

Ecological Characteristics and the Remediation Potentials of Opencast Mines at Čelarevo and Šajkaš Brickyards, Vojvodina, Serbia

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Abstract

The pedological and ecological characteristics of the local brickyard opencast mines at Čelarevo and Šajkaš have been investigated in the scope of their sustainable revitalisation potentials. The present environmental characteristics indicate the disturbance, i.e. the essentially different characteristics of the initial phases of soil formation in the quarry compared to surrounding undisturbed soils. The parent material characteristics and ground water level have a dominant role in the process of soil formation, which in turn has an essential effect on the occurrence of the prevailing woody vegetation, as well as on the potential selection of soil remediation methods.

Key words: opencast mines, revitalisation, soil, chernozem

Introduction

In the Vojvodina province, Northern Serbia, the consequences of soil degradation, damage and devastation are increasingly explicit. The negative processes lead to a significant decrease of the area of farmland, forest and various forms of protected natural parks. An especially endangered soil type is chernozem, the highly productive agricultural soil which occupies approximately 45% of the area of Vojvodina (Živković et al., 1972).

The impacts of different processes of degradation, damage, and finally the devastation of the most productive soils are multiple. Unfortunately, the consequences of the adverse effects cannot always be adequately mitigated, i.e. eliminated. One of the most frequent way of soil degradation in Vojvodina is raw material exploitation in many brickyards (Miljković et al., 2001). In this way, in addition to soil damage, a thick layer of parent material on which the soil was originally formed, is permanently lost. Raw material exploitation causes the changes of the relief, hydrological, ecological and site conditions in general.

The spontaneous soil renewal in the opencast mines of brickyards is a slow process which results in soil formation with the significantly poorer productive properties. Therefore, such areas should be subjected to the adequate rehabilitation procedures. This study presents the complex analyses of the present environmental status and proposes the sustainable rehabilitation methods of the brickyard opencast mines at Čelarevo and Šajkaš.

Material and Methods

Field observations and sampling of opencast mines at Šajkaš brickyard were performed in 1998, and at Čelarevo brickyard from 2001 to 2003. Those investigations included the analysis of geomorphological,

hydrological and vegetation cover characteristics. Special attention was focused on the morphological description of the surrounding undamaged soils, damaged soils and recent processes of soil formation. The samples for laboratory analysis were collected according to the standard pedological research procedure.

The physical and chemical characteristics of the soil were determined by laboratory analyses: particle size distribution (%) by the international B-pipette method with the preparation in sodium pyrophosphate (Bošnjak et al., 1997), determination of soil textural classes based on particle size distribution by using Atteberg classification, humus percentage (%) by Tiurin method in Simakov's modification (Škorić et al., 1966) and CaCO₃ percentage (%) was measured volumetrically by using Scheibler's calcimeter (Hadžić et al., 2004).

Results and Discussion

Both investigated localities are situated on the geomorphologic units which are only several metres higher than the ground water level. Because of that, during the excavation in both open pit mines, the first ground water level was uncovered. Mean annual air temperature in southern Bačka area is 11°C approximately. There is a difference in mean annual precipitation: 626 mm and 590 mm at the locality Čelarevo and Šajkaš respectively (Škorić et al., 1997; Ivanišević et al., 2003). Because of the higher precipitation sum at the locality Čelarevo, the brownised variety of chernozem is formed on loess-like sediments, while at the locality Šajkaš, calcareous chernozem is formed also on loess-like sediments. In both cases, it is the medium deep soilform. As for vegetation, the alluvial terrace in the surroundings of Čelarevo, i.e. the dynamic relief of the surroundings of Šajkaš, with a still preserved fossil fluvial morphology, are transformed into more or less continuous spreading crop fields.

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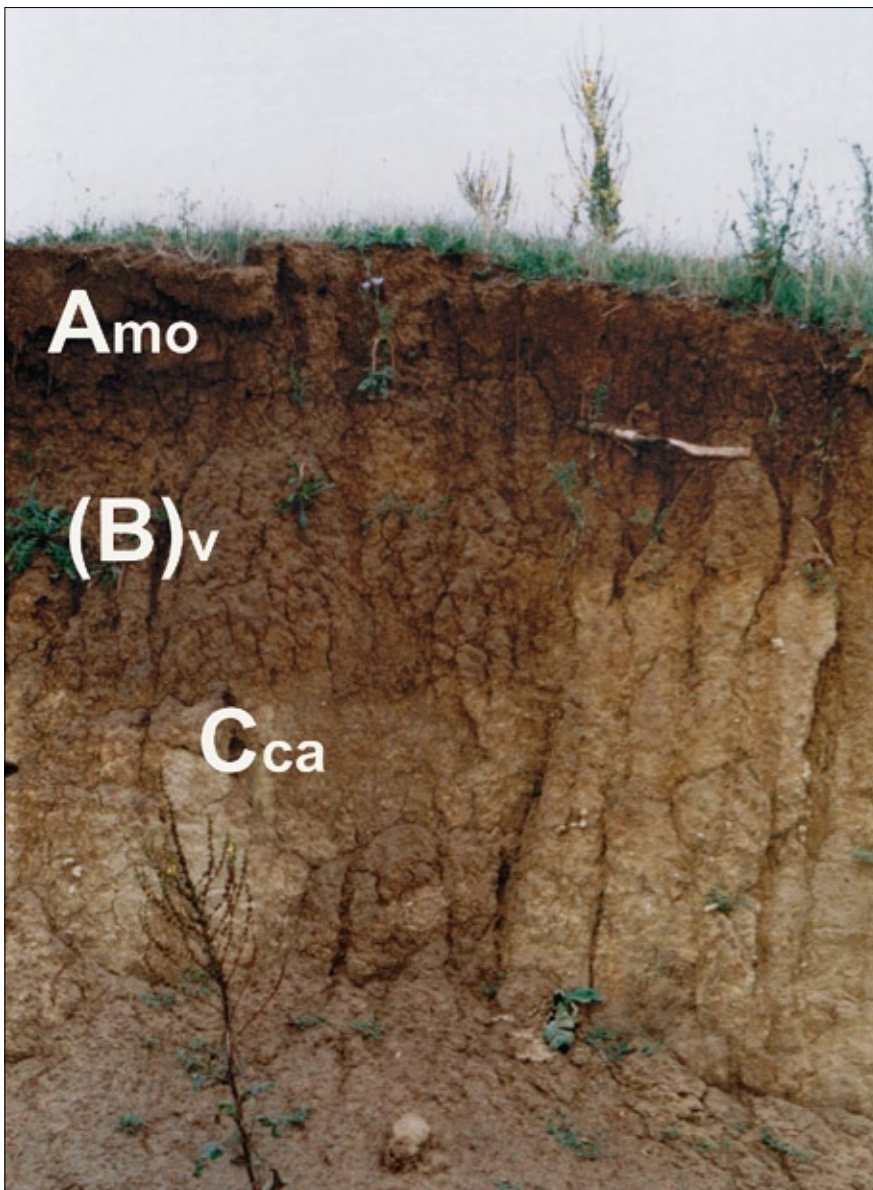


Figure 1 Morphological structure of the profile of undamaged soils in the vicinity of the brickyard quarries at Čelarevo, Čelarevo brickyard - autochthonous soil.

Morphological description of the profile:

A_{mo} (0-45 cm): brown clay loam, poorly humous, non calcareous, with gradual transition

$(B)_v$ (42-72 cm): reddish clay loam, poorly humous, with gradual transition

C_{ca} (> 72 cm): yellowish loesslike material with calcareous concretions, loam texture

Marsh vegetation, sparse forest vegetation, grass halomorphic and steppe vegetation appear only in the local depressions.

Figure 1 presents the morphological structure and the description of the profile of undamaged soils in the vicinity of the brickyard quarries at Čelarevo, which consists of the following pedogenetic horizons A_{mo} - $(B)_v$ - C_{ca} .

The morphological structure of the profile of undamaged soils in the vicinity of the brickyard quarries Šajkaš is different and it consists of the following pedogenetic horizons: A_{mo} - AC - C. The morphological description of the profile is the following: horizon A_{mo} (0-60 cm) is brown loam of grainy structure. This horizon is relatively rich in humus and the percentage of carbonates is high (21.60%). A_{mo} horizon is a gradual transition to AC (60-

85 cm) horizon which is a yellow-brown loam. This horizon is rich in carbonates, it is poorly humous, with gradual transition into C horizon consisting of dirty-yellow loess-like material.

The texture of the undamaged soils at the locality Čelarevo is clay loam, while

at the locality Šajkaš, it is loam (Tables 1 and 2). There is a significant difference in the particle-size distribution of the bedrock which is silty loam and sandy loam at the locality Čelarevo, and sandy loam and loamy sand at the locality Šajkaš.

The most significant difference in the chemical characteristics of the studied soils is difference in carbonate content presence. In contrast to the decalcified upper two horizons A and $(B)_v$ at the locality Čelarevo, where the higher percentage of carbonates was determined in the horizon C_{ca} and in the parent rock, investigated soil profile at Šajkaš characterized by significantly higher continuous presence of carbonate content. A higher presence of humus characterises only the upper humus accumulation horizons, while in the other parts of the profile, humus percentage is less than 1 %.

In the lowest part of the brickyard quarry at Čelarevo the first ground water level was uncovered and a small-size artificial lake was formed. The site type corresponds to the initial soil, and willows appear spontaneously in the form of young stands as the consequence of the surplus moisture in the lake. The depth of the excavation from the topographic surface to the bottom of the lake is 8 metres (Figure 2). Ground vegetation on the freshly excavated material consists only of plant species, and black locust is found on the slopes.

Different site types occur as the consequence of intensive land devastation which caused the changes of the site moisture regime. The opencast mine area provide possibilities for growth of different plant communities, both herbaceous and shrubs, i.e. woody species, depending on the topographic-hydrological conditions.

Similar environmental conditions also occur in the area of the brickyard quarry at Šajkaš. Škorić et al. (1998) report the occurrence of herbaceous, shrubby and woody plant species, depending on topographic and hydrological conditions.

After the removal of the most productive part of the soil, three site types were determined based on the main site characteristics. The lowest part, where the exploitation ceased 15-20 years ago, was afforested with Euramerican poplars. In

Table 1 The main characteristics of the soil at Čelarevo brickyard quarry

| | Horizon | Depth, cm | Silt+clay, % | Text. class | Humus, % | CaCO ₃ , % |
|----------------------------|------------|-----------|--------------|-------------|----------|-----------------------|
| Natural soil | A mo | 0-45 | 54.4 | Clay loam | 1.36 | 2.51 |
| | (B) | 45-75 | 58.1 | Clay loam | 0.82 | 2.50 |
| | Cca | 75 | 50.6 | Loam | 0.58 | 23.39 |
| Bedrock after exploitation | II level | | 65.8 | Silty loam | 0.44 | 24.24 |
| | III level | | 32.0 | Sandy loam | 0.41 | 20.86 |
| | sand layer | | 3.1 | Sand | 0.21 | 16.69 |

the given environmental conditions, on the freshly formed eugley, only individual poplar trees survived, and in the part with marked surplus moisture, there is an occasional natural regeneration of willows, which indicates that the site type is favourable for willows.

Site environment in the driest part of the quarry corresponds to the soil type chernozem with a significant damage. On this site type, the natural regeneration of white poplar (*P. alba*) was determined, i.e. the occasional incidence of the older white poplar trees in the community *Populetum albae* L., as it has already been stated: on the highest relief forms with different species of steppe grass vegetation. As the relief of the above site type is not homogeneous, individual white willow (*Salix alba*) trees

Table 2 The main characteristics of the soil at Šajkaš brickyard quarry

| | Horizon | Depth, cm | Silt+clay, % | Text. class, % | Humus | CaCO ₃ , % |
|----------------------------|----------------|-----------|--------------|----------------|-------|-----------------------|
| Natural soil | Amo | 0-60 | 55.4 | Loam | 3.42 | 21.60 |
| | AC | 60-85 | 53.8 | Loam | 0.97 | 24.27 |
| Bedrock after exploitation | C ₁ | 85-210 | 26.8 | Sandy loam | 0.47 | 13.78 |
| | C ₂ | 210-400 | 12.8 | Loamy sand | 0.90 | 15.44 |

ation of raw materials for building material manufacture requires very high investments for the establishment of the original topographic relations. Consequently, the most adequate method of reinstatement of opencast-mine areas is semi-rehabilitation, which is based on the correct selection of tree species, based on the ecologi-

tation can be performed with the clones of Euramerican black poplar *Populus x euramericana*. The limiting factor for many woody species, along with the physiologically active profile depth, is also the high calcareous content of the loess-like material at both investigated localities. With the increase of loess-like deposits thickness, the potential of successful black poplar growing decreases. On the highest parts of the terrain with thick loess-like substrate without the additional moisture supply, a proposed suitable species for biological rehabilitation is black locust, as a xerophyte taxa.



Figure 2 Čelarevo brickyard quarry.

occurs in the occasional lower depressions. On the damaged chernozem site type with less deep profile, the prevailing species is white willow, forming a natural forest of white willow *Salicetum albae* L. Individual incidence of white poplar (*Populus alba*) was observed on micro-elevations. Reed grows at places where ground water appears on the surface, i.e. in the part with permanent surplus moisture.

Depending on the method and intensity of rehabilitation processes, there are three levels of the degraded soil reinstatement: spontaneous rehabilitation, semi-rehabilitation and full or eu-rehabilitation. Spontaneous rehabilitation includes self-regeneration of natural vegetation on the degraded area. This is the process of revitalisation. Semi-rehabilitation means the establishment of forest and orchard plantations on degraded areas without the previous soil preparation. Eu-rehabilitation or full rehabilitation is divided into two phases, encompassing a series of operations by which the degraded or devastated areas are transformed into productive sites (Miljković, 1996; Miljković et al., 2001)

Eu-rehabilitation can change the topography and in this way the site conditions can be essentially changed, but in both analysed cases, the intensive exploita-

cal-production characteristics of the newly formed sites.

According to the bioecological characteristics of the species, in the lowest parts of the relief, biological rehabilitation should be performed with *Salix sp.* With the increase of the physiological depth of the profile, with the presence of the finer particle-size fractions, biological rehabili-

Conclusions

The exploitation of raw materials at investigated brickyard quareis has caused the permanent damage of the soil at both study localities. The removal of the most productive A, AC and (B) soil horizons initiated significant environmental changes conditions, so that soil formation is performed partly in hydromorphic conditions. Another limiting factor of the establishment of the more intensive pedogenetic processes is the chemical composition of loess-like parent deposits.

In the area of the analysed opencast mines, the spontaneous incidence of pioneer plant communities occurs as self-regeneration. Based on the laws of natural revitalisation, as well as the previous expe-



Figure 3 Šajkaš brickyard quarry.

rience in the cultivation of different woody species in Vojvodina, we are of the opinion that the method of semi-rehabilitation is justified, both from the economic and from the ecological standpoints. Bioecological characteristics of the species to be planted depend on the site conditions. In the lowest parts of the relief, semi-rehabilitation should be performed by planting *Salix sp.* With the increasing of the physiological depth of the profile, semi-rehabilitation of degraded soil is optimal with the clones of Euramerican black poplar *Populus x euramericana*. The limiting factor for the cultivation of woody species is the physiologically active profile depth and the chemical composition of loess-like sediments. With the increase of the carbonate content in the loess-like material, the potential of successful black poplar growing decreases. On the highest parts of the opencast mine terrain without the additional moisture supply, a suitable species for biological rehabilitation is black locust (xerophyte species). The above strategy of semi-rehabilitation of the damaged soil of brickworks quarries at Čelarevo and Šajkaš points to the multi-functional pos-

itive social functions of planting this form of non-forest green area.

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