

## THE INFLUENCE OF DEPOSITS FROM COPPER MINING AND SMELTING COMBINE BOR ON THE VEGETATION OF RIVERSIDE OF THE RIVER TIMOK (EASTERN SERBIA)

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### ABSTRACT

The quantity of tail and other harmful products of RTB-Bor (Copper mining and smelting combine Bor) have significantly increased since the mid twentieth century, and were carried into the lower stream of the river Timok, mainly through the Borska River. Flooding the surrounding areas and producing thick deposits of substratum with the extreme characteristics caused the devastation and degradation of the autochthonous plant communities and large areas of arable land. This caused the appearance of new, atypical species such as *Betula pendula* Roth, *Robinia pseudoacacia*, *Amorpha fruticosa*, *Calamagrostis epigeios*, *Erigeron Canadensis* and other species in the devastated and degraded community of *Salici–Populetum albae* in the areas of Tamnič, Brusnik and Bračevac villages, and they have significantly changed typical floristic composition of the community.

**Keywords:** tail, river Timok, devastation, degradation, phytocenose

**Abbreviations:** RTB-Bor – Copper mining and smelting combine Bor

### Introduction

Downstream the village Trnavac, the river Timok flows into the Big Gorge (Velika Klisura) which spreads northeast to the railway station in Brusnik, and its length is 24 km. On the area between the railway stations in Brusnik and Veljkovo, the Timok flows through a typical alluvial flat land with the average width of 1-2 km, and then it flows through the Negotinska valley. From Bregovo in Bulgaria to the place where it flows into the Danube, the length is 15.5 km and the Timok is a bordering river between Serbia and Montenegro and Bulgaria. The average flow of the river at the mouth is 35.8 m<sup>3</sup>/s. The biggest flow is in April (94.5m<sup>3</sup>/s), and the smallest – in August and September (7.87m<sup>3</sup>/s). Alluvial flat land by the Timok river get about 600 mm of water sediment a year (4).

The climate of the area is mostly continental. When we compare it to other areas in Eastern Serbia, winters are the coldest and summers – the hottest in this area. Thus, the annual amplitude of the temperature is the biggest here. The absolute maximum temperature in this area is 41.6° C, and the absolute minimum temperature is minus 26.5° C (9).

From the middle of the twentieth century, production of copper and the side metals in the RTB-Bor was intensified. At the same time, quantities of tail and other products increased and the Borska River carried them into the lower stream of Timok River (1). Water from the Borska River totally polluted Timok, in the degree that it often falls into the third, but mostly into the second class of the water bonitet (2). The Borska River

not only pollutes river Timok but also, in the period of high water level, it leaves enormous quantities of the deposit of different thickness (Fig. 1), which is formed over the former fertile alluvial deposits. On the site Supište, in the Tamnič area, the width of the deposits was up to 300 meters. The chemical composition of the deposits with the high content of the waste from the RTB-BOR is rather harmful for plants and has extreme acidity pH2.1. The waste mostly consists of SiO<sub>2</sub> (72.88%), Al<sub>2</sub>O<sub>3</sub> (11.56%), S (3.59%), CaO (1.30%), and Cu oxides (0.046%). Except these, some metals are found in small quantities: Cu (0.094%), Pb (0.071%), As (0.026%), Zn (0.016%) and other chemical elements (10).



Fig. 1. Tail deposits on the Timok riverside

Deposits of the tail made the habitats of the autochthonous willow and poplar community – *Salici-populetum albae* Drees, 1936 smaller (11) as well as valley meadows, arable fields and orchards, while the habitats with extreme conditions, where new, atypical species appear, became bigger. Changes of ecological factors in the river have also significantly degraded aquatic biocenoses (5, 6, 8). In order to revive the river and its

highly fertile littoral area, we should initiate a comprehensive ecological action.

In this work, the influence of the deposits on the white willow and poplar community in the Timok valley was investigated. The investigation was carried out on the degraded alluvial habitats in the Tamnič, Brusnik and Bračevac districts.

## Materials and Methods

Phytocoenologic investigations of the white willow and white poplar communities (*Salici-Populetum albae* Drees 1936)

were carried out on the surface of 15 km<sup>2</sup>, on the deposits of the river Timok, in the districts of Tamnič, Brusnik and Bračevac villages. The height above the sea level of the region is 75-83m. We applied the Braun-Blanquet method (3). Twenty phytocoenologic snapshots were taken, and out of them, we put 17 representative snapshots into two phytocoenologic. Plant species were determined by using the key terms from "Flora Srbije" (7) and the terms were coordinated with terms in "Flora Evrope" (12).

**TABLE I**

Participation of silver (white) birch (*Betula pendula* Roth.) and other plants in the community – *Salici-populetum albae* Drees, 1936) over the deposits in the river Timok valley

Community	Ass. <i>Salici - Populetum albae</i> Drees 1936											
	1	2	3	4	5	6	7	8	9	10	11	12
Number of releve	12.08.2003.						13.08.2003					
Date	The river Timok valley											
Locality	Tamnič						Brusnik					
Altitude (m)	80											
Substratum	Deposits											
Canopy	0,3	0,3	0,3	0,3	0,4	0,8 - 0,9						
Tree height diameter	6 ~ 18	6 ~ 16	6 ~ 20	6 ~ 10	5 ~ 12	4 ~ 10	5 ~ 16	5 ~ 20	5 ~ 20	5 ~ 12	8 ~ 12	8 ~ 10
Tree diameter (cm)	20 ~ 80	20 ~ 80	20 ~ 60	10 ~ 20	10 ~ 30	10 ~ 20	10 ~ 40	20 ~ 50	20 ~ 40	10 ~ 15	10 ~ 40	10 ~ 20
Size (m)	50 X 50					30 X 50				20 X 20		
Species												
<b>Tree Layer</b>												
<i>Betula pendula</i> Roth.	2.1	1.1	1.1	2.2	3.3	3.3	4.3	1.2	1.2	4.2	4.3	4.3
<i>Populus tremula</i> L.	3.2	1.1	3.3	-	2.2	3.3	2.2	3.3	2.2	2.2	+	-
<i>Salix alba</i> L.	1.1	1.1	-	-		1.2	3.3	4.3	2.2	-	-	2.1
<i>Populus alba</i> L.	1.1	1.1	-	-	+	3.3	3.2	4.3	2.2	-	-	-
<i>Robinia pseudacacia</i> L.	1.1	1.1	2.2	3.3	2.2	-	1.1	-	-	-	-	-
<i>Ulmus laevis</i> Pallas.	2.2	1.1	-	-	3.3	-	2.2	-	-	-	-	-
<i>Salix fragilis</i> L.	2.1	1.1	2.2	-	-	-	-	-	-	-	-	-
<i>Quercus cerris</i> L.	+	-	-	-	-	-	-	-	-	-	-	-
<i>Pyrus communis</i> L.	-	-	-	-	2.2	-	-	+	-	-	-	-
<i>Morus alba</i> L.	-	1.1	-	-	-	-	-	-	-	-	-	-
<i>Quercus frainetto</i> Ten.	+	-	-	-	-	-	-	-	-	-	-	-
<i>Acer negundo</i> L.	+	+	-	-	-	-	-	-	-	-	-	-
<i>Fraxinus angustifolia</i> Vahl.	+	+	-	-	-	-	-	-	-	-	-	-
<i>Malus sylvestris</i> Miller	-	-	-	-	+	-	-	-	-	-	-	-
<i>Crataegus monogyna</i> Jacq.	-	-	-	-	+	-	-	-	-	-	-	-
<i>Prunus avium</i> L.	-	-	-	-	+	-	-	-	-	-	-	-
<i>Cydonia oblonga</i> Mill.	-	-	-	-	-	2.2	-	-	-	-	-	-
<i>Juglans regia</i> L.	-	-	-	-	-	-	-	+	-	-	-	-
<i>Populus nigra</i> L.	-	-	-	-	-	-	-	-	-	-	-	-

<b>Shrub layer</b>												
Cover degree (%)	40	80	20	20	50	80	90	100	70	80	80	80
Height, (m)	1~6	1~2	1~6	1~2	1~5	1~5	1~5	1~5	1~5	1~3	1~3	1~3
<i>Betula pendula</i> Roth	2.2	+	2.2	2.2	3.3	4.3	4.4	3.2	3.3	3.3	3.3	3.3
<i>Rubus caesius</i> L.	2.2	1.1	3.3	2.2	1.2	3.3	1.2	4.4	3.3	3.3	3.3	3.3
<i>Amorpha fruticosa</i> L.	3.3	-	1.1	-	-	2.2	2.2	1.1	1.2	2.2	3.3	-
<i>Robina pseudacacia</i> L.	-	1.1	2.2	3.3	3.3	-	-	+	-	-	-	-
<i>Crataegus monogyna</i> Jacq.	-	-	-	1.1	1.1	-	-	-	-	2.2	2.1	-
<i>Salix alba</i> L.	1.1	-	-	-	-	-	+	-	2.2	-	-	3.3
<i>Populus tremula</i> L.	2.2	-	-	-	2.2	-	2.2	-	-	2.2	-	-
<i>Rosa canina</i> L.	-	-	1.1	-	1.1	-	-	-	-	-	-	-
<i>Populus alba</i> L.	-	-	-	-	-	-	1.1	-	2.2	-	-	-
<i>Populus nigra</i> L.	-	1.1	-	-	2.2	-	-	-	-	-	-	-
<i>Quercus frainetto</i> Ten.	-	1.1	+	-	-	-	-	-	-	-	-	-
<i>Cornus sanguinea</i> L.	-	-	+	-	-	-	-	+	+	-	-	-
<i>Juglans regia</i> L.	-	-	-	-	-	-	-	-	-	-	-	-
<i>Humulus lupulus</i> L.	-	-	-	-	-	-	1.2	-	-	-	-	-
<i>Ulmus laevis</i> Pallas	-	-	-	-	-	-	1.2	-	-	-	-	-
<i>Quercus cerris</i> L.	+	-	-	-	-	-	-	-	-	-	-	-
<i>Phragmites communis</i> Trin.	1.1	-	-	-	-	-	-	-	-	-	-	-
<i>Pteridium aquilinum</i> (L.) Kuhn.	-	5.5	-	-	-	-	-	-	-	-	-	-
<i>Salix caprea</i> L.	-	-	+	-	-	-	-	-	-	-	-	-
<i>Salix fragilis</i> L.	-	-	+	-	-	-	-	-	-	-	-	-
<i>Pyrus communis</i> L.	-	-	-	-	1.1	-	-	-	-	-	-	-
<i>Cydonia oblonga</i> Mill.	-	-	-	-	-	1.1	-	-	-	-	-	-
<i>Sambucus nigra</i> L.	-	-	-	-	-	-	-	1.1	-	-	-	-
<i>Prunus avium</i> L.	-	-	-	-	-	-	-	+	-	-	-	-
<b>Herb layer</b>												
Cover degree (%)	100	80	50	50	60	10	10	10	5	20	100	70
<i>Rubus caesius</i> L.	2.2	3.3	3.2	+	1.2	2.2	2.2	3.3	1.2	3.3	3.3	3.3
<i>Calamagrostis epigeios</i> (L.) Roth.	4.4	3.3	3.3	4.4	3.3	2.2	-	-	-	2.2	4.4	4.4
<i>Erigeron canaadensis</i> L.	1.1	-	1.1	-	-	+	-	1	-	-	-	-
<i>Populus alba</i> L.	2.2	2.2	-	-	-	2.2	-	-	+	-	-	-
<i>Berula pendula</i> Roth.	-	-	-	-	-	2.2	2.2	-	+	2.2	-	-
<i>Amorpha fruticosa</i> L.	3.3	-	-	-	-	2.2	-	-	-	-	2.2	-
<i>Populus tremula</i> L.	-	2.2	-	-	-	-	-	-	-	-	2.2	-
<i>Agrostis alba</i> L.	-	2.2	3.3	-	-	-	-	-	-	-	-	-
<i>Galium mollugo</i> L.	-	-	1.1	-	-	-	-	-	-	-	-	-
<i>Pteridium aquilinum</i> (L.) Kuhn.	-	4.4	-	-	-	-	-	-	-	-	-	-
<i>Populus nigra</i> L.	-	2.2	-	-	-	-	-	-	-	-	-	-
<i>Rumex acetosella</i> L.	-	-	-	-	+	-	-	-	-	-	-	-
<i>Cornus sanguinea</i> L.	-	-	-	-	-	-	-	+	-	-	-	-
<i>Artemisia vulgaris</i> L.	-	-	-	-	-	-	-	+	+	-	-	-
<i>Salix alba</i> L.	-	-	-	-	-	-	-	+	-	-	-	-

## Results and Discussion

Results of phytocoenological investigations in the zone of degraded forest community *Salici-Populetum albae* Drees, 1936. on the deposit zone of the river Timok, in Tamnič, Brusnik and Bračevac area are given in **Table 1**. We noticed the appearance of white birch (*Betula pendula* Roth) in the tree level, mostly on open places and forest margin. The species is found in smaller or bigger groups (**Fig. 2**), the average height is 10-15 m, and the diameter is 10-20 cm. Some trees reach the height of 20 m, and the bulk of 40 cm, and the natives cut them for different purpose. A birch reproduces fast, out of seeds, and is present in a high degree in the shrub layer and herb level. Besides, we noticed higher presence of black locust tree (*Robinia pseudoacacia*), mostly in the closed stand part. We also detected shriveling of the tops. We also noticed tops shriveling at white willow, after which, a birch tree spread. Of alochtonous species, we determined that false indigo (*Amorpha fruticosa*) appears in dense clusters, and reaches the height of 1.5-3m. We also noticed that there are not many herbs in the false indigo clusters. Besides false indigo, in the shrub layer and enlighten habitats of willow and poplar, we determined the presence of black locust, 1-5m high. The locust is in expansion and gradually becomes dominant on the terrain. In the herbs layer, *Rubus caesius* and *Calamagrostis episeios* dominate the deposits. *Calamagrostis epigeios* (**Fig. 3**) species is widely spread on the deposits and is found in the white willow and white poplar community. On the herb layer, we noticed an increased number and vitality of the following plant species: *Erigeron canadensis*, *Betula pendula*, *Amorpha fruticosa*, *Populus tremula*, *Agrostia alba*, *Pteridium aquilinum*, and other species.

Results of phytocoenological investigations of the deposit out of the forest community are shown in **Table 2**, that is the zone of valley meadows and area which was formerly cultivated and was extremely fertile. The area out of the white willow and white poplar community are overgrown with various plant species. The zone of macrophytes usually appears on the riverside, and here *Phragmites communis* and *Equisetum palustre* species usually appear. Sporadically, on some places, we can find *Amorpha fruticosa* and *Rubus caesius* species groups on the shrub layer, and their height is 1-3m. We want to emphasize the presence of *Calamagrostis epigeios* species, which is obviously in expansion because it inhabits not only the deposits, but also deserted fields and meadows in the riverside.



**Fig. 2.** White birch stands on the Timok deposits



**Fig. 3.** *Calamagrostis epigeios* on the deposits of the Timok riverside.

**TABLE 2**

Dominance of species *Amorpha fruticosa* L., *Rubus caesius* L. and *Calamagrostis epigeios* (L.) Rothe over deposits in the river Timok valley, outside of the canopy of the *Salici-populetum-albae* Drees, 1936 forest.

Number of releve	1	2	3	4	5
Date	12.08.2003.				
Locality	The river Timok valley				
	Tamnič				
Substratum	deposits				
Area size (m)	50 X 50				
Species					

<b>Shrub layer</b>					
Cover degree (%)	50	50	-	-	-
Height (m)	1 ~ 3	1 ~ 3	-	-	-
				-	-
<i>Amorpha fruticosa</i> L.	3.3	2.2	-	-	-
<i>Rubus caesius</i> L.	3.2	2.2	-	-	-
<i>Rosa canina</i> L.	1.1	+	-	-	-
<i>Juglans regia</i> L.	+	+	-	-	-
<i>Humulus lupulus</i> L.	1.1	1.1	-	-	-
<i>Prunus spinosa</i> L.	1.1	-	-	-	-
<i>Crataegus monogyna</i> Jacq.	1.1	-	-	-	-
<i>Malus silvestris</i> Miller	1.1	-	-	-	-
<i>Robinia pseudoacacia</i> L.	-	2.2	-	-	-
<i>Sambucus ebulus</i> L.	-	1	-	-	-
<b>Herb layer</b>					
Cover degree (%)	100	100	100	100	100
Height (m)	0.2 ~ 1 m				
<i>Calamagrostis epigeios</i> (L.) Roth	4.4	3.4	5.5	5.5	2.2
<i>Equisetum palustre</i> L.	4.4	1	2.1	2.2	5.5
<i>Rubus caesius</i> L.	+	4.4	2.2	2.2	+
<i>Polygonum hydropiper</i> L.	2.2	-	+	+	+
<i>Chrisanthemum vulgare</i> (L.) Bernh	+	-	+	-	2.2
<i>Hypericum perforatum</i> L.	+	-	+	-	-
<i>Lysimachia vulgaris</i> L.	-	1.1	-	-	+
<i>Phragmites communis</i> Trin.	-	-	1.1	1.1	-
<i>Erigeron canadensis</i> L.	+	-	-	-	-
<i>Populus alba</i> L.	-	-	-	1.1	-
<i>Amorpha fruticosa</i> L.	-	-	-	1.1	+
<i>Eryngium campestre</i> L.	-	-	-	-	+
<i>Cynodon dactylon</i> (L.) Pers.	-	-	-	-	+
<i>Cirsium vulgare</i> (Savi) Ten.	-	-	-	-	+

**Participation of the white birch (*Betula pendula* Roth) and other species in *Salici-Populetum albae* species, on the deposits in the riverside of the river Timok**

Former investigations showed that the deposits in the riverside of the river Timok were overgrown with well-developed white willow and poplar community *Salici-populetu-albae* Drees, 1936 before the formation of alluviums from RTB-Bor (11). Some trunks reached the height of 12-15 meters, and their diameters were up to one meter, and were used for building material and other needs until the mid twentieth century.

However, on the areas where deposits formed, in the Tamnič, Bračevac and Brusnik area, changes were recorded in *Salici-populetum albae* community, and they are the changes of the floristic composition and structure of the forest. Alder-tree (*Alnus glutinosa*) used to grow sporadically in the riparian area and then disappeared totally. White birch (*Betula pendula*)

appeared, to the high degree, in the tree layer (**Table 1**), mostly on open areas and forest margins. On the investigated terrain, the species appears in smaller or bigger groups. We want to emphasize that white birch (*Betula pendula*) does not spontaneously grow in the wider area in this part of Serbia, but is only grown as a park species in an urban environment. In the Timok valley seeds spread it, most probably through hydrochoria. The Timok riverside has favorable ecological conditions, high level of underground waters and acid substratum. The natives came across this species for the first time during the seventies and named it white birch. The birch reproduces itself through semination, grows fast and is present in a high degree in the shrub and herb layers. The natives cut it down and use it for different purposes. Besides the white birch, the tree layer is to a high degree overgrown with the following species: *Populus tremula*, *Salix alba*, *Populus alba*, *Robinia pseudoacacia*, *Ulmus laevis*, and *Salix fragilis* (**Table 1**). Besides these species, black locust (*Robinia pseudoacacia*) is often found in the community. It is an autochthonous species and the deposits conditions are obviously favourable for its growth, even though we detected tops shrivelling. Tops' shrivelling was also detected at white willow (*Salix alba*), and they may be caused by the mass appearance of white birch (*Betula pendula*) on the site.

On the shrub layer, we also determined mass appearance of birch, 1-5 meters high, (**Table 1**). Blackberry (*Rubus caesius*), 0.5-1 m high is also present to a high degree, and it is mostly found on smaller or bigger openings. Of autochthonous species, false indigo (*Amorpha fruticosa*) is found in dense clusters, 1.5-3 m high. We noticed that there are not many herbs in dense false indigo clusters. Besides false indigo, on the shrub layer, in enlightened willow and poplar stands, we found black locust. 1-5 m high, and it is in expansion and is becoming dominant on the terrain.

In the herbs layer, *Rubus caesius* and *Calamagrostis epigeios* (**Fig. 3**) dominate the deposits. *Calamagrostis epigeios* species is widely spread on the deposit, on the white willow community. In the herb layer we noticed extreme vitality of the following plant species: *Erigeron canadensis*, *Betula pendula*, *Amorpha fruticosa*, *Populus tremula*, *Agrostis alba*, *Pteridium aquilinum* and other species.

**Domination of the *Amorpha fruticosa*, *Rubus caesius* and *Calamagrostis epigeios* species on the deposits which are not under forests**

Some parts on the deposits which are not under poplar and willow forest are overgrown with different plant species. Near the river, *Phragmites communis* and *Equisetum palustre* are the most common (**Table 2**). On some places, in the shrub layer, we come across *Amorpha fruticosa* and *Rubus caesius* species groups, 1-3m high. We noticed a significant presence of *Calamagrostis epigeios*, which is obviously in expansion since it grows on both deposits and deserted arable fields and meadows of the river valley.

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## Conclusions

It can be concluded that waste deposits of various thickness and width formed the substratum of highly unfavourable ecological characteristics, of which, extreme acidity is the most obvious. It most probably cause the change of the floristic composition and the structure of the *Salici-Populetum albae* community, its devastation and degradation such as white willow shrivelling and the disappearance of the alder-tree, and the simultaneous appearance of new, atypical species.

The species *Erigeron canadensis*, *Populus alba*, *Betula pendula*, *Amorpha fruticosa*, *Populus tremula*, *Agrostis alba*, *Pteridium aquilinum* are characterised by extreme vitality.

The species *Amorpha fruticosa*, *Rubus caesius* and *Calamagrostis epigeios* are dominate on the deposits which are not under forests

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