University of Belgrade
Technical Faculty in Bor

31st International conference

Ecological Truth & Environmental Research

Editor
Prof. Dr Snežana Šerbula

PROCEEDINGS

Hotel Sunce, Sokobanja, Serbia
18–21 June 2024

PROCEEDINGS

31st INTERNATIONAL CONFERENCE

ECOLOGICAL TRUTH & ENVIRONMENTAL RESEARCH – EcoTER'24

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Publisher: University of Belgrade, Technical Faculty in Bor

For the publisher: Prof. Dr Dejan Tanikić, Dean

Printed: University of Belgrade, Technical Faculty in Bor, 100 copies, electronic edition

Year of publication: 2024

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

502/504(082)(0.034.2)
574(082)(0.034.2)

INTERNATIONAL Conference Ecological Truth & Environmental Research (31 ; 2024 ; Sokobanja)

Proceedings [Elektronski izvor] / 31st International conference Ecological Truth & Environmental Research - EcoTER'24, Sokobanja, Serbia, 18-21 June 2024 ; [organized by] University of Belgrade, Technical faculty in Bor (Serbia) ; [co-organizers University of Banja Luka, Faculty of Technology – Banja Luka (B&H) ... [et al.]] ; [editor Snežana Šerbula]. - Bor : University of Belgrade, Technical faculty, 2024 (Bor : University of Belgrade, Technical faculty). - 1 elektronski optički disk (CD-ROM) ; 12 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Preface / Snežana Šerbula. - Tiraž 100. - Bibliografija uz svaki rad.

ISBN 978-86-6305-152-2

а) Животна средина -- Зборници б) Екологија – Зборници

COBISS.SR-ID 147002889

The 31st International Conference
Ecological Truth & Environmental Research – EcoTER'24

is organized by:

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TECHNICAL FACULTY IN BOR (SERBIA)

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PREFACE

The 31st international conference Ecological Truth & Environmental Research – EcoTER'24 focuses on showing the latest research findings and innovations in the field of ecology, environmental protection and sustainable development. The conference will be held in Sokobanja (Serbia) in hotel Sunce in the period of 18–21 June 2024.

The aim of the conference is to connect the experts in various fields in order to transform attitudes and behaviors in everyday practices, as well as in the industry and economy sector which is essential for achieving the desired changes that our society must undergo.

The 31st international conference Ecological Truth & Environmental Research – EcoTER'24 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology; the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica; the University of Zagreb, Faculty of Metallurgy – Sisak; the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Society of Young Researchers – Bor.

These Proceedings encompass 119 papers from the authors coming from the universities, research institutes and industries in 15 countries: Brazil, Norway, USA, Spain, Austria, Libya, Italy, Israel, Slovenia, Croatia, Romania, Bulgaria, Montenegro, Bosnia and Herzegovina, North Macedonia, and Serbia. It is a great honor and pleasure to cordially wish a warm welcome to all the participants of the conference.

As a part of this year's conference, the 6th Student Section – EcoTERS'24 will be held. We appreciate the contribution of the students and their mentors who have also participated in the conference and hope that students will continue to explore and to be curious, since education is a never-ending process, and knowledge is continuously growing.

The organization of the EcoTER'24 conference has been financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

The support of the Donors and their willingness and ability to cooperate has been of great importance for the success of the EcoTER'24 conference. The organizing committee would like to extend their appreciation and gratitude to the Platinum donors of the conference – Serbia ZiJin Copper doo Bor and HBIS SERBIA, to the Gold donor of the conference – Elixir Group, as well as to the Silver donor of the conference – Serbian Chamber of Engineers.

We would like to express our sincere appreciation to all the authors who have contributed to the Proceedings. We would also like to express our gratitude to the members of the scientific, organizing and honorary committees, reviewers, speakers, chairpersons and all the conference participants for their support of the EcoTER'24. Sincere thanks go to all the people who have contributed to the successful organization of the EcoTER'24.

Prof. Snežana Šerbula,

President of the scientific and organizing committee

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EcoTER'24
31st International Conference Ecological Truth & Environmental Research
18–21 June 2024, Hotel Sunce, Sokobanja, Serbia
www.eco.tfbor.bg.ac.rs

RECULTIVATION OF RTH FLOTATION TAILINGS IN BOR, SERBIA

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Abstract

Degraded areas were formed by depositing flotation tailings at the location of RTH near Bor, in Serbia. The final conture of the flotation tailings was projected, and it is at the elevation K +390 m above sea level. In order to protect the environment, protection measures are taken at the flotation tailings by recultivation of all degraded areas. For this purpose, an analysis will be performed to determine the optimal method of recultivation. In order to prevent air pollution and erosion of tailings material through torrents and its transport to the surrounding land, special attention is paid to the possibility of afforestation and greening of degraded areas by deciduous and coniferous species. In this way, i.e. by applying biological reclamation, seedlings of birch, and juniper, are planned. The alternating combination of these plant species enables the binding of the substrate and gives a beautiful aesthetic appearance to the environment.

Keywords: recultivation, degraded areas, afforestation and greening.

INTRODUCTION

The RTH (Mine body H – **R**udno **T**elo **H**) flotation tailings pond (Figure 1) was formed southeast of the Bor flotation in the excavation area of the RTH open pit. After the excavation, space of the open pit RTH was filled, and due to the need to increase the volume of the storage area, the flotation disposal site was expanded to the northwest and southeast in the former valley of the Bor river. The river valley in the northwest towards the smelter slag disposal site and the abandoned open pit Bor was blocked by Dam 1 (Figure 1). Downstream, the valley of the Bor river is blocked by dam 2 (Figure 1). On the eastern side, the flotation tailings pit abuts the Eastern landfill of open pit Bor, and on the western side of the flotation tailings, a perimeter embankment has been erected.

The general characteristics of the soil of the flotation tailings in the area of Bor are lighter mechanical composition, degraded structure, high porosity and water permeability, mostly low humus content, dominance of fulvic acids over humic acids, low pH, high hydrolytic and exchangeable acidity of the soil and lower cation exchange capacity, high concentrations of arsenic (As) and copper (Cu) and low microbiological activity.

Compared to natural soils, the characteristic of flotation tailings soils is that they have a significantly lower content of the clay fraction, worse structural characteristics, lower cation exchange capacity values, lower humus content and less favorable humus absorption (dominance of fulvic acids over humic acids).

Based on the analysis of the flotation tailings, several conclusions were reached [1]:

- At dams 1 (one) and 2 (two) and the perimeter embankment of the RTH flotation tailings, uniform technogenic material prevails. Morphologically, this material consists of fine sand. This type of substrate conditions a poor water-air regime for plant development.
- In certain places on the dam where the sulfur sulfide oxidation processes have not progressed, the flotation tailings have a pH value of around 6. This flotation material has a neutral reaction with high values of active phosphorus and a complete lack of potassium.
- In the places where the oxidation of sulphur to sulphide took place the pH value of the substrate is about 3.
- The lack of clay particles with organic matter in the flotation tailings makes the substrate unfavorable for self-renewal and the development of plants on it. Particles of clay and humus in the flotation tailings serve to activate the work of the soil microflora and initiate the pedological processes of creating humus and accessible elements of plant nutrition. For these reasons, soil material rich in humus is added to the substrate.
- By introducing organic matter into the substrate in the form of humus, the microbiological process is accelerated and a continuous flow of plant assimilates is enabled for the development of grass cover and bushy types of plants foreseen by biological recultivation.

Figure 1 *Spacial representation of the location of the flotation tailing RTH*

DEGRADED AREA

The new project addresses the elevation of the dam from elevation K+378 to elevation K+390. Based on the projected state of the flotation tailings, with an elevation up to K+390, the surface area of the flotation tailings RTH, which will be treated by recultivation, was measured (Table 1). Total degraded area projected for recultivation is 551.200 m^2.

Table 1 *Degraded areas*

Area object	Area, m^2	
	Flat	**Slope**
K+385 – beach	414.000	
K+390/385 – internal slope		25.700
K+390 – kruna brane	16.800	
K+390/378 – spoljašnja kosina brane		94.700
Total	**430.800**	**120.400**
	551.200	

CHOICE OF RECULTIVATION METHODS

Due to the condition of the surfaces after the disposal of the flotation tailings and the specific pedological, microclimatic and climatic conditions, for the recultivation of the RTH flotation tailings, optimal recultivation with grassing is foreseen.

Based on the physical and chemical properties of the flotation deposol, the shape of the surfaces of the hydrotechnical facilities at the RTH flotation tailings pond and the preparation of the surfaces using the technical phase of reclamation, the biological phase of reclamation comes into consideration, namely:

- Weeding on the outer slopes of the dam;
- On the crown of the dam, afforestation and grassing;
- On the inner slopes of the dam, alternating belts of grass and shrub vegetation;
- Weeding and afforestation on dried areas of the storage area (beaches);

Reclamation works consist of two phases:

1. Technical phase of reclamation,
2. Biological phase of recultivation.

The phase of technical reclamation consists of the planning of soil material on damaged surfaces. The purpose of this layer - soil, is to cover the plateau, crown and slope of the flotation tailings dam. Agrotechnical works include all works on the preparation of the applied layer of soil for weeding.

The biological phase includes a complex of biotechnical and phytoremediation measures on prepared surfaces in order to restore the phyto-ecosystem. The biological phase will include grassing and afforestation of degraded areas.

SELECTION OF CULTURES FOR RECULTIVATION IN RELATION TO NATURAL AND ECONOMIC CONDITIONS

Taking into account the factors that influence biological recultivation, and above all the quality of the substrate (substrate), i.e. physico-chemical properties, habitat conditions and exposure of the tailings to the south, then the continental climate and the high proportion of winds from the WNW and NW, a combined method of afforestation was chosen and weeding of the flotation tailings pond. The choice of plant species was also limited.

Based on the above, the project seeks to favor the ecological functions of future forest-meadow ecosystems through biological recultivation. The mentioned future anthropogenically created ecosystems should provide a relatively healthy environment with healthy air, aesthetic impressions of landscape units with a rich color of grouped mixed different types of deciduous trees.

The characteristics of flotation tailings-flotisol are such that it has unfavorable chemical properties because it lacks clay particles and organic matter, which would activate the work of soil microflora and initiate pedological processes and the initial creation of humus, as well as providing accessible nutritional elements.

Acidic soil increases the mobility of heavy metal ions and their accumulation in plants in an amount greater than allowed. For a pH<6.5 in the soil, the mobility of Cd ions increases [2]. For pH<5.5, the mobility of Ni, Mn, Zn, Co and Al ions increases, while for pH<4, the mobility of Cu and Pb ions increases [2].

For these reasons, high-quality soil humus material is necessary on the degraded surfaces of the flotation tailings, i.e. the application of the technical and agrotechnical recultivation phase, which has the task of forming a layer by applying a cover (soil material) at a height of 0.5 m.

TECHNICAL RECULTIVATION

As part of the technical reclamation, in order to ensure the execution of the works, several operations will be carried out, namely:

1. leveling degraded surfaces,
2. planning of soil material according to projected areas,
3. agrotechnical works.

BIOLOGICAL RECULTIVATION

The biological phase of optimal recultivation is the application of phytomelioration measures on the previously prepared soil substrate (degraded surface) in order to establish and survive vegetation for the later formation of a stable ecosystem. The greening of the degraded area has primarily the role of environmental protection, and at the same time contributes to a better appearance of the environment and a better microclimate of the area.

A biological method of recultivation will be applied for the greening of degraded areas at the site in question, namely:

1. Sowing a mixture of grasses 49 kg/ha: Red fennel (50%), English rye (35%), Yellow star (10%), White clover (5%)
2. Woody plants: *Betula alba* L. (birch) – a total of 47,974 seedlings, *Acer campestre* L. (juniper) – a total of 4787 seedlings.

On the outer slope of the flotation tailings pond, only grass is planned. It will be done using hydroseeding. The other areas will be grassed using agricultural machinery. After weeding, the next phase is afforestation.

The planting of trees, chub, on the internal slopes of the dam will be done according to a triangular scheme at a distance of 3 m between the seedlings. This means that about 1100 seedlings can be planted on one hectare. The planting of trees on the crown of the dam will be done in two rows, with a space of 4 m wide for the road, 6 m between these rows. Birch seedlings are planted at a distance of 3 m. The total number of seedlings per hectare is about 1100.

For the beach of the flotation tailings, afforestation was designed according to a mosaic layout. At the same time, birch and chub are planted according to a square pattern at a distance of 3 m between the seedlings. In this way, about 96% of the area will be forested, while the rest will be the space reserved for the road (4%) for the passage of machinery.

Works on the formation, i.e. the raising of green areas on the beach consists of the formation of individual mosaics that will consist of shrubby and woody plants. Woody plants (birch) will be used within one mosaic. Planting will be done two meters from the edge at a distance of 3 m between seedlings (square scheme). In this way, about 1100 seedlings will be planted per hectare. Seedlings aged 2+1 will be used for planting.

Bushy vegetation (clump) will be used for roundabouts. Planting will be done two meters from the edge at a distance of 3 m between seedlings (square scheme). In this way, about 1100 seedlings will be planted per hectare. Seedlings aged 2+1 will be used for planting.

CONCLUSION

The goal of recultivation of flotation tailings is to restore the ecological integrity of disturbed areas. Revegetation is the most widely accepted and useful way of recultivating mining facilities in order to reduce material erosion and protect the soil from degradation.

The same must be done with plants selected based on their ability to survive and regenerate in the local environment, and on their ability to stabilize the soil structure.

The success, efficiency, and recultivation of flotation tailings are conditioned by the correct determination of the chemical, physical and biological properties of the soil.

Compaction, low water holding capacity, bulk density, lack of micro and macro nutrients and associated rooting limitations are the main factors limiting tailings productivity. Also, a high level of potential acidity (low pH) severely limits the productivity of the tailings pond. The acidity of tailings requires the planting of metal-resistant plants, which can grow in nutrient-deficient soils with elevated metal content. Planting different types of grasses, trees, which are rotated with legumes and indigenous species due to their adaptation to the lack of nutrients and fast-growing properties, will allow soil fertility to be restored and ecological succession to be accelerated.

The specificity of man-made soils is the irregular distribution of some characteristics by soil depth (porosity, humus content and microbiological activity), which is a consequence of their man-made origin.

The recultivation of degraded areas at the RTH flotation tailings is aimed at preserving the environment, and with the application of the foreseen technical and biological measures, good results can be expected despite the unfavorable basic substrate. In this case, no economic

profit is expected from the plantations, but only the protection of damaged soil from erosion and the improvement of the microclimate. In addition, the root system of seedlings and leaves that fall and rot on degraded surfaces will initiate pedological processes in the direction of humus creation.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Science, Technological development and Innovation of the Republic of Serbia for financial support according to the contract with the registration number 451-03-66/2024-03/ 200052.

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