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Evaluation of the Forest Reclamation of the Anthroposoil Dump at the Bílina Mines Created from Marlstone

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Abstract

When reclaiming the surface of the Radovesická dump in the North Bohemian brown coal basin, the most commonly used marls and marlstones are extracted in the foreland of filled-in territory. The most frequent reclamations are the formation of overgrown and humus anthroposoil. The soil properties of the anthroposoils for forestry purposes and the growth vitality of a broader assortment of woody plants in the age of 12 - 14 years are evaluated. It has been found that the very good growth vitality on these anthroposoils is shown by most of the trees of domestic origin (*Populus nigra* L., *Acer pseudoplatanus* L., *Pinus sylvestris* L., *Alnus glutinosa* (L.) Gaertn., *Fraxinus excelsior* L., *Betula verrucosa* Ehrh., *Quercus robur* L., *Tilia cordata* Mill.), including some of the tree species introduced (*Larix decidua* L., *Pinus nigra* Arn.) and reclamations of atypical atrophic soil horizons did not negatively affect their development.

Keywords

Anthroposoil Landfill, Forest Reclamation, Marlstone, Loamy Clay, Soil Properties, Growth Vitality

1. Introduction

A considerable proportion of the concealed overlying deposits in the surface mining of brown coal, especially in the area of the Bílina mines in the North Bohemian coal basin, also form the structurally heterogeneous substrates composed of sands, silt, gravel, claystone, burnt clays, and often the rocks already have coal seams with a higher content of coal impurities [1] [2] [3]. The reclamation measures needed when adjusting their soil properties prior to afforestation are more demanding, taking into account both the criteria of their hydro-physical (anti-erosion) and the chemical treatment. Most of the reclamation concepts of the land treatment affected by these overlaying rocks assume a variation in the formation of anthroposoils [4] or a counter-erosion [5] variation of the creation of anthropomorphic humus. When reclaiming the soil properties of these dump substrates, reclamation technologies are currently being used, where at higher slope conditions only the surface of the dump is layered over by available fertilizer soils, most commonly selectively hidden loess clay and a minimum thickness of 0.3 m, or the creation of combined overlays when the surface of the dump is first overlaid with marl rocks with a thickness of about 0.3 m and then with a cover of a humus horizon (topsoil) with a thickness of about 0.2 m. In the more favorable slope ratios, the reclamation variant is also used, where the mixing soil is mixed with the available land development sorbent (loess clay, marl rocks, lower quality humus horizons) applied at a rate of about 2000 t/ha to a total depth of 0.3 - 0.4 m. Depending on the soil conditions, reclaiming and other measures, which especially include the application of various wastes of organic origin, or industrial compost and sludge from wastewater treatment plants have also been verified from the waste water treatment plant. Similar measures for the treatment of soil properties on anthroposoils are also assessed [6] [7] [8] [9] [10].

2. Methodology

2.1. Evaluation of Anthroposoil Reclamation Variants

Variant "*A*" (*X*: 984793, *Y*: 778111, *Z*: 299, 4); includes the territory of the 1st stage of reclamation of the Radovesická dump (**Figure 1**), with the technical reclamation completed between 1992-1993. The technological process of reclaiming this area consisted of the introduction of muddy rocks at a rate of about 2000 t/ha, their spreading and crossing into the soil profile with a very deep tillage. This modified surface soil horizon was overlaid again with mixed rock at a rate of about 2000 t/ha and also technologically similar to the previous one. *Variant* "*B*" (*X*: 984912, *Y*: 778963, *Z*: 311, 2); includes the territory of the III. stage of reclamation of the Radovesická dump, with the technical reclamation completed between 1993-1994. The technological process of the reclamation of this area consisted of depositing marlstone at a rate of 2000 - 3000 t/ha, spreading it out, followed by overlaying this layer with loess earth at a rate of 2000 - 3000 t/ha and plowing it into the soil profile with a very deep plow. *Variant "C"* (*X*: 985365, *Y*: 777563, *Z*: 315, 8); includes the territory of the 1st stage of the reclamation of the Braňany dump with the technical reclamation in the years 1993-1994. The technological process of the reclamation of this area consisted of its overlaying with a cover of a humus horizon (topsoil) with a total thickness of 0.2 - 0.3 m.

2.2. Evaluation of the Growth Vitality of Forest

Assessing the growth vitality of forest tree species (*Populus nigra* L., *Populus nigra var. Pyramidalis* L., *Larix decidua* L., *Betula verrucosa* Ehrh., *Fraxinus excelsior* L., *Tilia cordata* Mill., *Pinus nigra* Arn., *Acer pseudoplatanus* L., *Alnus glutinosa* (L.) Gaertn., *Picea omorica* L., *Pinus murrayana* var. latifolia, *Quercus robur* L., *Pinus sylvestris* L., *Picea pungens* L.), based on determining the dendrometric quantities (total height, taking into account the thickness $d_{1,3}$) for 20 - 100 specimens from all tree species represented, (with regard to the frequency of their representation in the stand), in the case of *Betula verrucosa* Ehrh. (*variants "A" and "B"*) and *Populus nigra* L. (*variant "B"*) is the evaluation of individuals from the stage of primary succession. The statistical evaluation of growth vitality of the trees (using One-Factor Anova) was performed only for the taxa where the dendrometric quantity (total height) was captured in more than 30 specimens. As a control area for comparison of the growth vitality of forest trees on made of clustered rocks, a forest reclamation with a similar age was found, located on humus anthroposoils (overlap of the dump soil with a thickness of 0.2 - 0.3 m) in the area of the first stage of the anthroposoils Braňany dump (*variant "C"*).

2.3. Evaluation of Anthroposoil Quantities

With respect to the soil samples collected (Kopecky cylinders of 100 cm^3) from characteristic soil horizons, *i.e.* from the substrate affected and not influenced by the absorption rate of the sorbent, the grain composition, the soil reaction, the content of organic substances and carbonates, the absorption properties, the content of the acceptable nutrients (P, K, Mg, Ca), maximum capillary water capacity, maximum capillary absorption, porosity and bulk density were determined at the laboratory. The coefficient of the hydraulic conductivity is determined on the basis of field infiltration measurements using the Guelph Permeameter (**Figure 1**).

Figure 1. The wooded area of the Radovesice I dump.

2.4. Evaluating the Soil Properties of Anthroposoils

Reclamation variant "*A*"; the soil-forming substrate of the modified horizons via reclamation (0 - 0.5 m), can be characterized as a silt loam carbonate and granularity as a clay soil. The soil exchange reaction is slightly alkaline, the substrate has a very low content of organic substances, carbonate content is marl, cation exchange capacity is medium, absorption is completely saturated, has low phosphorus content, potassium, good magnesium, and very high calcium. From a hydro-physical point of view, it is a favorable variant for the surface treatment for dumps which is structural, strongly water-bearing and slightly porous. The substrate consisting only of dump soil (more than 0.5 m) may be petrographically characterized as siltstone and granularly as sand to sandy clay. The soil is slightly alkaline, the substrate has a medium content of organic matter (the presence of coal), is slightly calcified, cation exchange capacity is medium, absorption is completely saturated, low phosphorus, high potassium, very high magnesium, and high calcium and slightly porous.

Reclamation *variant* "*B*"; the soil-forming substrate of the modified horizon by reclamation (0 - 0.4 m) can be characterized petrographically as dusty claystone and grain-like clay. The soil exchange reaction is slightly alkaline, the substrate has a low organic content, is calcium, the cation exchange capacity is high, absorption is completely saturated, has a low content of phosphorus, potassium, very high magnesium, and calcium. From a hydro-physical point of view, it is a favorable variant for the surface treatment of the dump which is structural, strongly water-bearing and slightly porous. The soil horizon of 0.4 - 0.6 m can be petrographically characterized as dusty clayey carbonate and granular as clay soil. The soil exchange reaction is slightly alkaline, the substrate has a low content of organic substances, carbonate content is marl, cation exchange capacity is medium, absorption is completely saturated, has low phosphorus content, potassium, very high magnesium and calcium, the soil is strongly watertight medium porous. The soil-forming subsurface consisting of dump soil (more than 0.6 m) can be petrographically characterized as dusty claystone and grain-like clay. Soil exchange reaction is slightly alkaline, the substrate has a very low content of organic substances, is carbon-free, the cation exchange capacity is very low, absorption is completely saturated, has low phosphorus content, good potassium, very high magnesium, and low calcium, is moderately water-porous.

Reclamation *variant* "*C*", the humus horizon (0 - 0.3 m) formed from the overgrown horizon, can be petrographically characterized as dusty claystone and grain-like as clay to loam-clay, the soil reaction is neutral, the soil is slightly limestone, has a high organic content, the cation exchange capacity is high, it is completely saturated with absorption, has a low content of phosphorus, high potassium, magnesium and calcium, and, from the point of view of hydro physics, it is a favorable variant for surface treatment which is structural, strongly waterproof and medium porous. The soil horizon (0.3 - 0.8 m) which forms the dump substrate can be characterized petrographically as dusty claystone, grain-like as clay to loam-clay, the soil reaction is exchangeable neutral, the soil is carbon-free, with low organic matter, the cationic exchange capacity is low, absorption is completely saturated, has a low phosphorus content, potassium-rich, very high magnesium and calcium-friendly. The soil properties of the assessed reclamation variants are set out in Table 1 and Table 2.

2.5. Growth Vitality of Forest Tree Species on Anthroposoils

The unrivaled best growth vitality on the basis of the established dendrometric quantities is shown on the dump substrates reclaimed by treatment with high

Table 1. Grain composition.

Reclamation variant	Soil horizon (cm)	Content of category's granularity (%)				
		<0.001 mm	<0.01 mm	0.01 - 0.05	0.05 - 0.25	0.25 - 2.0
"A"	0 - 10	24.5	59.5	18.5	14.3	7.7
	10 - 30	28.8	64.3	15.2	13.7	6.7
	30 - 50	24.6	55.7	15.5	19.6	9.2
	50 - 80	2.8	6.5	2.9	4.5	86.1
"B"	0 - 10	26.1	48.9	17.2	18.1	15.8
	10 - 40	28.3	43.1	20.7	17.2	19.0
	40 - 70	30.2	70.7	18.6	8.1	2.6
	70 - 90	20.2	41.2	21.7	32.3	4.8
"C"	0 - 10	30.1	44.6	25.0	8.2	22.2
	10 - 30	31.3	49.3	24.6	9.0	17.1
	30 - 80	22.2	45.3	21.1	13.8	19.8

Table 2. Chemical and other soil properties.

Reclamation variant	Soil horizon (cm)	pHKCl	$CaCO_3$ (%)	C_{ox} (%)	CEC (cmol+/kg)	Acceptable nutrients Mehlich III (mg/kg)			
						P	K	Mg	Ca
"A"	0 - 10	7.2	26.0	1.28	12.5	2.3	155	268	37,869
	10 - 30	7.4	28.0	0.32	9.4	4.3	116	199	38,847
	30 - 50	7.6	26.0	0.44	9.9	1.0	89	225	36,713
	50 - 80	7.6	2.1	0.11	5.0	6.7	94	267	6120
"B"	0 - 10	7.1	3.0	1.22	23.1	12.1	138	259	9690
	10 - 40	7.3	4.2	0.98	21.1	7.5	158	353	13,238
	40 - 60	7.7	43.0	0.11	13.3	2.3	102	400	38,483
	60 - 90	7.8	0.2	0.60	7.5	4.1	131	565	1490
"C"	0 - 10	7.0	1.0	2.61	30.6	15.3	480	360	6010
	10 - 30	7.1	1.2	1.90	29.1	14.9	463	384	6343
	30 - 80	7.0	0.1	0.31	12.9	6.4	91	209	1796

amounts of marlstone *Populus nigra* L. *and Populus nigra* L., var. *Pyramidalis* L. These trees grow further in the growth prosperity are rivaled by *Larix decidua* L., *Pinus sylvestris* L. and depending on the soil properties created by anthroposoil *Alnus glutinosa* (L.) Gaertn., *Acer pseudoplatanus* L. and *Betula verrucosa* Ehrh. Another significant group of trees in terms of reclamation that can be utilized in the afforestation of these anthroposoils with lower taxonomical quantities are *Fraxinus excelsior* L., *Pinus nigra* Arn., *Quercus robur* L. *and Tilia cordata* Mill. In terms of both the reclamation and growth, it can be considered as a minor species of artificial planting of the origin introduced by *Pinus murrayana* var. latifolia, *Picea pungens* L. and *Picea omorica* L. The dendrometric quantities determined are shown in **Table 3**.

3. Conclusions

The long-term pedological and vegetation investigations carried out on the dump substrates reclaimed using marlstone can be summarized by these more general conclusions. The use of 20% - 40% of marlstone in the treatment of soil properties of sandy soils is the formation of sandy alluvium and 60% - 80% share of marlstone and the formation of clay soil. The amount of marlstone used for the reclamation (20%, 40%, 60%, and 80%) represents a similar increase in the soil alkalinity. Increasing the amount of marlstone (more than 20%) represents a further insignificant increase in the carbonate content, cation exchange capacity, phosphorus, potassium, and magnesium in terms of forestry. Using a 20% share of marlstone is also a positive treatment for the water management but increasing doses are no longer involved in a more significant treatment of this soil attribute. The most important factor in the use of marlstone for the reclamation purposes in the dumps, regardless of the textural character of the treated soils, is the presence of the substrates of coal seams, *i.e.* the increased content of variously eroded coal and pyrite which in the soil-forming process is extremely unfavorable for vegetation and a worsening hydro-physical and chemical status (after excessively drying out and having low absorption rates, adverse erosion properties, an increase in soil acidity). Due to the inaccessibility of suitable mechanical means which can be used in mixing damp soil with marlstone on the slopes with a slope angle of up to 16%, a variant was also used where only the surface of damp was covered with marlstone with a thickness of 0.2 - 0.3 m, or this soil horizon was treated with topsoil or loess loam with a thickness of 0.2 m. According to current knowledge on the welfare of forest tree growth at this site, this variant can be considered usable in the most extreme climatic conditions.

During the afforestation of the dumps treated by the reclamation methods using a high amount of marstone, a relatively wide range of tree species of the origin of the home (*Populus nigra* L., *Acer pseudoplatanus* L., *Pinus sylvestris* L., *Alnus glutinosa* (L.) Gaertn., *Fraxinus excelsior* L., *Betula verrucosa* Ehrh., *Quercus robur* L., *Tilia cordata* Mill.), including some of the species introduced (*Larix decidua* L., *Pinus nigra* Arn.) which also exhibit considerable ecovalence

Table 3. Growth vitality of forest trees.

Wood species	Reclamation status	Thickness $d_{1,3}$ (cm)	Height (m)
Pinus nigra Arn.	"A"	10.3	5.1
	"B"	11.0	4.8
Larix decidua L.	"A"	9.5	7.5
	"B"	9.0	7.7
Picea pungens	"A"	3.9	2.9
	"B"	3.3	2.7
Acer pseudoplatanus L.	"A"	4.2	4.7
	"B"	5.6	5.9
Quercus robur L.	"A"	4.1	4.9
	"B"	4.4	4.4
Tilia cordata Mill.	"A"	5.8	4.6
	"B"	6.9	4.4
Fraxinus excelsior L.	"A"	4.6	5.2
	"B"	4.2	4.8
Alnus glutinosa (L.) Gaertn.	"A"	4.8	5.0
	"B"	9.5	6.1
Tilia cordata Mill.	"B"	6.9	4.4
	"C"	7.1	4.2
Acer pseudoplatanus	"B"	5.6	5.9
	"C"	7.0	7.2
Fraxinus excelsior L.	"B"	4.2	4.8
	"C"	4.5	5.0
Alnus glutinosa (L.) Gaertn.	"B"	9.5	6.1
	"C"	8.6	6.9
Pinus sylvestris L.	"B"	8.4	6.4
Picea omorica L.	"A"	4.4	4.2
Betula verrucosa Ehrh.	"A"	8.9	8.5
	"B"	10.8	8.1
Pinus murrayana var. latifolia	"A"	4.0	3.6
Populus nigra L.	"A"	19.3	18.1
	"B"	18.6	14.2
Populus nigra L. var. pyramidalis	"A"	17.5	15.7

to the profiled soil properties of anthroposoils. In the case of woody plants that respond more significantly to the more favorable soil anthroposoils (application of topsoil and loess), only *Acer pseudoplatanus* L. and *Alnus glutinosa* (L.) *Gaertn* can be considered (**Table 3**).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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