESISTANCE OF HEAVY METALS IN THE ABANDONED MINING AREA OF SIDI KAMBER, SKIKDA, ALGERIA

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Mining activities produce large quantities of wastes which are highly contaminated with heavy metals. This can cause adverse effects on natural ecosystems, particularly on living organisms. The study reported here concerned the biomonitoring of pollution in the Sidi Kamber mining area, through the determination of various physiological mechanisms (bioaccumulation and translocation) and biochemical markers (chlorophyll (a) and (b), proline, total sugars and total proteins) active in resistance to heavy metals (Cd, Cu, Pb and Zn) contamination, using three plant species *Cistus monspeliensis, Rumex bucephalophorus* and *Verbascum sinuatum* as bioindicators. During the period of March-May 2015, soil and plant samples were collected from three different stations on and around the mine spoils and away from the mine in the study area. Soil and plant samples were systematically taken along a transect from the slope in the mining area, which included several extraction sites, depending on the altitude, biodiversity and distance from the mine. The total heavy metal fraction was determined by ICP-MS (Agilent, 7700X), whereas biochemical markers were determined by spectrophotometric techniques using a spectrophotometer *(Agilent, Cary 60)* using the following methods: Photosynthetic pigments determination (Lichtenthaler, 1987), Proline determination (Monneveux and Nemmar, 1986), Total proteins determination (Bradford, 1976) and Total sugars determination (Dubois et al., 1956). In addition, the translocation of heavy metals in different parts of the studied plants was measured by the calculation of the translocation factor (TF) according to the following formula: **TF**= Metal in leaves/Metal in roots.

The results revealed total contents of Zn, Pb, Cd and Cu higher than the regulatory limits of the European Union (EU-richtlinie 91/692/eWG.aBI eG. 31. dec. 1991 nr. l377. p.38). In addition, the bioavailable contents in plant tissues were found to be above normal values reported by Pugh et al., (2002) and Kabata-Pendias (2007), indicating that they may show signs of phyto-toxicity and therefore high soil pollution in this mining area. It was found that the studied plants are suitable for biomonitoring and phytoremediation of soils contaminated with heavy metals (HM). Nevertheless, despite these high HM levels, it appears that the plant species are not hyper-accumulators. The HM contents in the plants studied vary according to the plant species, the total metal content in the soil, and the bioavailability of metal as a function of soil physicochemical properties in the following order of abundance: $Zn \leq Pb \leq Cd \leq Cu$. It has also been found that *C. monspeliensis* accumulates more HM compared to *Cistus monspeliensis,* and *Verbascum sinuatum.* The TF of heavy metals Zn, Pb, Cd and Cu to the aerial parts of the plants proves to be a crucial indicator in the process of resistance to Zn and Pb. It has been found that *Cistus monspeliensis, Rumex bucephalophorus* and *Verbascum sinuatum* are better suited for the phyto-extraction of Cd and Cu and phyto-volatilization of Zn and Pb. In the case of Cu and Cd, a tendency to accumulate HM in roots and the ability to use plants in phyto-stabilization was also observed. The strategies of resistance of *Cistus monspeliensis, Rumex bucephalophorus,* and *Verbascum sinuatum* rely in large part on the action of biological molecules: chlorophyll, proteins, proline and total sugars as ligands for the disposal, accumulation or detoxification of HM pollution in different parts of plants. Obtained data showed also positive correlations (synergies) between Pb, Zn, Cd and Cu in plant tissues, which can be attributed to their common geochemical origin, similar behaviour and the human activities that introduce them into the medium. Negative correlations between Cu and Zn are attributed to antagonism and competition for active cell sites.

**Key words:** Biomonitoring, Biomarkers, Translocation Factor, Mining Area, Algeria

# PLANT COVER DIVERSITY OF TECHNOZEMES OF RECLAMATION LAND AT THE NIKOPOL MANGANESE ORE BASIN

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The study of the disturbed natural complexes evolution processes is important for the development of the most effective and rational methods of reclamation. The restoration of vegetation is one of the most informative components of ecosystems. Plant complexes, which have been formed during self-establishment, are an integral indicator of the dumps suitability degree for biological reclamation.

The objective of the work is to study the plants species composition on different variants of technozems and the natural steppe area. Species composition of plants have been studied on sod-lithogenic soils, on loess loams, on gray-green and red-brown clays, and on technozem with a chernozem bulk layer of the reclamation site of the Nikopol manganese ore basin (Pokrov, Dnipropetrovsk region). The study site in natural conditions is situated on the slope of the Kamenistaya gully (the eastern outskirts of Dnipro, 48°23'11"N, 48°23'11"E), the slope of the south-eastern exposure with a slope of 13°. The size of the test plots were 21 m × 45 m.

The vegetation of the study site on sod-lithogenic soils on loess loams is represented by 26 species of higher vascular plants that belong to 8 families. On the study site on sod-lithogenic soils on red-brown clays species richness is somewhat smaller (25 species from 9 families). At the study site on gray-green clays 22 species from 7 families have been detected. The smallest number of plant species (17 species from 8 families) has been found on the test site with a bulk layer of chernozem. Unlike plant communities on technozems, the species richness of the steppe area was much higher. At the study site on the steppe slope of the ravine has been found 51 species from 18 families.

Among the leading families on sod-lithogenic soils on loess were Asteraceae Bercht. & J. Presl (10 species), Fabaceae Lindl. and Poaceae Barnhart (in 5 species). In total, 57.69 % of the highest vascular plants from the total species richness belong to the dominating families. Family Apiaceae Lindl. was represented by 2 species; families Brassicaceae Burnett, Convolvulaceae Juss., Ranunculaceae Juss., Resedaceae Bercht. & J. Presl. were represented by one species of each.

The dominating family on the study site on sod-lithogenic soils on red-brown clays is the family Asteraceae (11 species). The subordinate positions are occupied by the families Poaceae (4 species), Fabaceae (3 species), Apiaceae (2 species), Convolvulaceae, Ranunculaceae, Resedaceae, Rosaceae Juss., Hypericaceae Juss. – for 1 species of each.

At the study site on a bulk layer of chernozem vegetation has been represented by families Asteraceae (5 species), Poaceae (4 species), Apiaceae and Fabaceae – for 2 species of each; Convolvulaceae, Ranunculaceae, Resedaceae, Rosaceae – for 1 species.

The dominating families at the study site on gray-green clays are the Asteraceae (9 species). The subordinate positions are occupied by Fabaceae (4 species), Poaceae (3 species), Apiaceae (2 species), Convolvulaceae, Ranunculaceae, Resedaceae, Rosaceae – for 1 species of each.

The basis of the systematic spectrum of vegetation cover of the study site on the steppe slope of the ravine is the Asteraceae family (16 species). Less abundant are the families of Lamiaceae Martinov (5 species), Fabaceae and Rosaceae (4 species each), Apiaceae and Euphorbiaceae Juss. (3 species each), Caryophyllaceae Juss. (2 species), Aceraceae Juss., Brassicaceae, Convolvulaceae, Resedaceae, Rubiaceae Juss., Boraginaceae Juss., Caesalpiniaceae R. Brown, Campanulaceae Juss., Moraceae Link., Violaceae Batsch (for 1 species each).

Representation of families on technozems is much less than in the virgin steppe area, which is associated with a relatively small ecological capacity of the habitat. It is a complex of unfavorable conditions for settlement and coexistence of the maximum possible number of species. Also, the limiting factor may be the variability of environmental habitat regimes.

**Key words**: Plant Cover, Vegetation, Recultivation, Reclamation

# PLANTS FOR PHYTOREMEDIATION AND BIOFUEL PRODUCTION

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Today decontamination of heavy metal polluted soils is a very important problem in Ukraine. Soils are always contaminated by pollutants, pesticide remains and heavy metals. Soil contamination is a result of functioning mining, metallurgy and chemical industry plants as well as non-rational application of chemical means of plant protection in agriculture. The range of such preparations as well as the areas of contaminated soils increase every year. That is why it is necessary to study innovative techniques of soil decontamination from heavy metals and their compounds. Phytoremediation with the help of plants is one of the most efficient decontamination techniques.

Rape, sugar beet, hemp, goosefoot, wild cereals, brown mustard (*Brassica juncea*) are widely used plants in phytoremediation in Ukraine. However, we believe that this list of plants should be supplemented with new plants taking into account uptake capability of their root system. Energy crops which quickly form strong root system and above-ground vegetative mass, have perennial life cycle, high coefficient of bioaccumulation, simple cultivation and phytomass harvesting technology can be new and important plants for phytoremediation.

Previous studies have shown that a combination of soil recultivation using fast-growing, woody energy crops with further energy utilization is successful and profitable. It is reasonably to use such woody energy crops as willow and poplar as well as grassy plants like sorghum, silver grass *(Miscanthus)* and switchgrass.

The research aim is to determine the uptake ability of plants which are capable to accumulate heavy metals and can be used for biofuel production. The research task is to establish the peculiarities of heavy metal accumulation in phytomass of energy crops as well as the use of these crops for energy purposes.

A field experiment with energy crops and their phytoremediation characteristics has been conducted according to general and special methodology. The experiment has been conducted on the soils of the central forest-steppe contaminated by heavy metals of different concentrations.

On average during three years of the experiment cadmium was characterized by the highest transition coefficient from the soil into energy crops plants. Transition coefficient of cadmium (K) in total phytomass was more than 0.5. Cobalt was characterized by the least transition coefficient, it was less than 0.1. Copper transition coefficient (K) was at the level of 0.5; transition coefficient of zinc and lead was less than 0.5.

Silver grass (*Miscanthus giganteus*) provides higher yield than switchgrass (*Panicum virgatum L*), though switchgrass has less dry matter content, higher accumulation of heavy metals in plant phytomass and maximum permissible concentration is lower than regulated standards. Phytomass of these crops can be used as a raw material for production of pollution-free biofuel.

Switchgrass and silver grass are the plants for phytoremediation which have the greatest ability to take up heavy metals. They are these species really classical hyperaccumulators like. These crops intensively take up heavy metals and partially accumulate them in the underground and above-ground parts. Content of heavy metals does not cause substantial plant morphological changes and does not suppress the uptake of heavy metals. Dense, fibrous root system of switchgrass and silver grass helps to extract pollutants from the soil without significant worsening of biomass quality. Having completed vegetation period, above-ground vegetative mass of plants can be properly processed, that is an additional source of non-ferrous metals and biofuel production.

Successful combination of phytoremediation with expanding of land areas under energy crops such as switchgrass, silver grass and others can ensure an efficient decontamination of polluted soils and obtaining biofuel. This combination facilitates increase of energy independence of our country and improvement of environment.

**Key words**: Phytoremediation, Heavy Metal Accumulation, Phytomass, Energy Crops

# PHYTOREMEDIATION POTENTIAL OF NATIVE PLANTS GROWING ON RECLAIMED COAL DUMPS

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In the formation of phytocoenoses on the reclaimed coal dumps the processes of self-growth by species most tolerant to conditions of acidification and salinization of soils play an important role. Besides, naturally occurring plant species should have an increased resistance to high concentrations of toxic substances, including heavy metals.

The purpose of this work was to study the tolerance of the prevailing forms of wild plants to increased concentrations of heavy metals and other toxic elements in soil substrates on coal dumps after their reclamation, and the prospects for using such plants for phytomining technologies.

The presented study was conducted on the basis of the Pavlograd experimental station for reclamation of disturbed lands in Western Donbass. Experimental plots were managed in the minefield area of "Pavlogradskaya" mine in 1976 where intensive deformation of the upper layers of the lithosphere and land subsidence with subsidy depth of 5–7 meters was registered. The basis of the plot was formed with a thick layer (8–10 meters) of mine rock intercharged with various topsoil layers. In total several variations of artificial soil profiles with different bulk thickness of mine rock and topsoil were created on the surface of the mine dump site to provide the following main land reclamation directions: natural overgrowing, agricultural and forest reclamation.

In this study the models of technogenic edaphotops based on capping the mine dumps with 30–50 cm layers of black-soil mass (chernozem) (variant 1) and red-brown clay (variant 2), being under natural overgrowth, were used to investigate plant ability to accumulate toxic or valuable substances from the mine dumps. Samples of soil substrates were taken from the depth 0–20 cm. Among subdominant species widespread on both experimental plots, such as *Artemisia austriaca*, *Festuca* spp., *Lathyrus tuberosus*, *Inula* sp., *Calamagrostis epigeios*, *Lotus ucrainicus*, and *Vicia* spp., the dominant species *Bromopsis inermis* was selected for chemical analysis. Soil and plant samples were treated and prepared in accordance with the standard methods for ICP-MS analysis.

It was established that pH of topsoil samples was 5.77±0.44 in chernozem in contrast to 8.38±0.09 in red-brown clay. The heavy/toxic metal concentration sequence in black soil substrates follows the order Fe > As > Mn > Zn > Cu > Cr > V > Co > Pb > Mo > Cd; in red-brown clay – Fe > Mn > Cu > V > Cr > Zn > Co > As > Pb > Mo > Cd, whereas the pollution index calculated as the ratio between the metal concentration in sample and its maximum permissible concentrations (MPC) indicates high level of chernozem pollution by As (pollution index in the range from 613.27 up to 1077.97), Fe (20.7), Zn (4.1), Co (3.0), Cu (2.4) and red-brown clay – by Fe (28.8), As (8.3), Cu (2.2) and Co (1.0).

Chemical analysis of the toxic substances in tissues of *Bromopsis inermis* growing on both chernozem and red-brown clay shows similar tendency for accumulation of heavy/toxic metals in the order Mn > Fe > Zn > Cr > Cu > Co > Pb > V > Mo > As > Cd. However, the values of the heavy metal transfer factor from soil in plant were established as below zero with maximum for Mo (0.84). It should be noted that the highest values of transfer factor were revealed for Re (1.04–1.19 in variant 1 and 1.0–1.42 in variant 2) and Rh (1.16-1.40 and 1.41–1.44 correspondently). For Ge the transfer factor was equal 0.044–0.137 (in variant 1) and 0.02–0.77 (in variant 2).

Thus, *Bromopsis inermis* growing on the reclaimed coal dumps is identified as a plant tolerant to heavy metals and other toxic substances and can be a good candidate for using in some phytomining techniques for phytoextraction (phytoaccumulation) of target valuable elements.

**Key words**: Phytoremediation, Coal Dump, Naturally Occurring Plants, Bioaccumulation

# GEOCHEMICAL SOIL MAPPING, PHYTOEXTRACTION OF CRITICAL ELEMENTS AND ENERGY PLANT PRODUCTION IN THE POST MINING AREA OF FREIBERG

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The soil, heterogeneous in nature, is a very important part of the environment. It plays a major role in the existence, health and functioning of the organisms found in it, the other compartments of the biosphere and the life forms in them. Therefore, a negative deviation from a healthy soil will have a great impact on the biosphere and the environment at large. Some of these unhealthy deviations are caused by human activities and the aftermath of such activities such as mining and resource prospecting within the earth crust. Since these deviations are now very common and because economic gains from mining and prospecting of resources must continue, several research works are focused on highlighting the possible ways of carrying out sustainable mining and restoring the soil back to health conditions.

The proposed research looks at the sustainable concept of bio-mining, which explores soil–plant relationships for resource recovery and promotion of economic gain in a sustainable way and has the potential to restore contaminated soils back to healthy status. Associated focus also includes investigating and highlighting other useful consequences of the soil–plant relations that aim to promote good soil and environmental conditions and generally, welfare of humans and other living organisms.

There are many contaminated soils within Freiberg and its environs resulting from mining activities in the region. To identify the elements in these soils, suggest possible bio-techniques for removal of contaminating elements, ascertain the possibility of recovery of useful quantities of critical elements by plants, and possibly make some economic gains, geochemical mapping of soils will be carried out on some selected field-sites and the technique of phytoremediation/phyto-mining will be applied.

From the geochemical mapping of soils in the selected fields, which is aimed at revealing the elemental compositions of soils, this research hopes to determine the level of contamination in these soils and the risks that the presence of these elements pose. The application of phytomining will reveal the bioavailability of these elements to plants under different conditions; provide information on the feasibility of resource recovery via phytomining, the possibilities of phytoremediating the contaminated soils and the best possible plants for phytomining/phytoremediation. In addition, the possibilities of making economic gains via bioenergy produced from biomass of plants used for the process of phytoremediation and phytomining will be investigated.

The outcome of the investigations will provide useful information for concerned authorities, remediation and bioenergy experts on the specific elements in the fields investigated, their amount, their environmental risks and the possibilities of extracting the contaminants from the soil using plants and making economic gains from phytomining and bioenergy production from some selected plants used for extraction of contaminants. In addition, the results of this research could be used in making environmental policies for the region of Freiberg and areas with similar contamination problems.

**Key words**: Geochemical Mapping of Soils, Phytoextraction, Critical Elements, Bioenergy Production

# ECOSYSTEM SERVICES AND ECOLOGICAL STRUCTURE OF TECHNOZEMS VEGETATION WITHIN NIKOPOL MANGANESE ORE BASIN

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The environmental characteristics of vegetation which is formed on various types of remediated soils were investigated. It is shown that the technozems vegetation represented by 91 species of vascular plants. The number of species in plant communities is dominated by the family Asteraceae, Poaceae, Fabaceae, Brassicaceae and Rosaceae. The taxonomic aspect technozems flora is a typical impression of the regional flora. In the succession of vegetation three stages of vegetation consistently and regularly replace each other, pioneer community stage, the stage of simple community and complex community stage. For therophyte projective cover share increases significantly, as if returning to a disturbed stage of succession dynamics. The nature of this phenomenon is assumed to be in the active flow pedoturbation elementary soil processes. Because of swelling and shrinkage phenomena that are characteristic of the young man made soils, forming a large network of cracks with considerable depth in the soil, are poured from the upper layers. Obviously, these technozems have a dynamic expanding capacity for wild plants. Optimal agricultural crops for cultivation in terms of agricultural land reclamation may be based on the concept of eco-trophic groups of crops. Ecological and trophic groups of cultivated plants is the equivalent trophomorph species in the wild. This makes it possible to apply ecomorphic analysis of vegetation to find optimal solutions in the agricultural land reclamation. Structure polnohor (plants ecological groups with different pollination types such as anemophily – wind pollination, entomophily – insect pollination, autogamy – self-pollination and other) indicates significant activity of consortial relationships that are formed between plants and animal populations. In general, the regional entomophilous flora share is 73%. From this indicator the figure in entomophilous technozem on gray-green clay is not very different, but in others such as technozems on loess-like loams or red-brown clays it is significantly higher. Prevalence of the entomophilous flora also indicates significant potential plant communities as the basis for beekeeping. Tight integration vegetation on reclaimed land in ecological processes emphasizes diasporophor structure. The share of dominating ballists differs little from this index in local flora. But the proportion of plants that use animals to transfer their diaspores is much higher than the regional flora. Thus, the share of endozoochor flora in the vegetation of reclaimed land is 1.49-3.23%, compared to 0.99% in the regional flora, that is 1.5–3.3 times higher. The share of epizoohor flora exceeds this figure compared with the regional flora by 1.8–6.8 times. Also open terrain promotes pervolvents, whose share in plant communities reclaimed land is 2.7–4.1 times higher compared with the regional flora. In the Raunkier's life forms structure of the vegetation cover is dominated by hemicryptophytes, somewhat inferior to them are therophytes. This structure tehnozems vegetation is characteristic for successional step bunchgrasses. Among coenomorphes are dominated by stepants (steppe species) and ruderants (ruderal species). Plant communities that have formed on technozems are identified as steppe pseudomonocoenosis with meadow and ruderal components. The technozems soil moisture mode is transitional between dryish and intermodal. The edaphotop artificial remediated ecosystems trophic mode is transitional from fertile to moderate fertile. Trophic and moisture modes are favorable for growing crops. The vegetation cover largely integrated into biocoenotic connection with the other components of the man-made ecosystems. Technozems vegetation features are a significant development in them endozoochors, epizoochors and pervolvents (tumbleweed-like plants).

**Key words:** Nikopol Manganese Ore Basin, Technozem Vegetation, Vegetation Cover

# RECULTIVATED SOIL HETEROGENEITY: ECOLOGICAL ASPECT

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Extracting minerals by the open method leads to the removal of the rocks to the surface which significantly disturbs natural processes in biogeocoenoses. After remediation activities anthropogenic biogeocoenoses are formed. In this biogeocoenosis on the rocks man-made soils are formed under the influence of environmental factors. Such man-made soils are called technozems.

One of the characteristic properties of reclaimed soils is their high heterogeneity, which is the reason for the vegetation cover variegation. Determining the heterogeneity degree of the soil conditions on the technozems is necessary to solve the problem of their use in the national economy.

The objective of the work is to assess the heterogeneity of the reclaimed soil and to identify the connection with the environmental conditions.

The soil heterogeneity in the reclamation area of the Nikopol manganese ore basin (Pokrov, Ukraine) has been determined on the basis of the penetration resistance indices at a depth of 50 cm. The sod-lithogenic soil on gray-green clays was chosen as a substrate. Study has been conducted on a regular grid. The distance between the measurement points was 3 m. The test polygon consists of 7 transects of 15 points (21 m × 45 m). To determine the external parameters the phytoindication method was used.

It was established that the reclamated soil penetration resistance increases incrementally with depth. The data of the layer are most variable at 5–10 cm from the surface. Geostatistical analysis showed the average level of spatial dependence of penetration data. The radius of influence varies between 4.31 and 15.89 m.

Data clustering of measurement points has resulted in the allocation of three clusters. They differ in the form of the vertical soil penetration resistance vector. The same places are combined into clusters, which form morphologically homogeneous areas and form the spatial structure of the experimental test site. Differences in clusters by external features have been found. In order to achieve this, discriminant analysis has been used. The scales of soil solution acidity and of the nitrogen assimilable forms content have reliable coefficients of discrimination.

Places of increased penetration resistance are characterized by the lowest level of nitrogen assimilable forms and high acidity. The lowest penetration resistance indicators are accompanied by territories with a higher nitrogen content.

The results of the study show that the heterogeneity of recultivated lands is not accidental. After forty years of reclamation, the heterogeneity of the bulk substrate shows certain regularities. They are expressed in the connection between morphological features with soil and climatic conditions. The cause of these changes in gray-green clay was the process of soil formation. The substrate is involved by the means of external factors. The acidity and the amount of nitrogen in soil are probably the limiting factors for plants at the time of the experiment. Selected areas represent separate morphological formations. Their independence is confirmed by distinctive features. These features are of different nature, but they reliably distinguish the allocated areas.

**Key words:** Soil Heterogeneity, Soil Penetration Resistance, Recultivation, Phytoindication, Geostatistics

## Session 3.

# ENVIRONMENTAL BIOTECHNOLOGIES

# VIABILITY OF *PICEA PUNGENS* F. GLAUCA IN THE KURTIN TYPE OF KRIVIY RIH PLANTATIONS

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A greater amount of natural dendroflora is not sufficiently resistant to technogenic conditions, therefore, the use of the introduced species has been started, in particular conifers. Usage of the representatives of the genus *Picea* Dietr. in the greening of the city gives a possibility to achieve the effect of permanent decorativeness in different seasons, they also have high phytoncide activity and intensive absorption of harmful gases. The most popular representatives of the genus *Picea* Dietr in Kryviy Rih, is the species *P. pungens* f. glauca, which grows in different types of planting: single, routine, group and curtain. The last type of planting is widely used by the «green building» during the landscaping of the city. However, it is visually noteworthy that the trees of *P. pungens* f. glauca that grow on the outside of the curtains are better than the trees that are located in their central part, which are more suppressed. The purpose of the work was to assess the viability of *P. pungens* f. glauca in the curtain types of planting in the conditions of Kryviy Rih.

To assess viability in the central part of the city, Pokrovsky district, near the roads 14 curtains with *P. pungens* f. glauca of different area (21–200 $m^2$), planting schemes, number of plants (11–46 individuals) and age (15–35 years) were investigated (total number of trees: 284). In trees of all plantations, the diameter of the trunk was measured at the level of 1.3 m, tree height, projection area and crown volume according to the standard method (Andreeva, 2002) and the state of health determined on the 5-point scale of V.T. Yarmishko (2002). The average indicators of a vital state were converted into percentages, taking into account the distance between the trees and the road. The estimated age of conifers was determined by the number of mutants (Mashinsky, 1978). Statistical data processing was carried out using a program package MS EXEL, the significance of the differences was determined by the t-criterion of student.

It was found out that plants in the curtains were planted at a different, usually small distance, relative to each other (0,5–5 m), while according to the rules of the minimum planting for them should be from 4–8 m (Mashinsky, 1978). The vitality of the tree depends on the correct choice of the area available per tree. When over-densely placed plants are mutually oppressive, the lower shaded needles fall, trees slow down the development of the root system, and there is a struggle for light, moisture and nutrients. In addition, all the trees (14 curtains) are exposed to toxic exhaust gases of vehicles, therefore trees become less attractive aesthetically.

Especially, the reduction of biometric characteristics is noticeable in the center of the curtain, because the trees there show poor growth, with a thin barrel, less complicated, with a deformed crown, some of them are old dead-tree. Accordingly, the average values of the height of the trees *P. pungens* f. glauca decreases from the outside of the curtain (7.3–11 m) to the middle (3.4–8.8 m). It is obvious that the average diameter of the trunk of the planting *P. pungens* f. glauca. The trunk diameter outside the curtain is larger and ranges from 14.4 cm to 27.1 cm, and in the center from 9.5–19.3 cm. In plants with larger area available, there is an increase in their diameter of the trunk and height. *P. pungens* f. glauca trees that grow outside the curtain were relatively higher than planted in the center by 19.2%–53.4% and by the diameter of the trunk by 34%–44.2%.

An assessment was also made of the living conditions of the curtain trees. It has been established that plants *P. pungens* f. glauca that grow outside the curtains have better average indicators vital state (75.3%) than trees growing in the center of curtain (47.6%).

Thus, for greening in Kryviy Rih it is pertinently to use *P. pungens* f. glauca plants, but their decorative effect, without additional agrotechnical measures (irrigation) and without complying with the rules of planting begins to fade from the age of 35 years.

**Key words:** *P. pungens* f. Glauca, Viability, Curtains, Biometric Characteristics

# APPLICATION OF BIOTECHNOLOGICAL METHODS OF VERMICULTIVATION FOR ECOLOGICAL RESTORATION OF MINING SITES

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The issue of land recultivation after the development of mineral deposits is topical. Technozems (technogenically transformed land) formed in the process of recultivation are significantly different from zonal soils by the level of fertility, physical, physicochemical, agrochemical and other ecologically important indicators. Soil-zoological studies indicate depletion of the species composition of soil invertebrates in the areas of recultivation, which does not allow effective functioning of the transformed ecosystems. An important aspect is the restoration of natural ecosystems on the territory of mining regions. Very important scientific and practical aim is the study of the possibilities of using biotechnological methods of vermicultivation in areas of biological recultivation by disturbances in the mining industry of lands.

The purpose of our research was the scientific substantiation of the application of biotechnology of vermicultivation in order to ensure positive changes in the ecological state of technozems with the aim of accelerated restoration of the biotic potential of disturbed biogeocoenoses. The task of our research was to search for technological methods and methods that will help to stop the degradation of techno-systems, to correct the direction of their development towards the soil-forming process, to strengthen the buffer capacity of ecosystems to negative factors.

To restore disturbed biogeocenoses, it is necessary to create an edaphotope, which must possess the optimal granulometric composition, positive physical, water-air and agrochemical properties. Then an autotrophic part of the biogeocenoses is formed, which will serve as the basis for the restoration of the heterotrophic block – animal, terrestrial and soil coenoses, as well as microbiocenoses: bacteria, unicellular algae, protozoa and lower fungi. Soil animals are directly involved in the processes of soil formation, which is important for the fast restoration of the ecological potential of technogenic-transformed lands and creating of full-fledged ecosystems. In our studies, the high efficiency of soil invertebrate (vermiculture) use for restoring the ecological and humus condition of different types of technozems is shown. To study the effect of biotechnology of vermicultivation on the soil-forming processes of technozems, studies were carried out of microbiological and agrochemical properties, as well as group and fractional composition of humus of samples of technozems and vermicomposts at different stages of application.

As a result of researches has been established that the introduction of a vermicompost into the soil with proper agrotechnics promotes the restoration of normal soil microflora, increases the total humus content in the soil, makes mineral nutrients more accessible for assimilation of plants, and also slows the process of mineralization of plant residues in the upper soil horizon for account of maximum fixation of humic substances and stimulation of microbiological processes of humification.

The application of biotechnological methods of vermicultivation is substantiated and technological methods of introducing vermicompost and population of worms on the sites of recultivation are developed. The measures proposed by us will help reduce the costs of recultivation and improve the recultivation process itself.

The main advantages of the proposed technology for improving the effectiveness of recultivation work with the help of vermiculture: improving the humus and ecological state of technozems, preventing the degradation of technozems. Therefore, the application of biotechnological methods of vermicultivation will be useful to accelerate ecological restoration of mining sites.

**Key words:** Biotechnology in Mining, Vermicultivation, Technozems, Recultivation, Accelerated Ecological Restoration

# THE USE OF PRETREATMENT OF PLANT SEEDS TO OVERCOME THE PHYTOTOXICITY OF MINE WASTE DUMPS DURING THEIR BIOLOGICAL RECLAMATION

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Donbass is one of the oldest and largest coal mining regions in Ukraine and the world. For today there are more than 1300 dumps in Donetsk and Luhansk regions, the main part of which are located within the cities. To reduce the pollution of the atmosphere and improve the sanitary state of the cities, the dump reclamation is carried out. Biological reclamation provides creation of plant communities for decorative and sanitary protective purposes.

One of the obstacles for biological reclamation is the phytotoxicity of the dumps, which inhibits the growth and development of plants. To overcome the phytotoxicity it is recommended to cover dumps by not phytotoxic soils with a layer not less than 20–30 cm. Application of soil reduces the intensity of rock oxidation and prevents the development of its phytotoxicity, as well as creates favorable conditions for the successful growth of plants. However, at present time it is relevant to search for the required amount of soil for the application as a protective layer, which in the conditions of our region is practically impossible to execute, and requires significant capital costs.

To solve such a problem it is suggested to generate a dragee for the plant seeds (pelleting). Dragee means covering of the seeds with a protective layer consisting of a mixture of peat, humus, mineral fertilizers and sticky substances. Such treatment of the seeds is conducted in a special apparatus. Described pretreatment of the seeds will create favorable conditions for the germinating capacity and plant growth without application of a protective layer of soil.

For the study samples from the dump of the mine "Zakhidna" were selected and their physical and chemical parameters (pH, amount of water-soluble salts, rock density, etc.) were determined. Based on the ecological conditions and qualitative composition of the waste dumps, the composition of the mixture and the technology for seed dragee were selected.

According to the recommendations, a seed mixture of cereals and legumes was used in the ratio 2:1 (*Avena* L. and *Medicago sativa* L.). The seeds of *Avena* L. and *Medicago sativa* were drageed with fertilizers, peat and lake silt, by spraying on seeds for 3 hours. Drageed and intact seeds were planted in the dump samples; as a control, clean soil was used. After the experiment the germination capacity of the seeds, the mass and size of the germs were determined.

It was established that drageed seeds on the dump samples had a better germination and a greater mass of germs in comparison with untreated seeds.

The greatest rate of germination was observed for the seeds of *Avena* L. and *Medicago sativa*, which ware treated with fertilizers and peat. *Avena* L. seeds showed rather high percentage of germination when treated by fertilizers only.

The smallest germination was observed for the seeds which were treated by lake silt, which is probably associated with application of the dragee technology. In general, the dragee of seeds improves its germinating by 30–50%.

Thus, selecting the necessary nutrients in accordance with the environmental conditions at the reclaimed dumps and performing the dragee of the seeds, it is possible to carry out the biological remediation step without applying a protective layer of soil. This will not only accelerate the process of reclamation, but also significantly reduce the cost of its reclamation.

The use of seed dragee before planting can be recommended for the reclamation of dumps that are in difficult conditions, where it is impossible to conduct a mining technical stage of reclamation.

**Key words**: Mine Waste Dumps, Phytotoxicity, Dragee of the Seed's (Pelleting)

# HEAVY METAL ACCUMULATION IN ROOTS OF *TARAXACUM OFFICINALE* WIGG

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Soil is an active acceptor for some elements, heavy metals in particular. Microelements are firmly sorbed and interact with soil humus layer. At the same time some plants are resistant to soil contamination and can be used as bioindicators. For this very reason the use of the most common urban flora species in the system of ecological monitoring enables to assess pollution level of various cities and industrial agglomerations.

The objective of the paper is to assess protective attributes and specifics of translocation of different threat level elements of a synanthrope – *Taraxacum officinale* Wigg. The object of the study is the roots of *Taraxacum officinale* and the soils of plant habitat. Soil sampling from 0–10 cm layer and plants roots were taken in late September, sample preparation was performed according to established practices. The content of total and mobile (in ammonium acetate extraction pH=4.8) forms of Zn Pb Cu Ni Cd in soils and elements in plant material was determined by atomic absorption spectrophotometer C-115 (manufacturer Ukraine). Translocation coefficient was calculated as ratio of element content in plants roots to its mobile forms content in soil (Barman et al., 2000; Gupta et al., 2008). Statistical processing of experimental data was conducted according to standard methods of parametric statistics at 95% significance level (Yegorshyn, 2005).

Technogenicity of heavy metal mobile forms for the areas of high and moderate contamination forms a falling row which is ranked as follows: Zn>Pb>Cu>Ni>Cd. For sampling sites of insignificant level and conditional control heavy metal accumulation row is ranked as follows: Zn>Ni>Pb>Cu>Cd.

The results of the determination of Ni Cu Zn Pb and Cd content in plants roots indicate that *Taraxacum officinale* is capable of their accumulation. A consistent pattern of HM accumulation for the areas with varying degrees of contamination isn't observed. The conditional control forms a falling row, which is ranked as follows: Zn>Ni>Pb>Cd>Cu, that is congruent with mobile forms content, apart from cadmium and copper. Similar accumulation series, which are ranked as follows Zn>Cd>Ni>Pb>Cu, was observed for the sites near the passage leading to rolling mills in Ryazanov street. Concurrently the content of Ni and Cu for a slightly contaminated area is statistically inaccurate.

However, the characteristics of environment contamination level requires ascertaining of both mobile forms of pollutants in the soil and the index of metal transition in the system "soil-plant". In view of this, translocation factors were calculated or barrier block "soil – plants roots". Strong anticoncentration barrier subject to control and pollution (translocation indices < 1.0), was proved for cadmium only. However, at one of high-level sampling sites it is > 1. Under contamination conditions *T. officinale* does not concentrate copper and zinc (translocation indices > 2.0). Consequently, Zn is an absolute leader in accumulation and bareer-free migration in the system "soil-plants roots".

In conditions of heavy metal technogenic pollution environmental driver of plants ultimate composition forming plays a significant part. In our research we were observing mobility decrease of one of the most dangerous elements – Cd. Although its content in roots makes which difference, strong anticoncentration barrier is fixed subject to control and pollution. The leader in accumulation in both soil and plants roots is Zn, which reaches vegetative organs in bareer-free manner.

The interrelation between heavy metal accumulation in soil and plants roots enables to use *Taraxacum officinale* for applying phytoindication. We consider it essential to conduct further detailed research of *Taraxacum officinale* adaptive reactions with a view to further creating of bioindication scales.

**Key words**: Phytoremediation, Heavy Metals, *Taraxacum officinale*

# SHORT-TERM EFFECT OF DISPERSION OF RESIDUAL SLUDGE ON THE SOIL *EUCALYPTUS CAMALDULENSIS* DEHNH, TIARET (ALGERIA)

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Silvicultural upgrading of sewage sludge is an alternative to current solutions. It presents a lower risk of contamination of the human food chain than its use in agriculture. In this context, the use of forest plantations can offer many advantages.

Therefore, the aim of this work was to study the characteristics and to exploit the residual sludge of the Tiaret wastewater treatment plant using forest plantations.

Wastewater treatment produces a large amount of sludge. The different uses of disposal such landfills or incineration and agricultural use, have negative consequences for the environment. A valorization using forest plantations may appear in some situations as an alternative to current solutions, it optimizes the degradation and recycling of organic and mineral elements. The fertilization of forest plants by wastewater treatment plant's sludge, presents a lower risk of contamination of the human food chain than its use in agriculture. In this context, the use of forest plantations can offer many advantages. The objective of this study is to evaluate the fertilizing characteristics of the sludge from the Tiaret wastewater treatment plant and to improve the quality of the soil studied. Henceforth, the sludge used contains only a small proportion of metallic trace elements that are far below the AFNOR standards, and therefore it does not present any risk of toxicity.

One-year-old *Eucalyptus camaldulensis* were transplanted into pots with mixtures of sludge and soil, where the sludge content was 20%, 40% and 60%. The physico-chemical measurements of the substrates and the biometric measurements of the plants (height, base diameter, diameter mid-height and number of leaves) were carried out within six months of planting.

The results demonstrated the positive effect of sludge application on soil parameters studied. We also found a significant difference in the increase of height and the number of leaves in plants treated with sludge. Biometric values for all plants in sludge mixtures were higher than those for control plants (100% soil). The 60% sludge substrate yielded the best results, with the exception of the stem diameter, with an average and a standard deviation of: height 49.4 ± 24.1 cm, number of leaves 68.8 ± 6.2 while the mean height for control plants was 34.3 ± 12.8 cm and the mean number of leaves was 40 ± 3.8. The addition of sludge provides soil modification and supplementary feeding for forest planting.

These experimental data have shown that sewage sludge can be used as fertilizers. But it is necessary to continue investigations in the long term that will establish technical references and guides validated by field experiments.

**Key words**: Fertilization, Biometric Measurements, Plant Growth, *Eucalyptus camaldulensis,* Tiaret

# EVALUATION OF ANTIFUNGAL ACTIVITY OF ANAEROBIC DIGESTATE AND ITS EFFECT ON GROWTH AND YIELD OF MAIZE

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Pakistan is an agricultural country. The increased population leads to increasing demand for food. Unfortunately, crops are infected by different microbes and nutrient deficiency of soil adversely affects the yield of the crop. Furthermore, the use of chemical fertilizers like Nitrogen, Phosphorus, Potassium (NPK), Urea, Diammonium phosphate (DAP) and pesticides have environmental consequences. Therefore, so there is need to find alternative renewable and sustainable biofertilizers.

Maize is capable of phytoextraction from contaminated soil and one of the top growing crops in Pakistan. Unfortunately, it has low yield compared to other countries due to deficiency of organic matter, widespread nutrient deficiencies (deficiency of phosphorus and nitrogen), unbalanced use of fertilizers, disease, and pest.

Digestate as partially degraded organic material residue has been suggested for the control of a few plant diseases and as a better replacement for the chemical fertilizers.

The present study was designed to evaluate the antifungal activity of anaerobic digestate and its effect on growth and yield of maize. The antifungal activity, minimum inhibitory concentration (MIC), and minimum fungicidal concentration (MFC) against selected phytopathogens (*Colletotrichum coccodis, Pythium ultimum, Phytophthora capsci, Rhizoctonia solani, Bipolaris oryzae and Fusarium Fujikuroi*) was determined by microtiter plate method. The effect of various fertilizers on different growth parameters height, diameter, chlorophyll, leaf area, biomass, and yield were studied in field experiments.

The extracts from anaerobic digestate have shown antifungal activity against selected phytopathogens, the highest activity was noted against *P. ultimum,* the MIC activity was high in case of *P. ultimum* and *B. oryzae.*

The present study concludes that anaerobic digestate has a positive effect on maize growth and yield as well as an antifungal activity which can be potentially a good biofertilizer. Maize can be a potential for phytoextraction technology in contaminated soils when anaerobic digestate is applied in soil due to its liquid and organic nature, soil nutrients and elements can easily be taken up by roots. In this way, we can remediate or extract the elements from contaminated soil by the plant through biofertilizer. However, maize plant can be used as a substrate in anaerobic digestion process so that we can produce energy (biogas) through this process and also extract the desired elements from various extraction procedures.

**Key words**: Phytoextraction, Growth and Yield of Maize, Biofertilizer

# ROLE OF PLANT SURFACE LIPIDS IN THE PROCESS OF PHYTOREMEDIATION

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Surface lipids (SL) of plants (epicuticular waxes) are complex mixture of highly hydrophobic substances which have most important functions of control of water status; anti-adhesive, self-cleaning properties; protection against radiation, pathogens and chemicals penetration. Also, as plant SL play pivotal physiological and ecological roles, it might be advantageous to adapt their composition and properties to environmental stresses, for example, for high concentrations of some exogeneous chemicals. Some water plants, representatives of *Helophytes* are used in remediation in constructed wetlands and are shown to have specific content of SL. Helophytes (synonyms – emergent water plants, marsh plants, etc.) are used for treatment of contaminated waters and are good absorbers of aromatics.

The aim of the investigation was to analyze if SL of plants really were changing under influence of pollutants and to determine the scale and directions of these changes. SL were obtained from leaves of healthy and good developed plants *Phragmites australis* (Cav.) Trin ex Steud., *Typha latifolia* L. grown in Dniepr botanical garden (control) and in the sewage ponds of Dniep varnish-dye plant (exposed) with complex contamination with organics and heavy metal salts. Spectral (Fourier transform infrared, FTIR), molecular-dynamic characteristics (thermogravimetric analysis coupling with FTIR in air and in nitrogen atmosphere, TG-FTIR) and content of components (GC-MS) were considered. FTIR-spectra of SL of control and exposed plants had some differences in the „finger-print" area. Thermogramms (TG and DTG) and evolutional profiles of water, carbon dioxide and carbon monooxide had many differences in control and expposed plants that confirms their different molecular-dynamic characteristics, dependent on content and associative abilities. We have found more total quantity of SL in exposed plants than in control. It possibly means that the influence of pollutants activates biosynthesis of SL. Dominating fatty acids in SL of both control species were fatty acids of $C_{16}$ and $C_{18}$ groups; among hydrocarbons prevailed odd numbered $C_{25}$ - $C_{29}$ components that all are typical for water plants. Changes in SL composition took place under influence of contaminants: in both species the content of fatty acids increased in SL of exposed plants in comparison with control; especially significant was increasing of unsaturated fatty acids. Process of adaptation to toxicants in SL of both investigated species differed in influence on biosynthesis of long-chained compounds: in *Phragmites australis* we have found inhibition of elongation, resulting in a decrease of long-chained fatty acids and hydrocarbons; in *Typha latifolia* there was a strong increase of the content of fatty acids with chains more than $C_{20}$, that gave possibility to explain TG-FTIR curves of 2 exposed sample. Some differences between control and exposed plants were found in minor components of SL. In the case of the investigated plants the formation of SL in the process of adaptation to xenobiotic exposure may require the appearance of such protective molecules also.

We may conclude that contaminants influenced on biosynthesis of SL components; these changes concern processes of elongation and desaturation of SL components; the response to contamination is specific for each specie. Such influence of contaminants to our mind may occur in two ways: as proper enzymes or enzymatic systems inhibition (promotion) or as direct including of metabolites derived from toxicants of organic nature (for example pyruvate) to SL biosynthesis. These data support the idea that there may be found species among emergent or terrestrial plants with flexible system of SL formation and they could be good objects for monitoring investigations.

**Key words:** Surface lipids, Constructed wetlands, Helophytes, Fatty acids

# BIOMONITORING OF ECOLOGICAL STATE OF THE ENVIRONMENT IN THE ZONE OF INFLUENCE OF THE "CHERVONOGRADSKA" MINE OF THE LVIV-VOLYN COALFIELD

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Coal mining has a very negative impact on the environment and it requires monitoring studies to assess the degree of environmental pollution.

Biological organisms are able to respond to negative changes in the environment. In particular, the environmental state of the environment can be estimated using the integral index of the fluctuating asymmetry of the assimilation apparatus of perennial tree plants. Fluctuating asymmetry are minor and random deviations from the strict bilaterally symmetry of biological objects. Fluctuating asymmetry of organisms by bilateral signs is an independent manifestation on one or both sides of the body, but to varying degrees of expressed signs, which makes it possible to use the fluctuating asymmetry to assess the stability of the organism's development. The degree of severity of the fluctuating asymmetry depends directly on the force of the factor's influence, the stronger the effect of the factor, the greater the deviation from the norm has the index of fluctuating asymmetry. A number of researchers have evaluated many urboecosystems in terms of fluctuating asymmetry. This method is not often used to assess the quality of the environment within the influence of mining objects. So we tried to apply the method of fluctuating asymmetry in the conditions of man-made influence of coal mine.

The research was conducted on the territory of the "Chervonogradska" mine. An analysis of the stability of development was carried out on an example of a leaf of Silver Birch (*Betula pendula*), as it is widespread. The material was collected after the growth of leaves was finished in August 2013, 2014 and 2017. We took 100 leaves of trees from each item (from 5 trees to 20 leaves). In total, 500 leaves were harvested and processed. The collection of leaves was based on the methodology of V. Zakharov. The method of determining the stability of the Silver Birch development by the magnitude of the fluctuating asymmetry of the leaf is based on the leaf measuring system. On each sheet we performed 5 measurements on the left and right sides of the leaf: the width of the halves of the leaf; the length of the second vein of the second order from the base of the leaf; the distance between the bases of the first and second veins of the second order; the distance between the ends of these veins; the corner between the main vein and the second from the base of the second-order vein. In addition, we took dusts from sheet plates, which were weighed and analyzed for the content of individual heavy metals.

According to the results of the calculations, we described the quality of the environment in the territory of the "Chervonogradska" mine. The rate of fluctuating asymmetry ranged from 0.041 to 0.041U within the background area. This indicates an initial deviation from the norm. Sheet plates have an asymmetry index within the limits of 0.053–0,055 on the upper part of the slagheap, 0.49–0.54 on the slopes of the slagheap, 0.47–0.51 at the foot of the slagheap. The value of the index of fluctuating asymmetry over 0.055 characterizes the ecological state of the environment as critical. The values of the indicator of the fluctuating asymmetry are closely correlated with the mass of dust collected from the surface of the leaf.

The dynamics of fluctuating asymmetry changes during field studies indicates a stable environmental situation within the background area and on the upper part of the slagheap and the deterioration of the environmental state of the environment on the slopes and foot of the slagheap.

*Conclusions.* The method of fluctuating asymmetry of birch leaves is characterized by good reproducibility. The values of the fluctuating asymmetry are closely correlated with the mass of dust. Therefore, the method of bioindication for determining the fluctuating asymmetry of the Silver Birch can be successfully applied to monitor the man-made impact of coal mines on the ecological state of the environment.

**Key words**: "Chervonogradska" Coal Mine, Fluctuating Asymmetry, *Betula pendula*

# PHYTORECULTIVATION OF ROCK MASS DUMPS WITH APPLICATION OF PRODUCT OF UTILIZATION OF INDUSTRIAL WASTES AS A FERTILIZER

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One of the types of man-made landscapes are dumps of spent rock mass, which, occupying significant areas of the earth's surface, change the terrain, are sources of secondary pollution of atmospheric air by dust and subsequent infiltration of weathering products into soil and groundwater. Among the existing ways of solving this problem is phytorecultivation of the surface of dumps as ecologically expedient. When the realization of this technology it is necessary to take into account the deficiency of nitrogen and sulfur compounds in the rock mass, which are necessary for the growth of plants. Therefore, it is recommended to use fertilizers or substances, which are available to them by composition to create primary conditions for the growth of plants.

The aim of the work was to investigate the possibility of using the product of neutralization of spent mother liquors from caprolactam production by the sludge of water treatment of a thermal power plant in the technology of phytorecultivation of dumps of a mining and concentrating enterprise as a fertilizer. To achieve this goal, the following tasks were set: obtaining fertilizer as a product of joint utilization waste of chemical and energy industries, determining the effect of fertilizer on the growth of weed plants in phytorecultivation technology.

The spent mother liquors of caprolactam production contain ammonium sulfate (acidic pH), and the chemical treatment water treatment waste of the thermal power plants is identified as limestone (alkaline pH). To obtain fertilizer in the utilization of waste, a neutralization method was used with the yield of a product with a neutral reaction of the medium. The obtained fertilizer contains calcium sulfate, ammonium sulfate, microelement impurities, which enrich the substrate for phytorecultivation with biogenic plant nutrients.

To investigate the effect of the fertilizer application on the growth processes of plants, experiments were conducted with test cultures of *Digitaria ischaemum* Schreb., *Setaria glauca* L. and *Calamagrostis epigeios* (L.) Roth. In laboratory conditions, the fertilized rock mass was seeded in the tanks with seeds of said species and cultivated under optimal conditions of temperature, illumination, and irrigation. As a control, a sample with a rock mass without applying fertilizer was used.

After two weeks of growing on a substrate of rock mass with fertilizer (a product of neutralization of industrial waste), plants were recovered from the substrate and the lengths of their aboveground and underground parts were measured. The lengths of the aboveground parts of plants considerably exceed in the samples with the addition of fertilizer to the substrate in comparison with the control experiment. In this case, the dosage of applying fertilizer to the rock mass is important, since phytotoxic effect was manifested in overestimated doses - inhibition of growth processes occurred. The most positive result was obtained in experiments with *Calamagrostis epigeios* culture, which proved to be the most sensitive to fertilizer application and more resistant to its high doses. The obtained results were confirmed by indices of the wet mass of plants.

Proceeding from the experimental data, the following conclusions were drawn: introduction of fertilizer into the rock mass of dumps (the product of neutralization of spent mother liquors of caprolactam production by the sludge of water treatment of the thermal power plant) in concentrations optimal for reaction of the medium of the soil substrate, leads to strengthening of growth processes in plants in phytorecultivation technology; the phytotoxic effect of applying high doses of fertilizer was recorded in different plant cultures; the most sensitive to the positive effect of fertilizer and simultaneously resistant to its overestimated concentrations was the cultivation of *Calamagrostis epigeios*; the fertilizer obtained during the utilization of waste can be recommended for increasing the efficiency of the implementation of the technology of phytorecultivation of spent rock mass dumps.

**Key words**: Phytorecultivation, Fertilizer from Industrial Wastes, *Calamagrostis epigeios*

# RESEARCH OF THE VEGETATIVE COVER OF ABANDONED COAL DUMPS

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Abandoned coal dumps have various chemical and mineralogical compositions. Under the influence of internal and external physicochemical processes in combination with climatic and hydrogeological conditions, the chemical composition of the dumps undergoes serious transformations. This can lead to the inhibition of growth and death of plants that grow on the dumps and adjoining areas. Therefore, the control of the state of phytomeliorants growing on waste heaps is an important link to the rehabilitation of the mining territories.

Research of the vegetation cover was carried out on the territories adjacent to the abandoned coal dumps in one of the largest mining regions of Western Ukraine, namely in the Chervonohrad mining area, where coal has been mined for over 50 years. For the research there were selected 5 test sites with dimensions of 20 m × 20 m. As a control site the village of Volytsia (Sokal District) was selected. This village is being not affected by mining operations.

The toxic impact of the dumps on the condition of trees and shrubs was assessed using a technique that comprises measuring biometric indexes of trees growing within the selected test sites. The thickness of tree trunks at a height of 1.3 m and their height were measured. Besides, the morphometric approach was used in order to investigate the level of fluctuating asymmetry (FA) for *Pinus sylvestris* L. and *Betula pendula* Roth.

The best growth indexes for *Betula pendula, Populus tremula* L., *Pinus sylvestris, Robinia pseudoacacia* L., *Salix caprea* L. were established at the dump base in contrast to the top of dumps were significant deflationary processes were observed resulting in appearance of dip gullies with the width 2–4 m and depth 1–3.5 m.

There were measured the length, width and thickness of fir-needles, as well as the length of two paired needles. As a result of the conducted research, it was found that the diameter of coniferous trees was within the range of 0.12–0.35 m, while the height was 0.4–1.1 m. It should be noted that within the test sites located close to mines the height of trees was less than at the control site. The smallest length of needles was found at the 1st test site located in the zone of impact of the mine waste dumps. A similar situation was observed for such indexes as the width and thickness of the needles. The highest values of these indexes were found at the control site. The FA indexes at the 1st and 2nd test sites 2.5–3.5 times exceeded those at the control site.

The results of evaluation of *Betula pendula* FA indexes showed negative impact of the mine waste dumps on the state and development of leaves compared to the control site. The FA index (average values) for samples growing on the mine waste dumps 2.3 times exceeded the comparable values at the control site. According to the FA indexes, the smallest score (I) was received at the control site, such values characterize the quality of the environment as "conditionally normal". The FA indexes values in different parts of the heap varied, resulting, however, in the highest score (V) that characterized the quality of the environment in the mine waste dumps area as a "significant deviation from the norm".

The assessment of the vegetation cover of the mine waste dumps allows determining the resistance of certain plants to the impact of toxic elements. Besides, there was substantiated a list of phytomeliorants with the highest resistance to specific conditions that can be the basis for phytoreclamation and eventually reduce the negative impact of the mine waste dumps in general on the environment.

**Key words:** Coal Dumps, Vegetation Cover, Phytomelioration, Bioindication

# SELECTION OF LIPIDS FROM BLUE-GREEN ALGAE

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Annually Ukraine consumes about 200 million tons of fuel oil equivalent, however, the mining from country's natural resources is only 80 million tons. That is why, at present economic situation with such balance of domestic and imported energetic material biofuel can become an important potential resource.

Recently technologies for producing the biofuel with weeds as the main source have been developed. It is due to the fact that weed cells naturally synthesize a great amount of lipids, which can be effectively refined into biodiesel that is the fuel manufactured from biological material – the substitute for common diesel fuel.

Despite a large number of studies on the use of cyanobacteria for energy production, the technology of collecting and processing blue-green algae did not find mass application, due to the lack of data on the prospects for pre-processing biomass cyanobacteria with the goal of increasing the completeness and intensification of their biodegradation, lack of rational strategies and technologies for collecting and processing cyanobacteria. Therefore, conducting a complex of general studies that would allow the use of cyanobacteria during their vegetation as raw materials for energy production will allow not only to manage the ecological safety of the region but also to obtain an additional amount of energy needed by the state.

Lipids are a biological group of material that are distinguished by chemical structure, properties and physiological functions. The main characteristic of this material is indissolubility or bad dissolubility in water and dissolubility in such organic dissolvents as liquid carbons, spirits, eters and esters, acetone, chloroform etc. Lipids are the stocking form of energy and they perform an important role in the property of floating weeds. The total amount of lipids in weed cells ranges considerably. Blue and green weeds can contain from 2 to 18 percent from dry substance of bio mass, yellow and green ones can contain 5-10 percent, some green weeds can contain 37, 3 percent and diatoms contain 35 percent.

The aim of the investigation is providing ecological security of the Dnipro river under the conditions of the uncontrolled development of cyanobacteria and their usage as the material for producing energy sources.

The objective of this study is the extraction of lipids from cyanobacteria with the help of Folch method for obtaining energy sources and avoiding ecological risks by using them in energetic technologies.

The method of research include analytical and experimental investigation with the usage of modern control equipment, using Folch techniques.

Thus, the development of scientific investigations of using biomass of blue and green weeds for getting energy is an essential step in providing Ukrainian energy security. In this case the state of ecological safety is also improved (at the expense of reducing the impact of cyanobacteria products degradation on the environment).

**Key words:** Algae, Lipids, Biomass, Blue-Green Algae

# BIOUTILIZATION OF WASTE AGROINDUSTRIAL COMPLEX FOR RECEIVING BIOGAS

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*Relevance.* A main problem of many countries is the search of promising energy sources. Biomass (wood, straw, plant residues of agricultural production, manure, etc.) is considered one of the key renewable energy resources of the future. Annually, juice factories in Ukraine produce thousands of tons of fruit and berry waste, which during 1-3 days undergo microbiological spoilage. Therefore they are not suitable for processing for food purposes. The most promising gaseous fuel is biogas. Its receipt is an effective way of utilizing agricultural waste. Biogas is a mixture of the main components: methane ($CH_4$ – 55–70%), carbon dioxide ($CO_2$ – 28–43%), as well as in small quantities other gases, for example hydrogen sulfide ($H_2S$ – 1%).

*Goals and objectives.* The purpose of the work is to obtain biogas from agricultural and food waste. The object of research is potato waste, grape and apple pulp, waste of sugar beet, wheat straw. Subject of research is volume of biogas, methane content in biogas.

*Methods.* In a flask (1 liter) 0.4 kg of investigated waste was loaded and sealed with a stopper with a tube connecting the container, a water jacket and a gas flask receiver. As a seed material for methane fermentation of waste, biohumus was used. It was mixed with water in a ratio of 1:1. Biohumus contains methanogenic bacteria *Methanococcus, Methanobacteriales* in different ratios. The concentration of dry water-soluble compounds in the sowing material was 4.5%. The flask receiver and the gas meter were filled with water. The receptacle was placed in a laboratory drying cabinet, in which experiments were carried out at a constant temperature of 55 °C. The volume of gas was determined by the volume of the squeezed liquid from the flask-receiver into the gas meter. The separated gas was analyzed for carbon dioxide and oxygen content. For methane fermentation, the pH and temperature parameters, which depend on the process of obtaining biogas, were monitored.

*Research results*. It is known that in the liquid waste of the food industry methane fermentation occurs easily due to the presence of low molecular weight metabolites – the products of the life of a specific microflora: pure rations of alcohol, wine and beer yeast. These wastes have a low concentration of dry matter. Methanogenic bacteria do not develop in highly concentrated media. Therefore, the acidity of the waste medium (pH = 5–8) and temperature (up to 30–40 °C) allows them to be included in the methane fermentation cycle without additional costs. These wastes have a low concentration of dry matter. The results of the research showed that from 100 g of waste the following volume of biogas can be obtained: from the waste of grapes – 0.042 $m^3$, waste of apples – 0.033 $m^3$, sugar maize pulp – 0.023 $m^3$, potato waste – 0.031 $m^3$, straw – 0.034 $m^3$. The chromatographic analysis showed that the content of methane was 53–56% on average.

*Conclusions*. On the basis of the obtained results it was established that all investigated waste is a promising raw material for biogas production. Recommendations for production are developed. Upscaling from the lab experiments, it is possible to get from 1 t in the industry: of waste of grapes – 420 $m^3$ of biogas, waste of apples – 330 $m^3$, of wheat straw – 340 $m^3$, of waste of sugar beet – 230 $m^3$, of waste of potatoes – 310 $m^3$ of biogas. The results of experiments demonstrate the effectiveness of the anaerobic method of biotransformation of the agro-industrial complex waste, which provides high rates of destruction of organic substances, the output of biogas with high methane content and the stability of the course of anaerobic reactions. The use of the proposed technology allows solving environmental problems of utilization of vegetable wastes and obtaining alternative sources of energy. The use of biogas-technologies allows solving the following tasks: energy (energy from the use of fuel biogas), environmental (disinfection of waste, utilization of greenhouse biogas), agrochemical (obtaining high-quality fertilizers), economic (profit from sales fertilizers, reduction of pollution charges environment).

**Key words**: Biogas, Grape and Apple Pulp, Wheat Straw, Potato and Sugar Beet Wastes

# JUSTIFICATION OF MIXTURE COMPOSITION FOR RECLAMATION OF THE LANDS DISTURBED AS A RESULT OF UNDERGROUND COAL MINING

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Underground coal development is accompanied by significant deformations of the earth's surface, changes in the hydrological mode of groundwater and surface water, as well as other negative consequences. Subsidence of the earth's surface leads to the flooding of its settlements, industrial objects, communications, agricultural and forest lands. As a result, there are areas with low productivity, reduced agricultural and aesthetic value. Thus, there is a need to develop the system of reclamation of disturbed lands for their further effective use.

In most cases, rocks after coal processing are used for dips backfilling. Usually, these rocks may contain toxic elements that inhibit plant growth. Therefore, justification the composition of soil mixtures, which can be used for the reclamation of disturbed lands, is a really actual problem.

In the presented work it was proposed to use resources available in the coal mining regions, namely loam and rocks after coal processing (empty rock), with the following ratio:

- Variant 1 (control): 100% loam (L) and 0% of the empty rock (ER);
- Variant 2: 80% L and 20% ER;
- Variant 3: 50% L and 50% ER;
- Variant 4: 40% L and 60% ER;
- Variant 5: 30% L and 70% ER;
- Variant 6: 0% L and 100% ER.

The empty rock and loam were dried, ground, then weighted in appropriate proportions (variants 1–6), mixed and used for the experiment.

A growth test was conducted to determine the overall toxicity of the test mixtures. The essence of the growth test was to take into account changes in the growth rates of germs of indicator cultivated plants grown on the investigated samples of mixtures. For testing the toxic properties of the experimental mixtures the crop species *Triticum aestivum* L. was used.

For the study of the toxicity of soil samples, in a vessel, 100 g of substrate hydrated up to 70% by boiled drinking water were added, and then 20 germinated seeds of test culture were sowed into each vessel. After 2 weeks, the plants were carefully released from the soil, washed and dried on a filter paper. Then, the length of the roots and stems was measured.

It has been established that the growth processes of plants grown on pure loam and on the empty rock (variants 1 and 6) are significantly different that indicates the presence of toxic properties of the rocks after coal processing. After adding a mixture of loams in different ratios, the toxic properties of the empty rocks are reduced. It should be noted that at ratio of 80% and 30% of loam (variants 2 and 5) there is a significant deviation of below-ground growth processes from the control mixture. It indicates the inefficiency of adding loams in such proportions to reduce the toxicity of the ER. According to the ratio of 40% and 50% of loam, this mixture does not show a significant deviation from the control sample. Addition of the loam into the mixture in such proportion reduces the toxicity of the empty rocks and makes it suitable for the creation of reclamation mixtures.

The growth index of the above-ground part of the plants has shown similar tendency to the values of the root lengths. The results obtained on two bioindicative measures confirm the effective addition of 40% of loam in the reclamation mixture.

Thus, the most optimal is the addition of 40–50% of loam to the rocks after coal processing. However, from the economic and technological point of view, the most optimal will be the addition of 40% loam, which is sufficient enough to reduce the toxic properties of the empty rocks and confirms the possibility to use this mixture for the reclamation purposes.

**Key words:** Underground Coal Mining, Reclamation, Bioindication, Loam, Empty Rock

# PROSPECTS FOR OBTAINING VALUABLE PRODUCTS FROM CYANOBACTERIA BIOMASS

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Relevance. The construction of a thread of reservoirs on the Dnieper River in the middle of the twentieth century allowed to solve a number of important issues related to navigation, supply of water and electric power to industrial facilities, etc. At the same time, the hydrological regime of the river ecosystem underwent radical changes, which significantly affected the species composition of the river. Heating of significant water masses and a high level of their eutrophication made the problem of the Dnieper's "blooming" actual due to the mass development of representatives of photosynthetic cyanobacteria. In the middle course of the Dnieper, the main species, which accounts for the bulk of the organic matter from the “blooming spots” is *Microcystis aeruginosa*. Subsequent dying of the biomass of cyanobacteria involves a significant part of oxygen dissolved in water in the destruction processes, which leads to its even greater shortage in heated water. This, in turn, provokes the fish and other hydrobionts to be killed. This problem is especially acute for the past 10 to 15 years.

Goals and objectives. The urgency of the surplus organic matter accumulation problem in the thread of reservoirs due to the “blooming” of the river makes the scientific community set the goal of developing methods for collecting and utilizing excess biomass. Among the priority tasks, it is necessary to provide a comprehensive study of the chemical composition of microorganisms causing “blooming” and the search for effective ways to extract the most valuable of them.

Methods. In the course of laboratory studies conducted on the basis of the Department of Biotechnology and Bioengineering of the Kremenchug National University, biological methods were used, in particular microscopy to determine the species composition of microorganisms from “blooming” spots, as well as physical-chemical methods: sedimentation, centrifugation, extraction, etc. Laboratory and industrial models of biogas reactors were also constructed, where the organic substance selected directly from “blooming” water bodies was used as a substrate.

Results. The literary sources and direct analysis of the chemical composition of bacterial biomass generally confirmed the feasibility and prospects of its economic use. The simplest way to recycle excess organic matter from aquatic ecosystems can be its biotechnological processing in order to obtain as a main product a gas mixture based on methane – the so-called biogas. Conducted at a temperature close to natural one in the summer months (+35 °C), laboratory experiments proved the possibility of obtaining volumes of biogas comparable to the volumes of organic substrate from which it is synthesized. The content of methane in the obtained samples was close to 75%, while the content of hydrogen sulphide was minimal, which is one of the advantages of this technology. Also, as a by-product, a spent substrate containing a high percentage of nutrients can be considered. In experiments with biotesting on seeds of rye and mustard, the phytostimulating effect of the preparation on the basis of the spent substrate in a dilution of 1:100 was noted. Concentrated biomass of cyanobacteria itself is the source of a number of valuable substances potentially having a fairly wide range of applications. So in a number of experiments, lipid extraction was performed, from which it is possible to extract hyaluronic acid, a valuable raw material for pharmacology and cosmetology. In the course of the destruction of the *Microcystis aeruginosa* cell walls, together with their internal contents, phycocyanins also enter the water – substances that are used in the preparations for HIV diagnostics and on the control of oncological diseases. These pigments can also be used as food colorings.

Conclusions. A quite effective biotechnology for the processing of excess organic matter from blooming reservoirs has been developed. It assumes the production of a biogas mixture based on methane as the final product, as well as an organo-mineral fertilizer from the substrate used in the methanogenesis process. Being primarily environmental, the proposed technology may be profitable in the conditions of small farms located in close proximity to the places of biomass accumulation. The development of other methods of utilization of cyanobacteria and other hydrobionts mentioned above requires additional studies aimed at finding the most efficient and economical ways of their industrial implementation.

# RESEARCH OF SECONDARY BIOMATERIALS AS POTENTIAL ENERGY SOURCE FOR MINING LABOUR

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The increase of ecology-economical indexes of mining industry processes is related largely to the improvement of existing and creation of new methods of conduct of explosive works. It is known that the labour intensiveness of explosion preparation during realization of openwork is 30–40% from the general mining process, with the use of underground method the specific gravity of drilling-blasting works increases to 50–70%. Therefore a relevant task is the choice of the explosive materials providing on the one hand efficiency of technology, and with another – its ecological safety. Exploding composition represent the systems including explosive and unexplosive components chemically untied among themselves. Among them in mining operations the dynamites, ammoniates, oxyliquites, dynamons, igdanites and etc. are most often used. The various carboniferous materials having high absorbing ability (wood or cork powder, peat, moss, some synthetic materials) belong to the unexplosive substances performing function of solid carriers-adsorbents. Taking into account that in composition oxyliquites it is possible to change both an explosive component (to use liquid oxygen, mixture of oxygen with ozone, beryllium or other) and unexplosive, it does not limit the selection of source of raw materials. In addition, carbon-containing secondary plant materials are characterized by rather high heat combustion (for a sunflower husk – 15,5-17 MJ/kg of thermal energy).

In this regard an objective of this research is the analysis of different types of the biomaterials representing carboniferous adsorbents and a potential energy resource on their basis and also justification of a possibility of use of such substances in exploding composition.

Researches of separate parameters of different types of wastes of vegetable cultures (sunflower husk, buckwheat and rice husk) were conducted by their rough-down, namely drying on air to an air-dry state – capillary moisture 12%, then they were mechanically crushed on the special centered impact mill with a step disk rotor designed by employees of Ukrainian State University of Chemical Technology. The design of this type of mill makes it possible to regulate the granulometric composition, the physical and mechanical properties of the finished product and the degree of its drying (moisture) by increasing the temperature in the grinding zone. The productivity of the mill used for fibrous materials is 200 kg/h. In according to data of chemical analysis, the general maintenance of an organic part in vegetable samples was presented by a carbon (more than 50%), hydrogen (to 6.0%), nitrogen (to 1%), sulphur (to 0.05%) and low ash-content (2-4%). A small amount of sulfur compounds will lead to less toxic products of the explosion. It should be noted that the power capacity of the studied biomaterials is concentrated mainly in a lignin-carbohydrate complex. By means of the scanning microscope the microstructure prevailing (72%) fractions with sizes of particles <100 μm was studied. It was established that the received particles are characterized by acicular shape and spherical shape, there are not undesirable processes of decrystallizing (amorphisations) of supramolecular structure of cellulose in them, and it creates availability to aeration and favorable conditions to reaction behavior of oxidation. To the important technical parameters of the biomaterials prepared by the offered method it is necessary to take porosity and developed specific surface (to 150 $m^2/g$).

Thus, the crushed biomaterials received on the basis of industrial wastes (sunflower husk, buckwheat husk) can serve as a valuable resource of explosive mixes and solve thereby technical, an environmental problems of utilization of secondary raw materials.

**Key words:** Exploding Composition, Secondary Biomaterials in a Mining Production, Energy Resources, Porosity and Adsorption Power

# BIOEDAGRADATION OF THERMOPLASTIC POLYURETHANES

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*Relevance.* Pollution of the environment by the waste of polymers – the planetary problem. Decomposition of waste takes place in the environment during decades and centuries. It is prospectively sustainable to use of plastic biomaterials, which can easily be destroyed in the soil. Starch is one of the cheapest raw materials for the organization of industrial production of biopolymers. Due to its polysaccharide nature, starch is easily digested by microorganisms of the soil.

*Goals and objectives.* The aim of this work is to study the properties of biodegradation of thermoplastic polyurethane that contains starch. The object of research is a thermoplastic polyurethane, that contains starch. The subjects of research are the mass of film samples, specific density and viscosity of solutions of thermoplastic polymer.

*Methods.* The thermoplastic polyurethane was dissolved in dimethylformamide. The concentration of polymer in a solution is 20%. Starch (concentration of 10, 30 and 50%) was added into the solution of polymer. The control is a solution of the polymer without starch. A thermoplastic polyurethane film, that contains starch, was maintained into the biohumus. Biohumus is a product of processing of sunflower husks by vermiculture *Eisenia fetida* (requirements of TU 3336406.002-95). The weight of the samples was measured with an accuracy of 0.00001 g. The density was determined by the method of hydrostatic weighing. The viscosity of the polymer solutions was determined by a capillary Ostwald viscometer. Destruction of films was studied by microscope of ICBM 1-E (increase of 400 times).

*Research results*. It was found that the reduction of the mass of samples depends on the concentration of starch in the thermoplastic polyurethane. At concentration of starch 10 and 30% reduction of film weight is 10–13%, at concentration of 50% starch, filmweight decreases by 20%. In the control version, the film lost its weight by 4% only. This indicates that starch initiates the decomposition process of the thermoplastic polyurethane.

The study of the change in the density of thermoplastic polyurethane compositions filled with starch during exposures during 45 days in a biohumus showed that the duration of exposure significantly affects the magnitude of the specific gravity. Within 15 days, a slight change in density was observed, and the subsequent exposure of the film samples to the substrate contributed to a significant increase in specific density, which could be explained by the introduction of the particles of the biosubstrate into their surface. In addition, an increase of the concentration of starch in the thermoplastic polyurethane is accompanied by a decrease in density, which is the result of a decrease in the molecular weight of the polymer during the destructive action of microorganisms.

The concentration of starch in the polymer substantially affects viscosity changes. Thus, an increase of the concentration of starch contributes to a decrease of the viscosity of the solution of the thermoplastic polymer. At exposure of 45 days in biohumus, the viscosity of the solution of thermoplastic polyurethane is reduced.

*Conclusions*. The results of studies indicate that the addition of starch in thermoplastic polyurethane contributes to the biodegradation of matrix polymer - polyurethane. Consequently, the biodegradation of the investigated polymeric compositions is accompanied by a decrease in the molecular weight of the macromolecular compound. Creating mixtures of plastics with starch, which initiates their biodegradation, is the simplest and cheapest way to obtain promising polymeric compositions.

Products of biodegradation of polyurethane after their assimilation by microorganisms and microbes enrich the soil with useful elements and natural fertilizers (biohumus). Application in industry and life of packing containers, etc. materials from biopolyurethane will help to reduce environmental pollution.

**Key words**: Biodegradation of Thermoplastic Polyurethane, Biohumus

# ALTERNATIVE ENERGY SOURCES: ELECTRIC CURRENT FROM LIVING PLANTS

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Today we would venture to say that the global changes of the twenty-first century evoke the need for alternative, environmentally friendly energy sources. From ancient times people used the energy of the sun, water and wind. At present, supporters of the traditional energy, which became a symbol of mind and science, are against the return to the past. But the world has come to another point of view, where the less harmful to the environment production comes to the fore. Therefore, it is worth talking not about returning to the past, but about rethinking the present and innovative look to the future.

Ukraine is rich in renewable sources of energy, which are available throughout the whole territory of the country. The main components of "green" energy include solar, geothermal and wind energy, bioenergetics. Alternative energy brings energy with less negative consequences for the environment and human health than conventional energy. It does not increase the average temperature of the atmosphere, leaving the area of glaciers without alteration and does not lead to global climate change on the planet. It is practically inexhaustible, and that's why it will provide energy for more than one generation of descendants.

We have developed an active mini-model of an alternative energy source that uses the energy of photosynthesis to obtain an electric current from the plant vital activity as the natural biological process in which the respiration of plants, roots and the decay of organic residues in the earth occur. Carbon dioxide is the gas which is both emitted and connected with water during the mentioned process, and only then it forms a carbonate acid that in its turn dissolves the compounds of calcium and magnesium. The carbonaceous acid is subjected to reversible hydrolysis, creating at the same time the acid medium. Also, the process is contributed greatly by the introduction of mineral fertilizers (nitrogen, for example, sulfuric acid ammonium), which is also useful for the growth and development of plants, and for the acidity of the soil.

This peculiar battery consists of eight plastic containers in which specially designed electrodes are embedded, which are connected in series with wires. The electrodes are separated by a ground, and from the top the plants are being planted. Soil is a unity of three phases: solid, liquid and gaseous. Between tiny particles of minerals there are drops of water and air bubbles. Moreover, the elementary unit of the ground – a micelle or clay-humus complex – is a compound system through which the potential difference arises. On the outer shell of such a system a negative charge is formed, on the internal one a positive charge is made up. The negatively charged micelle shell attracts positively charged ions that are in the medium. So that electrical and electrochemical processes are constantly occurring in the soil.

Thus, in plastic containers mosses have been planted that grow well in the acidic medium. Each container has a volume of 0.4 cubic decimeters, from which 0.5 volts were received, and from 8 containers with a total volume of up to 3 cubic decimeters – about 4 volts, enough to ignite LED.

This way the electricity is produced without any harm to the plant and this process is continuous. In conclusion, the method is environmentally safe, and it is possible to use large areas of fields for electricity production, which can be used for lighting, power supply of various devices, charging of batteries.

**Key words**: Soil, Plants, Electric current

# BIOTECHNOLOGICAL ASPECTS USE OF WASTE IN ECOLOGICAL SAFETY

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The purpose of work was application of biotechnologies for providing of ecological safety of motor transport. Experimental researches are conducted after standard methods both in laboratory and in operating, terms. The special motor stand was used.

It is set that the use of binary fuel mixture (mixtures of traditional fuel-oil and biofuel) allows to reduce total toxicity of exhaust gases of diesel cars, especially during work of engines on the modes of idling and partial loads. The most diminishing of emission toxicity is about 30–35%, which corresponds to the biofuel content in the binary mixture of 45–50%. We used mixture which includes 50% biofuel, which was named by B-50.

In quality of raw material for the receipt of biodiesel fuel different biological components are used. We investigated the food industry waste. One of such wastes there is a soapstock –by-product of process of alkaline refining of sunflower oil. Essence of the method applied by us consists in diminishing of viscidity a soapstock. Glycerin which is included in composition a soapstock gives it viscidity and closeness. Therefore, to get a biodiesel fuel, it is necessary to delete glycerin, substituting it by an alcohol. For this purpose, we used sorbent derived from wastes of agricultural production. During the reaction, the soapstock after treatment with the sorbent were first heated to 60˚C (to accelerate the reaction), and then a catalyst and an alcohol (butanol) were added. Ferrum (III) sulfate was used to accelerate the reaction. As a result of defending mixture exfoliates, a biodiesel fuel formed in an overhead layer, below is a soap layer, and there is glycerin on a bottom. Glycerin and soap layer are separated, and a biodiesel fuel was washed to remove tailings of soap, catalyst and other possible admixtures. An output of ethers of fat acids was about 95%, that exceeds this value a parameter in absence of cleaning of coabstock. The receipt of biodiesel fuel from fat-containing wastes of food industry allows to decrease the expense of oil at the traditional method of its production. Besides, addition of biodiesel component can reduce the toxicity of engine exhaust.

On the basis of simple calculations, we conclude that the use of the biodiesel component in the mixture makes it possible to save 10 450 $m^3$ of diesel fuel per year in the city of Kremenchug.

Conclusion. In order to reduce the toxicity of vehicle emissions, it is proposed to use a mixture of diesel fuel with biofuel (in a ratio of 1:1). For a receipt last the grounded biotechnology is with the use of departure of food industry (to the soapstock) which gives the possibility to reduce ecological risks in the places of waste deposits, and also to reduce the volumes of consumption of traditional hydrocarbon raw material.

We see the prospects of subsequent researches in the scientific and practical study of other factors forming of ecological risk.

**Key words:** Biotechnology, Wastes, Soabstok, Sorbent, Ecological Safety

# THE INFLUENCE OF MERCURY POLLUTION ON THE GROWTH OF BIO-INDICATOR PLANTS

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Heavy metals are found naturally in the earth, and become concentrated as a result of human caused activities. Common sources are from mining and industrial wastes, vehicle emissions, lead-acid batteries, fertilisers, paints, treated woods, aging water supply infrastructure, and microplastics floating in the world's oceans. Heavy metals enter plant, animal and human tissues via air inhalation, diet and manual handling. Most of these chemicals including mercury, lead, cadmium and their compounds are among the most common and highly toxic substances capable of accumulation in living organisms. Heavy metals with excessive exposure to environmental objects behave like ecotoxicants that negatively affect not only individual organisms, but also the ecosystem as a whole.

Mercury (Hg) enters the environment as a result of its natural evaporation from the Earth's crust, and as a result of industrial pollution. The urgency of the problem of environmental pollution by mercury is explained, first of all, by a wide range of its effects on the human body.

One of the methods for assessing the toxicity and soil contamination is the growth vegetation test, which makes it possible to evaluate the effect of toxic substances, in particular heavy metals, on the growth of plant-bioindicators.

A characteristic feature of heavy metals is their ability to transfer, absorb and localize in certain parts of the plant tissues. Some plants have the ability to excess accumulation of heavy metals in special vacuoles of the cell, without involving them in the physiological processes of the cell (hyperaccumulators).

To assess the effect of metals on the physiology of the plant, a number of bioindication tests were performed. Wheat seeds (Tríticum) and mustard seeds (Sinapis alba), which have hyperaccumulative properties, were chosen as the object of the study.

As a substrate for seeding test plants, a standard ground mixture with a pH of 5.0–7.0 was selected containing common black chernozems, complex organic fertilizers and a natural growth promoter – biohumus. A mixture of soil soil for seedlings weighing 100 grams was placed in special containers for growing seedlings with a volume of V = 150 $cm^3$.

For watering plants, the solution of mercuric chloride ($HgCl_2$) was taken. The maximum permissible concentration (MPC) of mercury in soils is 2.1 mg/kg. The main idea of the experiment was to study the impact of various concentrations of mercury on phytoindication activity of plants. At the same time, the amount of working solution of mercury to irrigate 100 g of soil in each container with plant seedlings was estimated as 20 ml. In this volume, the mercury content in MPC units was 0.05, 0.1, 0.25, 0.5, and 1.0, respectively. It is assumed that the volume of the 20 ml solution is calculated for consumption by plants in 100 g of soil and evaporation, but without the formation of a filtrate. The duration of the laboratory experiment covered 21 day.

During the experiment, the intensity of growth of plant biomass and the phenomenon of phytotoxic effect were observed. It has been established that an increase in mercury concentrations to 3…5 MPC causes an average phytotoxic effect in the form of a slowing down of plant growth. Nevertheless, with little mercury concentrations, a visible phytotoxic effect was not observed, that can be explained by the ability of the soil humic complex to bind and fix heavy metals.

**Key words:** Heavy Metals, Mercury, Growth Test, Phytotoxic Effect

# INVESTIGATION OF PHYTOINDICATION EFFECTS DUE TO CADMIUM CONTAMINATION

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Heavy metals are one of the most dangerous contaminants in the natural environment that cause toxic effects in the cells of plants and animals. They are not decomposed in the environment but consequently accumulated in the tissues of living organisms. Penetrating, for example, plants, heavy metals can adversely affect the metabolic processes, which ultimately leads to a reduction in yield and poses a threat of contamination by toxicants to the further food chain.

Cadmium is generally one of the most dangerous heavy metals for environmental components that easily migrates through the trophic chains of terrestrial and aquatic ecosystems accumulating in plant and animal cells.

One of the methods for assessing toxicity and soil contamination is the growth vegetation test, which makes it possible to assess the effect of toxic substances, in particular heavy metals, on the growth of plant indicators.

A characteristic feature of heavy metals is their ability to transfer, absorb and localize in certain parts of the plant. Some plants have the ability to hyperaccumulate heavy metals in special vacuoles of the cell, without involving them in the physiological processes of the cell (hyperaccumulators).

To assess the effect of metals on the physiology of the plant, a number of bioindication tests were carried out. Wheat seeds (Tríticum) and mustard seeds (Sinapis alba), which have hyperaccumulative properties, were chosen as the object of this study.

For seeding purposes, a soil mixture according to the Ukrainian standard TU U 26.8-2976501030-001:2006 was applied. The soil with pH value of 5.0–7.0 contains the following ingredients: common black chernozem, peat, lowland peat, complex organomineral fertilizers and natural growth stimulant – biohumus, natural structuring components (coarse-grained sand, coniferous land, perlite). A mixture of soil for seedlings weighing 100 grams was placed in special containers for growing seedlings with a volume of V = 150 $cm^3$.

For pouring the seedlings the working solution of cadmium chloride ($CdCl_2$) was applied. The working solution was prepared on the basis of the following calculations: 1 maximum permissible concentration (MPC) = 0.1 mg Cd/100ml.

The working solution was watered in a volume of 20 ml per 100 g soil in each experimental container with seedlings, without the formation of a filtrate. At the same time, watering of plants was carried out in various dilutions, which contributed to a different accumulation of heavy metal in containers and, accordingly, phytotoxic effect. So with one-time irrigation, the following doses of cadmium (in MPC fractions) were received in the tank: 0.05, 0.1, 0.25, 0.5 and 1.0, respectively. The duration of the laboratory experiment was 21 days.

During 21 days the intensity of plant biomass growth was recorded, however, the differences in dependence on different cadmium concentrations were not significant, which is related to the ability of the humic complex of soils to bind and fix heavy metals.

**Key words:** Heavy Metals, Cadmium, Growth Test, Phytotoxic Effect

# INFLUENCE OF GREEN PLANTS ON DISTRIBUTION OF SOLAR RADIATION UNDER CONDITIONS OF URBAN BUILDING

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The environmental function of vegetation provides a comfortable living conditions for people in the city. Green plantations affect the gas composition of air and the degree of its pollution, form the climatic characteristics of urban development, reduce the influence of the noise factor, have phytoncide properties, form a comfortable environment for human habitation.

The microclimate in the urban development significantly depends on the distribution of solar radiation fluxes. This is a complex task, which depends on many factors. The intensity of solar radiation for each area depends on its geographical location, geometric and other factors and is determined by special methods. In Ukraine, the share of diffuse (scattered) component of radiation is high and varies from 21% in summer to 60% in winter. In summer, the density of the heat flux of solar radiation in our latitudes reaches 1 kW / m2, which, as a rule, determines the microclimate parameters of streets and premises. Green plantations, especially trees, can significantly influence the distribution of solar radiation over the surfaces of urban buildings, structures and infrastructure objects.

It was developed a mathematical model which finds the distribution of heat fluxes of solar energy, depending on the characteristics of urban buildings, location and size of green spaces. With its help, the distribution of solar radiation on a 12 m wide street was investigated. On the street's sides there are buildings of 12 m height, which corresponds to the height of the five-story building. It was assumed that at a distance of 1.5 m from the left building there is a row of pyramidal trees 6 m high and 2 m wide. The height of the sun above the horizon and the azimuth angle between the direction of the road and the direction to the sun were 80o and 60o, respectively.

The results of the research show that in the shadow zones from tree crowns, the resulting heat flux is substantially lower than that of areas illuminated by direct sunlight. It was shown that the presence of a green zone on the street is capable of 10-20 times reduce heat flows to the surface of the road and the walls of buildings.

The results of the study can be used to determine the microclimate parameters within the street and inside buildings. It is also possible to assess the impact of green street plantations on energy costs for stabilizing microclimate parameters inside buildings in the summer. This will allow estimating the carbon monoxide emissions that are needed to generate energy for air conditioning of the premises.

**Key words:** Green Areas, Solar Radiation, Urban Development, Microclimate, Heat Flow, Mathematical Model

# THEORETICAL MODEL INTEGRATING OF RENEWABLE ENERGY INTO THE MINING INDUSTRY

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Renewable energy (RE) for the mining industry has perspectives for implementation and development. The political and economic mechanism plays a significant role towards RE penetration into the mining industry. The purpose of this theoretical model is to give a tool to energy policy makers and decision-makers for taking a decision in favor or disfavor RE penetration. The theoretical model integrating of RE into the mining industry has been developed as a complex model divided by parts.

This model consists of three main parts. The first part contains the internal indicators (have a direct influence on a mine) at the micro level (local scale) including the categories such as incentives, barriers, and effects towards RE penetration. All these categories are divided under the certain sub-categories providing the detailed components of each category. The basic step of this part is to value each component. In this case, the incentives and effects are supposed to have a positive impact and barriers have a negative impact on the model.

The second part contains the government's support mechanisms category including five sub-categories. This category covers the internal indicators at the macro level (global scale). Hereby, these mechanisms have a direct influence on mining companies establishing a bottom-up approach towards RE implementation. While, mining companies can push the government establishing a bottom-up approach at the same time.

The third part contains the simulative initiatives as the external indicators (have an indirect influence on a mine) at the macro level. This category provides the policies towards developing of RE technologies, infrastructure, and marketing mechanisms. To a RE technological category belongs developing hybrid energy systems towards energy transition, developing RE at regional and local level, load management of electricity, and promotion of storage technologies. To an infrastructure category belongs grid reconstruction and development and grid connection requirements. Consequently, to a marketing mechanisms category belongs RE demand oriented power and direct marketing of electricity.

This theoretical model will be used for developing a guideline for decision-makers and policy makers. We will afford the experts to give their opinions towards evaluation of all these categories and sub-categories. Further, the contribution of the experts will provide us the data with specific value to approve the theoretical model. It will be known, which categories have strong and weak influence on the model. Thereby allowing us, based on this model, set up recommendations for energy policy makers and decision-makers.

**Key words:** Mining industry, Renewable energy, Theoretical model

## Session 4.

## OTHER ENVIRONMENTAL ASSESSMENT TECHNOLOGIES

# ENVIRONMENT ASSESSMENT AND MODELLING OF SALTS TRANSFER IN FOUR LAND RESTORATION SCHEMES IN THE COAL MINING REGION

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The mining district where the Western Donbas coal mines are emplaced has accumulated wastes in the form of tailings, heaps, dumps, and slurry deposits. Meantime, only small part of the waste from these sites is "recycled" in other areas such as road filling, dams and embankments construction. The environmental impact of these materials remains little-studied. The toxic salts mobility as a result of weathering processes has not been estimated and no data exist concerning the transfer of toxicants migration. Accordingly there is great concern rising from high concentrations of toxic salts in these sites. The land reclamation practices are of paramount importance to provide environmental and health regional safety. Moreover, the need for new technologies of natural resource extraction requires new, effective and low cost landscape restoration technologies to achieve a considerable abatement of toxic compounds migration. Main goal is to assess and model salts profile distribution in different artificial land reclamation trials. Objectives: a) to create long-term database of salts distribution for the last 30 years; b) to apply different mathematical approaches to create several numeric models of vertical salts migration; c) to check forecasts in conditions of Pavlograd land reclamation station of DSAEU. Numeric models of the salt transfer at mine dumps were created on the basis of the theory of physic-chemical hydrodynamics of porous media. All variants are solved with the boundary condition of Dankverts – Brenner on the earth's surface and 1 kind on the border of the unsaturated zone and full water saturation. Migration parameters were determined from the analytical dependencies. The solution of the forecasting tasks on the quantitative assessment of the effectiveness of remediation for different periods was performed by the Thomas method. The adequacy of the models is confirmed by comparing the results of forecast with model observations. Models were designed to quantify the migration of macro- and microcomponents in time and space. We considered the following four types: a) without reclamation; b) reclamation in rainfed conditions to grow crops; c) with irrigation system; g) with wild vegetation. The salts migration process case has been studied along artificial soil profiles for land reclamation. A case study is presented as mathematical exponent model. The first model represents the blade which is poured out without reclamation. The process of moisture transfer is infiltration. It provides a slow desalinization of the upper layers, stacked rocks with a speed of 1-3 cm/year, depending on the magnitude of the salinity. The second model shows the migration of salts on reclaimed spoil rainfed agriculture. The presence of evaporation creates a mode of upwards moisture transport. The negative consequence is the increased salinity of the bulk soil. The third model differs from the previous embodiment by the replacement of rainfed agriculture on a systematic irrigation with mine waters of low salinity. The model allows choosing the optimal salinity water for irrigation. A complex assessment of oxidizing-reducing conditions along reclaimed lands has been made. The mathematic modeling and long-term forecast of the water-salinization condition changes in the reclaimed lands has been completed. The calculations of the groundwater table dynamics for reclaimed minelands (without and with horizontal drainage for irrigation) were conducted. The fourth model involves the free growth surface of the blade natural vegetation with low transpiration and is characterized by the accumulation of salts on contact with bulk clay layer.

**Key words**: Coal Mining, Western Donbass, Salt Transfer, Land Restoration

# COPPER IN COAL MINING PRODUCTS OF VIZEYSKA LVIV-VOLYN COAL BASIN MINE: ECOLOGICAL, GEOCHEMICAL AND TOXICOLOGICAL ASPECTS

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Coal producers create special natural and man-made systems, which spread over large areas and affect all components of the biosphere: living and non living, biogenic and abiogenic matters. An important aspect of such a natural and man-made system is the distribution of individual chemical elements in concentrations much higher than background values. In the ecological sense, distribution of bioavailable forms of heavy metals, that can be determined in water-soluble and acetate-ammonia extracts, is the matter of high importance.

The authors have investigated the distribution of various forms of copper within the waste heap of the Vizeyska mine (Lviv-Volyn Coal Basin). This metal belongs to the second class of danger. The metal content was separately determined in the rocks of different lithological composition and the degree of thermal transformations: burnt and unburnt samples of argillites, siltstones, sandstones and soils at a distance of 50 and 100 m from the heap. Sampling was carried out in accordance with all-Union State Standard 17.4.4.02-84, preparation of solutions of extractors from the heap rock and soil was carried out in accordance with State Standards of Ukraine 4770.9: 2007. Copper concentration in extracts was determined by the atomic absorption method using the AAC-115-M-1 spectrometer.

The concentration of copper in acetate-ammonia extract ranges from 0.5 mg/kg in burnt siltstone to 5.49 mg/kg in unburnt argillite; in soils its amount decreases from 0.28 to 0.19 mg/kg depending on the distance from the heap. In aqueous extract, the concentration of Cu varies within the following limits: in unburnt argillite 2,7 mg/kg; in burned argillite, unburnt siltstone, burned siltstone, burned sandstone and unburnt coal <0.1 mg / kg (below detection limit); in the soil at a distance of 50 and 200 m from the foot of the heap < 0.1 mg / kg (below detection limit).

The maximum allowable concentration (MAC) of copper labile forms (in acetate-ammonium buffer extract) in soils is 3.0 mg/kg. The concentration of copper in soils at a distance of 50–100 m does not exceed the corresponding MAC. However, high concentrations of copper in unburnt argillite (up to 5.49 mg/kg) poses significant risks to the environmental safety of the research area.

Despite the general tolerance of plant species and genotypes to this element, copper is considered to be highly toxic. Among other factors the indirect toxic effect of copper on winter wheat is determined by varying the intensity of $Ca^{2+}$-dependent metabolic processes that determine the regulation of cell division and root growth. Copper is highly toxic to most fresh invertebrates. Therefore, the MAC of drinking water (European standard – 0.05, USA and CIS – 1.0, WHO – 2.0 mg/l) is higher than the fishing MAC – 0.01 mg/l. Using modified Allium test A. Dovgalyuk found that the effective toxic concentrations of copper are 23 times lower than the approved MAC of this metal in the soil and is 0.13 mg/liter.

In the human body prolonged absorption of copper along with disturbances of metabolic processes may cause cirrhosis of the liver. There are some reports about the influence of copper on the metabolism of artificially fed infants. Acute poisoning of people in the case of consuming copper with drinking water in doses of 0.14 mg/kg and above was reported.

*Conclusions.* Copper concentration in the acetate-ammonia extract from the heap rocks of the Viseyska mine (Lviv-Volyn Coal Basin) varies from 0.5 mg/kg to 5.49 mg/kg and from 0.28 to 0.19 mg/kg in acetate-ammonia extract from soils in the mine area. That may be dangerous for the state of the environment.

**Key words**: Lviv-Volyn Coal Basin, Copper, Waste Heap of the Vizeyska Mine, Bioavailability

# NEUTRALIZATION EFFECT OF THE FLY ASH AND COAL DUMP WASTES

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Acidic and/or alkaline wastes, or wastes that change their pH level over time, create an increased danger to the environment and human population. These wastes can be formed due to activity of all basic branches of industry (agriculture, energy, metallurgy, food, chemical, mining, production and processing of petroleum products, etc.).

One of the most serious problems causes the waste from the mining industry and coal extraction in the form of waste heaps and waste dumps. The presence of light-dissolving salts (mainly chlorides) as well as pyrites (up to 5-10%) in the coal dumps of the Western Donbass, for example makes it impossible to plant greenery or use dumps for agricultural purposes without significant cost for their reclamation. As a result of oxidative processes, sulfuric acid is formed, which leads to a strong acidification of the environment and migration of acidic components at significant distances beyond the mining objects, pollution of surface and groundwater sources by sulfate and hydrogen ions. The pH after the end of the oxidation process of sulfides may reach 1.3-2.0.

The most optimal solution of the problem connected with acid formation in abandoned coal dumps is their neutralization by alkaline wastes to normalize the pH level. The method of neutralization needs a volumetric determination of the concentration of acids and alkalis in solutions.

The main purpose of this work was to determine the neutralization potential of aqueous extracts from industrial wastes with alkaline pH values for their subsequent use as possible addition for acid wastes from mining and coal processing.

The subjects of the research were samples of coal dumps of mine Pavlogradska (experimental plot without reclamation), selected from a depth of 30–45 cm. The age of the dumps is about 60 years, which indicates the duration of the weathering processes with the formation of sulfuric acid and leaching of metals (pH of the water extract were from 2.65 to 3.32). As a neutralizer the fly ash of the Prydniprovska Thermal Power Plant was used (pH of the water extract was $10.63 \pm 0.04$). To establish the point of equivalence the method of potentiometric titration was used (end point of pH = 7.0, titrants: 0.1 N solutions of HCl and NaOH). For pH measuring the water extracts of fly-ash and coal-dump waste were made in the ratio of 1:10 (waste-water). Titration was carried out in three replicates.

During titration experiments it was established that 0.52 ml of HCl was spent on the neutralization of the fly ash with an initial alkaline pH of 10.63 to a neutral pH of 6.80. Neutralization of acid rock with an initial pH of 3.32 to 6.84 required 2.06 ml of NaOH. A point of equivalence was found as 1.0 ml (both for HCl and NaOH needed for neutralization of the water extracts of fly-ash and coal-dump waste correspondently), at which the pH was only 4.32. The desirable end point of titration was not achieved, which proved a high potential for acid formation in the conditions of coal dumps and necessity to use an increased amount of fly ash. A study on the determination of the optimal ratio of ash-rock showed that the neutral value of the solution (pH 6.95) of the ash-rock mix was observed at the dilution of 3 parts of the fly ash extraction to one part of the rock dump extraction (dry weight).

For investigation the toxic properties of the water extracts of fly-ash and coal-dump a growth test (germination capacity, length of stem and primary root) on the basis of *Sorghum sudanense* seeds was used. It was established that the most optimal substrate for plant cultivation is the ratio of fly ash:coal dump rock (dry weight) as 3:1.

Thus, neutralization of the coal dump wastes with acidic values of pH can be possible on the basis of the fly ash use creating favorable conditions for phytoreclamation of the abandoned coal dumps.

**Key words:** Coal Dumps, Fly Ash, Acidity/Alkalinity, Toxicity Bioindication

# CHRONOLOGICAL STUDY OF THE VEGETATION OF FOREST MASSIF OF SDAMAS

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The massif of Sdamas to which our contribution relates is located in West Algeria, it is an integral part of the mountains of Tiaret.

The main objective of this work is to quantify the plant diversity of existing plant groups, and to understand the architecture and the structure of the various groups of vegetation by the method of floristic analysis and statistical analysis.

The bioclimatic study revealed a drier bioclimatic environment and shows that our region belongs to the semi-arid stage with cool winter.

About vegetation diversity, we have been able to describe a list of characteristic species of the maquis of Western Algeria. The main dominant species in the floristic composition are *Tetraclinis articulata, Pinus halepensis* and *Quercus coccifera* for forest species and *Pistacia lentiscus* and *Phillyrea ssp* for pre-forest species.

The factorial analysis of the correspondences (FAC) allowed us to treat the floristic and ecological variables jointly. This overall treatment allowed us to have a view on certain aspects of plant groups and plant formations in the study area, and to verify that there are indeed original floristic groups characteristic of the area of Sdamas.

Factorial correspondence analysis, performed on species inventoried in the region of Sdamas, shows that the acting ecological factors are the bioclimate, the nature of the substrate and human action. They explain the great part of the information provided by the different axes. Indeed, the bioclimate, through the atmospheric drought, is the main factor of the diversity of the formations of the Sdamas mountains. For its part, human action (overgrazing, fires and deforestation) contributes to the drying up of environments. Finally, the nature of the limestone substrate (calcium carbonate) can cause pressure on vegetation in the same direction as human action, as the two preceding factors affect plant performance and geographical distribution of species.

For further analysis of dynamics, the aim is to analyze the land cover of the Sdamas region over a 43-year interval grouped into 9 thematic classes: Mineral Surfaces (Urban Planning), Wetland, Thuja stand, mixed stand, maquis, grounds of alf-alfa, bare soils and fallow, maquis of Pine. The spatial and temporal dynamics of land use require regular monitoring of vegetation cover from remote sensing imagery. It is for this reason that we relied on field data to perform the diachronic analysis with three well-defined scenes 1972, 1998 and 2015, using Landsat satellite images (MSS, TM and ETM +). The analysis of these maps allows us to observe the different changes that take place at ground level. We found that the natural plant cover has undergone a strong degradation, disruption and regression from maquis with a dense cover to degraded (garrigue) because of the different human activities, namely: fires, overgrazing, clearing, urbanization, (a remarkable increase of population in the communes of the study area).

Moreover, inadequate and ineffective forestry interventions and work, and the lack of continued protection. has aggravated pressures due to human activities. Indeed, the degradation and the regressive changes of plant communities in this region and in the whole of the Mediterranean area are man-made, and it remains the main cause of the fragmentation of natural ecosystems.

**Key words**: Dynamics, Cartography, Remote Sensing, Sdamas, Tiaret

# ECOLOGIC APPROACH TO THE RESTORATION PROCESS AT AREAS DEGRADED BY MINING OPERATIONS

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Donetsk Region belongs to the zone of the most Ukrainian critical ones in provision with water and the quality of water. The main reason of the water quality deterioration is anthropogenic pollution due to untreated water discharge by the region's industrial enterprises to water objects.

When worked-out mines are abandoned using the combined method then water pumping is continued from immersed underground workings at least 100 m deep to prevent the impoundment of surface plots settled. The pumped water shall be desalinated and clarified. Demineralization of these flows is the technical problem associated with considerable costs.

In accordance with the existing sanitary norms and regulations mine waters must be purified before their discharge to open water reservoir as they contain substances which concentrations exceed maximal values permitted for piscine.

Besides, for mining enterprises under liquidation the issue of restoration and topsoiling together with biodiversity at the abandoned areas of open pits and industrial grounds of closed mines is of primary importance.

In this connection we find prospective the biological water purification using higher aquatic plants that will form the humus part of the productive layer after cells' die-off and decompose. The restored space will be reformed to the labyrinth of channels filled with flows where hydrocoles grow on walls and bottom. The suspended substances of flows are partially deposited on the channels' bottom however the larger mass is captured by numerous developed micro-hairs of rhizomes thus being transferred to the bound state. It is due to mineral substances absorption by plants and protozoa that salts and suspensions content in the aquatic environment get reduced.

The productive layer is formed from the captured particles and died-off organs of hydrocoles to become the basis for biota development.

To provide the whole-year water purification, prevent the effective reduction of mine water discharge purification in winter period, and the water overheating in summer the authors propose the design of a tubular geo-thermal heat-exchanger installed in a borehole. It includes coaxially positioned pipes, the inside one being manufactured of low thermal conductivity material. The water is supplied to the heat-exchanger, to the gap between the outside and the inside pipe, due to hydro-dynamic flow strength while its output is provided via the cavity of the inside pipe. Geo-thermal power provides the stable maintenance of the water temperature on the outlet of the exchanger as well as in the channel on the level of +12…260 °C. Mine shafts can be used as heat-exchangers, supports as the outside pipe, and airlift water discharge as the inside pipe. Water withdrawal will be done from an immersed mine level.

So, the proposed technology allows the effective whole-year water flows' purification at mining enterprises as well as acceleration of the processes of productive soil formation at abandoned areas and industrial grounds of closed enterprises.

**Key words:** Higher Aquatic Plants, Biological Purification, Geo-Thermal Power

# STUDYING THE POSSIBILITY OF USING RED-BROWN CLAY FOR RECLAMATION OF COAL WASTE DUMPS

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The coal mining industry, as the source of the main fuel resource and the main energy resource, has particular importance for Ukraine. The largest coal regions of Ukraine include Donetsk, Lviv-Volynskyi and Dnipropetrovsk brown coal ponds. Their total area is 3% of the total area of Ukraine.

The coal dumps are formed after deep excavation works and the processing of rock extracted from great depths. They can include rock with elements in reduced form, such as $Fe^{2+}$, $S^{2-}$, $Mn^{2+}$, $Cu^{+}$, other elements and compounds. The surface of dumps quickly reacts with oxygen from atmosphere. The inclusions of pyrite ($FeS_2$) convert into $Fe^{3+}$ and sulfuric acid as a result of oxidation. Dumps should be reclaimed or can be used as secondary mineral resources for the avoidance of formation of lifeless landscapes.

The main task of reclamation is to create biologically productive areas of the earth's surface with the necessary conditions for plant growth. The layers are usually applied in the following order: clay screen, layer of mine rock, potentially fertile soil and fertile soil. Black soil is widely used as the fertile soil layer. However, this method has disadvantages and relatively high cost.

The present study was conducted on the basis of the Pavlograd experimental station for reclamation of disturbed lands in Western Donbas located near the mine "Pavlogradska". The objective of the presented study is the quality of soil from two reclaimed plots of coal dumps from mine Pavlogradska. The 50 cm bulk layer of black soil has been heaped on the first plot; 50 cm red-brown clay layer has been heaped on another plot.

The purpose of the study is to determine the total salt content of experimental plots and consider the prospects of using the red-brown clay as top soil for coal dump reclamation.

The soil samples were selected according to the current ISO 4287:2004 and ISO 10381-2: 2004 in the range of 0–70 cm depth in increments of 10 cm in triplicate. They were dried in a muffle furnace; soil water extraction was received in the ratio of 1:10. The pH index of water extraction was determined according to GOST 17.5.4.01-84. The electrical conductivity (EC) was determined according to ISO 11265:2001. For the determination of the organic substances the method of dry burning according to the State Standard of Ukraine Б В.2.1-16:2009 was used. Total and dissolved content of the elements were measured using inductively coupled plasma mass spectroscopy (ICP-MS). Samples preparation was performed by acidic melting according to ISO 11464:1994 and the State Standard of Ukraine ISO 14869-1:2005.

The results have shown that black soil salinity is much more intense than in clay. Index of conductivity significantly increases at the depth of 20–30 cm. However, EC index of red-brown clay remains unchanged at the depth of 40–50 cm. The clay pH is higher than that of the black soil. Results obtained from analyses of content of $NO_3^-$, $NH_4^+$, $PO_4^{3-}$ have shown that both clay and chernozem are poor of mineral nutrition of plants. Clay has significantly higher total contents and water-soluble contents of Mn and Co in comparison with chernozem. Moreover, in some cases, the total content of heavy metals in chernozem exceeds its concentration in clay-soil mixtures almost twice.

Thus, according to the obtained results, the processes of vertical salt transport in chernozems are faster and also have a greater ability to accumulate heavy metals than clay. The above factors give grounds for considering clay to be used as an alternative variant of the fertile layer for the reclamation of coal dumps.

**Key words**: Coal Waste Dumps, Reclamation, Red-Brown Clay

# REPEATING POLYETHYLENE DERIVATIVES OF THE LOW DENSE OF HRYBVOVITSKY DUMP

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*Relevance.* The dump in the village Veliky Gribovitchy near the city of Lviv (Lviv Solid Waste Landfill) is one of the largest environmental pollutants in the Lviv region. At present, the landfill is closed. The reason for the closure was the fire that arose on its territory on May 29, 2016, and the subsequent shift of a significant amount of garbage. Among the whole variety of polymer waste in the landfill, is the largest share of low density polyethylene waste (LDPW). The main products on the basis of LDPW, which fall on the Gribovitchy waste dump, are containers after repeated use, various packaging materials.

*Goals and objectives.* The purpose of the work is to determine the technological and operational properties of materials on the basis of mixtures of LDPW waste with the commodity LDPW for the establishment of the possibility of recycling of polyethylene waste from landfill.

*Methods.* Materials for researches were mixtures based on waste LDPW and commodity LDPW (grades 10203-003, 10702-020 and 10603-007). LDPW waste was collected on the surface of the Gribovitsky landfill site and subjected to purification from extraneous impurities, dirt before their granulation, and the production of standard samples for research ISO R527 (type 2). Experimental data were obtained using standard techniques and state-of-the-art methods for investigating the structure and properties of polymeric materials.

*Research results.* Investigation of the rheological properties of LDPW-based mixtures has shown that as the temperature rises, the viscosity of LDPW and its waste products decreases. For LDPW waste, the melt viscosity decrease at the same temperature, compared to the LDPW, is more significant. Throughout the studied interval of shear rates of all melt materials, the values of their effective viscosity are not constant. This suggests that, with increasing tensile displacement, the anomaly of the viscosity of the molds manifests itself to a greater extent.

One of the important methods by which one can determine the structure of polymer macromolecules is infrared spectroscopy (IR spectra). In the IR spectra of LDPW waste, unlike the IR spectra of the commodity LDPW, there are additional bands that can indicate the presence of a polymeric material in the process of natural aging. This process is accompanied by oxidative degradation. Confirmation of oxidative destruction of material is the presence in the waste LDPW of a band in the region of 1900 $cm^{-1}$ and strips with an absorption rate of 1740 $cm^{-1}$, which corresponds to valence fluctuations of carboxyl groups.

Thermomechanical characteristics of polymer materials, which are related to the flexibility of macromolecules and their internal structure, should be investigated using thermomechanical curves. From the obtained thermomechanical curves it can be seen that the melting point of the $T_{pl}$ of the commodity LDPW is ~ 128 $^0C$ and is higher than its waste ($T_{pl}$ ~ 117 $^0C$). Obviously, this is due to the decrease in the molecular weight of LDPW waste, in contrast to the commodity LDPW, and, accordingly, with some changes in the crystalline structure of the materials under study.

Performance indicators of materials based on mixtures of thermoplastics significantly differ from the commodity homogeneous thermoplastics. They can be broadly regulated by the physical condition of the material, the nature of the source components, the nature of the distribution of ingredients in the volume of the material, heat treatment or technological conditions of processing, affecting the process of melt crystallization and the formation of various supramolecular structures.

*Conclusions.* To improve the environmental situation on the territory of Gribovitchy landfill, LDPW waste can be recycled with a commodity LDPW for the production of «non-technological» products. In order not to make significant changes in the technological process of manufacturing products on the basis of commodity LDPW it is possible to add waste LDPW in an amount not more than 20 % by weight. The presence of a small amount of waste is not significantly influenced by the operational performance of the products and the ability to process the material, compared with the commodity LDPW

# COST-EFFECTIVE TECHNOLOGY FOR HEAT POWER STATIONS ASHES PROCESSING AND UTILIZATION

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The heat power stations (HPS) ashes generated by the burning of coal are on the one hand, the source of environmental pollution. On the other hand, they pose the source of raw materials for industry. There have been accumulated hundreds of millions tons of ash in Ukraine's HPS ash disposals, still containing a number of valuable components. Furthermore, HPS disposals are annually filled with fresh ash inflow of more than 10 million tons. Despite the content of phase terms with high consumer properties in a number of ashes is relatively high, we can only partially assign them to technogenic minerals due to the lack of cost-effective methods of valuable components recovery. Therefore limited quantities of HPS ashes are used up to the present.

The main objective is to create a technically sound and cost-effective technology for separation of HPS ash into several components. Ash is a complex polymineral system, which is characterized by nonuniform composition. Depending on reactivity and mineral composition of burning coal, the content of valuable components in produced wastes varies widely. Thus the content of carbon in wastes can range from 12 to 45% within a few hours. Four groups of methods of separation of polymineral systems are used in the beneficiation of evils: gravitational, magnetic, electrostatic and flotation. A small concentration of some components and their thin membrane is disclosed bean before the separation process that is achieved by the influence of reagents and particle size reduction. The developed method is flotation, providing the carbon-containing concentrate with ash content of not more than 25%. The flotation process is carried out in the presence of a specific reagent effective to separate evils. Obtained by flotation the beneficiation of fly ash-cake (mineral ash fraction) may have an ash content of 94 – 99%. Consequently, the feasibility of separation of narrow grain-size fraction from 40 to 150 μm with average ash content of 33% can be seen from the distribution analysis of HPS fly ash. The "carbon" product can be floated (enriched by flotation). After flotation ash content of carbon concentrate can amount less than 20% along with sulfur content about 0.4%. The sulfur content complies with European requirements. Carbonaceous concentrate can be used as a fuel additive to the fuel oil thermal power plants. The calorific value of it is 5000 – 6000 kcal/kg.

Hypotetical scheme of the separation of ash into two components was developed. It is possible to get rich with carbon fraction due to fractioning, filtering, flotation and drying. We call this fraction as "second coal". By the other words this technology for ash processing allows obtaining products of specified quality regardless of the conditions of coal burning at the HPS. A pilot unit for ash separation was tested at the Pridneprovsk HPS. Installation was working for 600 hours at the initial sol throughput of 5 – 8 t/h or carbon concentrate throughput of 1 – 1.5 t/h. According to developed technology, industrial installation for ash enrichment was put into operation in 1997 at the Luhansk HPS with capacity of 400 thousand tons per year. Ukrainian heat power stations burn mostly gas coal, anthracite, ash-removal containing 15–25% carbon, which limits use in the construction industry. Standards of all countries in the world, including Ukraine, are to restrict the carbon content in the ash for concrete to 3–5%. This requirement is not inconsistent not only for anthracite coal ash, and the ash from the combustion of gas coal of Ukraine, which contains 6–8% carbon. As a chalenge of the energetic problems in Ukraine, there is an urgent need for research on the preparation of pellets from biomass energy crops and fly ash.

The samples of anthracite coal ash were taken in Prydeneprovska, Zmyivska and Zelenodolska HPS. Termogravimetry analyzes were conducted to estimate the prospects to burn it separately or (and) in mix with biomass of energy crops and agricultural residues.

**Key words**: Heat Power Stations, Ash, Pellets from Biomass Energy Crops and Fly Ash

# THE IMPACT OF COAL WASTE HEAPS ON THE ENVIRONMENT OF SOKAL DISTRICT OF LVIV REGION

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The environmental situation in Sokal district is one of the most complicated in Lviv region, which is caused by man-made environmental impact of mining, coal preparation and chemical industries. Most of the territory is occupied by coal waste heaps.

Chervonograd mining region is centered in the Sokal district of the Lviv region. According to engineering geological zoning it belongs to the central part of Lviv-Volyn Coal Basin, located at the western border of Ukraine with Poland on the border of Volyn and Lviv regions. This basin is the south-east part of Lublin Coal Basin, which spreads over the large territory in Poland.

One of the major air pollutants within Sokal administrative district and Chervonohrad industrial area is mining industry that is a part of the State Enterprise "Lvivvuhillia" and "Lviv Coal Company" (Central Coal Enrichment Plant "Chervonohradska"). Harmful air emissions of the State Enterprise "Lvivvuhillya" varies from 6.3 to 7.1 thousand tons per year (sulfur dioxide – 3.9–4.1 thousand tons; nitrogen dioxide – 0.7–0.9 thousand tons; carbon monoxide – 1.0–1.2 thousand tons; solids – 0.7–0.9 thousand tons).

Production activities of mining complex that led to significant changes in the landscape of the region (ground subsidence in the coal bed working areas are 2–4 meters deep), includes environmentally hazardous facilities like waste heaps (the total area of which is 265.9 hectares and the volume of accumulated waste products is 42.1 million cubic meters), coal stores, storage ponds and mine water filter beds. The part of burned rocks in the total amount of rock recovered over the years of mining operation is around 25–30%.

The most dangerous sources of pollution are the burning coal waste heaps. Their combustion causes hazardous air emissions over the vast area. The burning of waste heaps is activated by the moisture and oxygen. The most prominent representative is the waste heap of "Lviv Coal Company", which is located in the village of Sielets, Sokalsky district, Lviv region.

Burning waste heaps are the source of air emissions of around two dozen pollutants: hydrogen sulfide, carbon monoxide, carbon dioxide, sulfur dioxide, hydrogen sulfide, nitrogen oxides, sulfuric acid, sulfur dioxide, hydrogen cyanide, ammonia, cyanides, thiocyanates, etc. It was determined that during combustion of 1 kg of rocks the air emissions tend to 6.7 up to 8.7 mln. $m^3$. Numerous scientific studies have established that at temperatures of rock above +100 °C Hg is transferred in an elemental form, and at temperatures below +100 °C it is transferred in the form of chloride (HgCl). Also Cd and Zn can be transferred in small amounts in the elemental form at temperatures above +400°C. In the temperature range of +200-400°C prevail forms of CdCl, $ZnCl_2$ and $ZnBr_2$.

Lithologically waste heaps are represented by argillites, siltstones, sandstones, coal and other rocks. Over 70% of waste heaps are made up of clay argillites, which promotes sorption of heavy metals (Li, B, P, Zn, Pb, Bi, Co), and due to high sulfur content (pyrite) – Hg and As. Significant sulfur content in waste heaps causes local fires, resulting in sulphides transformation into sulphates and acidic water formation in the foot hill of waste heaps.

It is well known that temperature inside burning coal waste heap reaches +1000°C and even more. The combustion process lasts for 20 years. The above indicates that the use of heat that is released during the combustion of coal waste heaps can solve three problems, namely environmental, economic and social ones.

**Key words:** Coal Waste Heap, Combustion, Environmental Hazard

# IDENTIFICATION OF ORGANIC COMPONENTS OF SOLID WASTE ON SATELLITE IMAGERY WHILE MANAGING ENVIRONMENTAL SAFETY

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Solid domestic wastes contain a components which can become nutrients for a pretty wide spectrum of types of microorganisms some of which are harmful for human and environment. The climate on territory of Ukraine promotes their intensive reproduction in such conditions. All organisms, including microorganisms, mainly consist of carbon and therefore represent the carbon containing components of waste dumps, namely organic. Monitoring of the conditions of microbiological pollution of urban systems on the territory of which surely there are solid waste damps as part of technogenic and ecological safety of these systems, can take one of main places in ecological safety management systems.

Data of remote scanning of Earth (RSE) from the Space is such source of information, that allows to get an actual operative picture of places of location of illegal waste dumps with low time expenses. RSE methods in combination with Geo Information Systems (GIS) and methods of mathematical modeling provides possibilities for complex studying of sources of formation of ecological danger and making decisions about ways for handling them. For successful carrying out tasks of the study it is necessary to use Space images of ultrahigh spatial resolution (0.5 – 15 m) in spectral diapason 0.4 – 1.1 microns with spatial reference.

The present study was carried out for the example of Dergachi polygon of solid domestic waste in Kharkiv region. Results of the study shows that in this case using of universal method we can not allocate the solid waste dump on the general background of a Space image with acceptable accuracy because this task solves many errors of 1st kind. For the polygon implementation of allocation of presumable place of accumulation of waste was executed using a model that was based on analysis of statistical moments of different orders (average value, dispersion, asymmetry and excess) in accordance with following algorithm: a) finding of average number of pixels in specific part of image by the way of developing of its model in program Toolbox/Model maker using the command Focal Scan/Fokal Mean; b) marking on the image the sector of polygon that corresponds to selected model for calculation of average number of pixels; c) developing of model of dispersion in Focal Scan/ Focal Standard deviation and presenting it on picture and then selecting of diapason of values of dispersion using histograms; d) determination in accordance with histograms of required parameters for detection of zone of accumulation of waste and then allocation of areas of carbon containing materials and organic components of legal or illegal dumps from other components of landscape; e) loading of image in program Arc Map, creation of shape-files and classification, vectorization and calculation of value of area.

Thus, in present study a model was developed that is based on the method of exclusion («cutting-out») on image of sectors of dump with low degree of danger such as construction debris and rock masses. This model allows to allocate areas of carbon containing materials and organic components of legal or illegal dumps. That allows increasing of efficiency of implementation of ecological monitoring.

**Key words:** Ecological Safety; Earth Remote Scanning; Organic Pollution, Waste dumps; Space Image; GIS-Technologies

# REMOTE-SENSING METHODS OF INDICATOR ESTIMATIONS OF GARDENING TERRITORIES PLACED BY MINING INDUSTRY WASTE

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Today across the world there are huge areas that are occupied by badlands left after intensive mining. Breeding dumps, sludge dumps, places of storage of ash and slag often represent a biological desert, which is difficult to remediate. For example, such places are sulfur rock dumps of mines in Donbas as a result of insufficient mineral nutrition and high acidity with sulfur concentration. Such zones show a low rate of self-growth and gardening. Mining wastes that accumulated for many years contain toxic components that are priority sources of environmental pollution.

The emergence of a sustainable vegetation cover in the post mining areas indicates the beginning of their biological recovery process which tends to accelerate and form a sustainable ecosystem. Vegetation is the dominant factor in the environment formation that can serve as an indicator for assessing the processes of disturbed lands remediation.

Using traditional field (labs) methods for studying vegetation cover in areas occupied by industrial waste are associated with a number of difficulties. For example, some places, such as ledges, loose embankments, swampy areas, can be dangerous to access and unsafe for botanical studies. In addition, such field research requires a lot of money for labor resources.

Modern GIS-technologies in combination with remote sensing methods based on multispectral satellite imagery allows to significantly simplify estimation of the vegetation cover and biomass on large areas. Moreover, they allow assessing the state of vegetation by biophysical indicators, followed by spatial and statistical analysis of the study areas.

The aim of the work was to investigate the dynamics of green plantations state on the rock dump territory with its sanitary protection zone of the coal mine "Stepova" (Pershotravensk, Dnipropetrovsk region) using remote-sensing methods.

The work used multispectral aerial photographs of high resolution that were obtained from the Sentinel-2A satellite. These images were processed in the ESA SNAP program using atmospheric correction modules and a biophysical processor. As a result, the maps of the surveyed territory were constructed for the summer periods of 2015 – 2017 according to the following indices: vegetative index, chlorophyll content in leaves, water content in leaves, coefficient of plants' absorption of solar radiation, canopy index and coating coefficient of leaves. Further on these indicators, a spatial statistical analysis of the territory was carried out using the ESRI ArcMAP program and the area statistics tools.

As a result of the analysis it was established that the area of green plantations on the territory of the sanitary protection zone increased during the study period by 5.8%. The area of green plantations on the territory of the dump almost did not change (-1.2%), as well as the state of plants on the average weighted indicators of chlorophyll and water content in the leaves.

Thus, based on biophysical indicators of the state of vegetation obtained using GIS-technologies combined with remote-sensing methods are advisable to evaluate the processes of ecosystem restoration in post mining areas.

**Key words:** Badlands, Reclamation, Gardening Territories, Remote-Sensing Methods

# TECHNOLOGICAL AND ENVIRONMENTAL ASPECTS OF UTILIZATION OF HYDROLYSIC SULFURIC ACID OF PRODUCTION OF PIGMENT TITANIUM DIOXIDE

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Ukraine is one of the five countries producing strategic titanium raw materials. Testing of titanium objects from the standpoint of complexity will ensure their rational development and significantly increase profitability. The country has 40 deposits, of which: 1 – unique, 13 – large, 12 – prospected, 5 – developed. The deposits of titanium ores with commercial reserves have been explored since several decades. Other deposits reserve resources have been estimated in advance and constitute, conditionally, the "titanium reserves base of the country". At the same time, the total reserves and the reserve base of titanium ores of Ukraine, according to their estimates, "exceed those of any other country in the world."

Industrial titanium extraction is mainly produced from ilmenite – $FeTiO_3$ (36.8% iron, 31.6% oxygen, 31.6% titanium) and rutile – $TiO_2$ (60% titanium, 40% oxygen). «Sumykhimprom» annually consumes up to 150 thousand tons of ilmenite concentrate and produces 45 thousand tons of titanium dioxide by sulphate technology. At 1 ton of $TiO_2$ 3.5 tons of $FeSO_4 \cdot 7H_2O$, 1 ton $FeSO_4 \cdot H_2O$ and 9–10 tons of hydrolysic acid with the content of 15–18% of $H_2SO_4$ are formed.

Hydrolytic acid can not be reused in the production cycle of titanium dioxide. The suspensions of titanium hydroxide present in it can lead to premature hydrolysis of the solution. The main direction of its utilization is the evaporation to a concentration of 55% with subsequent use for the production of superphosphate. The costs of processing and neutralizing hydrolytic acid may exceed 30% of all production costs.

Considering that about 10 million tons of solutions of hydrolytic acid are produced annually in the world, the need to develop and introduce fundamentally different technological processes of acid regeneration becomes obvious.

A promising technology for utilization of waste – hydrolysis sulfate acid is the oxidation of iron(II) compounds to produce sulfuric solutions of iron(III) compounds. The best oxidizer of $Fe^{2+}$ compounds, based on its availability, low cost and the absence of negative effects on further technological processes, is air oxygen. The disadvantage of the process of oxidizing $Fe^{2+}$ with air oxygen is that this process is realized at elevated temperatures. However, the introduction of nitric acid or oxygen compounds of nitrogen, products of its decomposition, which act as a catalyst in the solution of $Fe^{2+}$, allows efficient oxidation at 25–50 °C.

Iron (III) compounds can be used as an oxidizing agent, at atmospheric pressure, what allows to use simpler and less expensive instrumentation for technological processes. In acidified ferric sulfate solutions can be dissolved chalcocite ($Cu_2S$), covetal (CuS), bornitis ($Cu_5FeS_4$), chalcopyrite ($CuFeS_2$) and sphalerite (ZnS). This makes it possible to consider water-soluble compounds of ferric iron as one of the most industrially acceptable effective oxidants.

This paper presents the results of a study of the effect of physicochemical, hydrodynamic factors and temperature on the rate of oxidation of $Fe^{2+}$ ions by air oxygen in the presence of catalytic amounts of nitrogen oxides. The orders of oxidation reactions of $Fe^{2+}$ over NO in the gas diffusion film and in solution were determined and amounted 1.9 and 1.06 respectively. And also, the value of the rate constant of oxidation of $Fe^{2+}$ in solution, which becomes $0.9 \cdot 10^6$ $M^{-2}c^{-1}$. A mathematical model has been developed. This model makes it possible to give practical recommendations on the selection of mass exchangers, the main technological regimes and the parameters of their operation.

**Key words:** Production Cycle, Titanium Dioxide, Waste, Utilization, Mathematical Model

# COMPARISON OF THE SOIL RADIOACTIVE AND HEAVY METALS POLLUTION WITH PHYSIOLOGICAL PARAMETERS OF TEST PLANTS AT THE FACILITIES OF SUKHACHEVSKY INDUSTRIAL SITE

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The work aimed to assess the impact of Baza S uranium ore storage site and Sukhachevskoye uranium mill tailing impoundment on physiological parameters of test plants.

For the city of Kamenskoye and the Dnipropetrovsk region there is much tension around the issue of handling radioactive waste from the uranium production of the former Production Association "Pridneprovsky Chemical Plant" (PCP), one of the largest uranium processing enterprises in the Soviet Union from 1948 to 1991.

Taking into account that the processed raw materials and wastes of the PCP production are sources of radiation and chemical hazards, the study of the distribution of radionuclides, heavy metals and associated chemical elements is important.

On the territory of the investigated objects 20 samples of the upper soil layer were taken, 10 points on the uranium ore storage "Baza S" and 10 points along the internal contour of the second section of the uranium mill tailing impoundment "Sukhachevskoe". Samples of soil were taken in the places where the test plants grew. As a control point, the soil taken in the area of the Kamenskoye meteorological station was used.

To determine the sterility of the pollen, *Barbaréa vulgáris*, *Sālvia officinālis* and *Chelidónium majus* were used as test plants. For the growth test, we used *Raphanus sativus* and *Secále cereále.*

The content of natural and man-induced radio nuclides is given as well as exposure dose rate. $U^{238}$, $Th^{230}$, $Ra^{226}$, $Pb^{210}$, $Th^{232}$, $K^{40}$ and $Cs^{137}$ concentrations were measured using HPGe low-background semi-conductor gamma-spectrometer with GMX40 ORTEC detector, exposure dose rate of gamma radiation was measured using DKS 97 dosimeter.

Specific activity of radionuclides at the sampling points at the uranium ore storage "Baza S" (kBq / kg): – of the uranium series: $U^{238}$ = 0.03 – 13.2, $Th^{230}$ = 0.03 – 14.9, $Ra^{226}$ = 0.04 – 12.7, $Pb^{210}$ = 0.3 – 0.35; – thorium series: $Th^{232}$ = 0.02 – 0.51; $Cs^{137}$ and $K^{40}$ at the background level.

Using IRIS Intrepid II ICP atomic-emission spectrometer, the content of trace elements As; Cd; Pb; Se; Zn; B; Co; Cr; Cu; Ni; Sb; Al; Ba; Mn; Sr; V and accompanying elements was measured. Correlations were established between radionuclide specific activity and metal concentration in soil of Baza S uranium ore storage site.

The content of the mobile forms the I–III hazard classes and accompanying elements in the soil of the uranium ore storage "Baza S" far exceeds the concentration on the uranium mill tailing impoundment "Sukhachevskoe".

Comparison of data about the bioindicator damage with the magnitude of the gamma radiation exposure dose and the specific activity of radionuclides in the territory of the uranium ore storage "Baza S" and the second section of uranium mill tailing impoundment "Sukhachevskoe" does not allow to make a firm conclusion about the correlation dependence between these factors.

In general, the value of the test plants pollen sterility on the uranium ore storage "Baza S" is less than in the second section of the uranium mill tailing impoundment "Sukhachevskoe". The depressing effect on the relatively elongated root and culm was exerted by almost all soil samples, but stronger effect was for the uranium mill tailing impoundment "Sukhachevskoe". Only for some samples an increase in the length of the root and culm relative to the control sample was observed.

A correlation was found between the concentration of mobile forms of some elements and the specific activity of the isotope $U^{238}$.

**Key words:** Uranium Mill Tailing Impoundment, Uranium Ore Storage, Radionuclides, Heavy Metals, Specific Activity, Exposure Dose Rate of Gamma Radiation, Bioindication

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**Applied Biotechnology in Mining: Proceedings of the International Conference (Dnipro, April 25-27, 2018). – Dnipro: National Technical University "Dnipro Polytechnic", – 2018. – 91 p.**

**In English Language**

Підп. до друку 01.04.2018. Формат 60x84/8. Папір офсет.

Ризографія. Ум. друк. 32,5. Обл.-вид. арк. 28,4.

Тираж 100 пр. Зам. №

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