

Conference Paper

Reforestation of Brown Coal Dumps in Bashkortostan: Characteristics of the Soil and the Condition of Birch (*Betula pendula* Roth) Stands (Results of a 35-year Experiment)

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Abstract

In 1980–1984, reforestation of the dumps of the Kumertau brown coal deposit (Republic of Bashkortostan, Russia) was carried out. Birch stands were created on the dumps of overburdened rocks. The authors studied the agrochemical properties of soils, described the state of birch stands and established the patterns of metal accumulation in birch organs 35 years after reforestation. It is established that 35 years after planting birch trees on the dumps, the trees are characterized as ‘healthy’. The concentration of copper, zinc, lead and cadmium in birch organs changes in the following sequence: root system > bark > shoots > leaves. Soil formation processes are noted in birch stands on dumps. The upper (0–20 cm) soil layer acidity shifted by two units to the acidic side. There is a slight decrease in the content of phosphorus and the exchange forms of calcium and magnesium. Thus, birch is a promising tree species for the reforestation of mining industry dumps.

Keywords: dumps, reforestation, *Betula pendula* Roth, metal accumulation, soil formation processes

1. Introduction

During mineral deposit exploitation, dumps from overburdened rocks are formed, which leads to ecosystem destruction and environment pollution [1, 2]. Reforestation of mining industry dumps is carried out to reduce secondary pollution of the environment during wind and water erosion and to restore biological productivity [3, 4]. The study of the condition of tree stands makes it possible to evaluate the results of dump reforestation and determine the prospects for the elimination of accumulated environmental damage. The purpose of the study was to examine the state of birch

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stands, evaluate the metal accumulation features in woody plants and characterize soil cover formation after reforestation of the dump of the Kumertau brown coal deposit between 1980 and 2017.

2. Methods

The objects of research were birch (*Betula pendula* Roth) stands planted in 1980–1984 after the reforestation of the dump of the Kumertau brown coal deposit. Estimation of the life state of birch stands was carried out by the Alekseev method [5]. Selection of plant and soil samples was carried out during the vegetation period (from June to August). For the determination of metal content, the plant and soil samples were ashed in a muffle furnace at a temperature of 450 °C. To determine the mobile forms, soil samples were extracted with an ammonium acetate buffer with a pH 4.8. The content of copper, zinc, lead and cadmium was determined. The content of the metal total and the active forms in the soil was determined by atomic absorption spectrometry in the Contr-AA (Analytic) [6]. The metal content in plant samples was determined on a STA (MU 08-47/136) using an inversion voltammetric method. Ecotoxicological assessment of soils was determined by the maximum allowable concentration (MAC) of metals. The humus content was determined from the concentration of organic matter (GOST 26213-91) with subsequent transfer to the total carbon. The acidity and the total absorbed bases were determined by the Kappen method (GOST 27821-88). The composition of the absorbed bases (Ca^{2+} and Mg^{2+}) was determined by the CINAO method (GOST 26487-85). The content of active phosphorus and potassium was determined by the Machigin method with CINAO modification (GOST 26205-91). The nitrogen content was determined by the Cornfield method. The obtained data were processed with conventional statistical methods.

3. Results

Birch plantations growing on the dump ($L_V = 93.3\%$) and in control soil ($L_V = 93.6\%$) are characterized as 'healthy'. Geologically, the dumps are characterized by great heterogeneity and are represented by sedimentary rocks [7] – conglomerates, sandstone, limestone, ancient alluvial sands and pebbles, Permian and Tertiary clay. These contain a wide range of chemical elements: copper, zinc, cobalt, calcium, manganese and others. Of these elements, the greatest danger to the environment is presented by copper, zinc, lead, and cadmium. In dumps and control soils under birch stands, the

content of the total forms of copper, zinc and cadmium corresponds to MAC, with the exception of the control soils, where one finds that zinc exceeds MAC 2.2 times (Table 1). The content of metal active forms in dumps is much lower than the background level and MAC.

TABLE 1: The content of total and mobile forms of metals (mg/kg) in birch (*Betula pendula* Roth) stands on the dumps of the Kumertau brown coal deposit ($n = 30$).

Cu		Zn		Pb		Cd	
Total Forms	Active Forms	Total Forms	Active Forms	Total Forms	Active Forms	Total Forms	Active Form
Dumps							
13.60 ± 1.86	0.66 ± 0.09*	78.08 ± 48.50*	0.57 ± 0.04	10.27 ± 0.37**	0.22 ± 0.01	0.48 ± 0.10	0.09 ± 0.02
Control (leached chernozem)							
13.67 ± 1.06	0.36 ± 0.04	192.0 ± 11.58	1.43 ± 0.30	4.80 ± 1.47	0.33 ± 0.09	0.62 ± 0.08	0.08 ± 0.02
Maximum allowable concentration (MAC)							
23	2	85	23	32	6	1.5	0.24
Source: Authors' own work.							
Note: * - $p < 0.1$; ** - $p < 0.02$.							

The morphological markers of soil formation under the canopy of birch stands on dumps are noted. In birch stands, the upper 1.5 cm of soil consists of a litter of fallen leaves and branches: a humus-accumulative horizon with a total thickness of up to 10 cm develops deeper.

A feature of woody plants growing on dumps is the ability to accumulate chemical elements from the soil in various organs (roots, branches, leaves), which reduces the spread of pollutants in the environment [8–11]. Birch accumulates the largest amount of zinc (in bark and shoots) and lead (in shoots and roots). The greatest amount of copper accumulates in the birch root system, which indicates the barrier role of roots in the transit of copper to the above-ground organs (Table 2).

It was found that zinc in birch organs is distributed as follows: branches > bark > leaves > roots. The maximum lead content is observed in the branches: there is no excess of MAC. In all organs of birch, cadmium exceeded MAC.

After the reforestation of dumps, soil is formed. In soils under birch stands on dumps (Table 3), a high content of total carbon (21%) was found, which is due to the presence of brown coal particles in the soils. In soils under birch stands, the substrate reaction varies from weakly alkaline to weakly acidic. For 30 years in the soils under birch stands, the content of exchange forms of calcium and magnesium and active forms of phosphorus has decreased, which is associated with their leaching out of soils. In

TABLE 2: The average content of metals (mg/kg) in birch organs on the dumps of the Kumertau brown coal deposit ($n = 90$).

Elements	Birch organs							
	Dumps	Control	Control	Control	Dumps	Control	Dumps	Control
	Roots		Bark		Branches		Leaves	
Cu	27.39±2.28	21.56±1.60	16.40±2.70	19.49±2.90	2.63±0.12	3.67±0.15	4.12±0.54	2.82±0.30
Zn	17.47±1.25	19.96±1.10	52.65±1.94**	25.29±2.90	53.26±0.99	42.70±1.70	19.07±3.08	18.90±1.20
Pb	2.39±0.19	1.80±0.20	1.57±0.24	4.08±0.30	3.32±0.18	2.38±0.14	0.10±0.01	0.16±0.02
Cd	0.27±0.02**	0.45±0.03	0.62±0.18	0.76±0.20	1.06±0.14*	0.43±0.10	0.32±0.06	0.14±0.02

Source: Authors' own work.

Note: * - $p < 0.1$; ** - $p < 0.02$.

soils under birch stands on dumps, there is a decrease in acidity ($pH = 5.2$), which is consistent with the results of other researchers [12].

TABLE 3: Agrochemical characteristics of the dumps of the Kumertau brown coal deposit.

Depth of sampling, cm	Total carbon, %	pH, aqueous	P ₂ O ₅ for 100 g active	Ca ²⁺	Mg ²⁺
mg/eq for 100 g					
Dumps before reforestation (1982–1986)					
0–20	1.02	7.53	3.85	25.0	7.0
Dumps after reforestation (2016–2017)					
0–20	21.0	5.20	2.70	21.0	6.0

Source: Authors' own work.

4. Conclusion

The life state of birch stands on dumps is estimated as 'healthy'. It is established that in soils on dumps and in control soils, the content of active forms of metals is comparable with the total content of elements. The greatest average amount of metals is noted in perennial parts of plants (root system, bark, and branches), and the smallest – in assimilation organs. The metal accumulation in birch roots is an adaptive reaction aimed at the survival of this tree species in the pessimal conditions of the dumps. The life state of birch stands proves the success of the reforestation of the dumps of the Kumertau brown coal deposit. The formation of soils under the canopy of birch stands on dumps is marked. During the formation of soil under the canopy of birch stands on dumps, there are positive changes in parameters such as the content of total carbon, phosphorus and exchange forms of calcium and magnesium and the level of acidity.

This indicates the contribution of birch stands to the biological remediation of industrial dumps.

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