Effect of covering with natural topsoil as a reclamation measure on mining dumpsites

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Abstract
Soil reclamation after open-cast brown coal mining is a way of landscape restoration. Covering of the dumpsite earth with natural topsoil (topsoiling) is a common reclamation practice. We compared soil characteristics between areas with natural topsoil cover and without this cover on two different dumpsites. It was shown that natural topsoil cover increased organic carbon content and humus quality of the soil and slightly increased the content of available phosphorus that is generally deficient in the dumpsite soils of the region. In contrast, contents of available calcium and magnesium were lower on the covered sites; however, the supply of these nutrients is still very good. Natural topsoil cover also decreased the content of clay. However, the total and capillary porosity decreased. The effect of topsoil cover on soil pH was not consistent between the two sites under study. The effect of topsoil cover on soil heterogeneity was also assessed using geostatistics. In conclusion, the natural topsoil cover can generally improve the starting quality of the developing soil.

Key Words
Soil reclamation; mining dumpsites; basic characteristics; topsoil cover; spatial heterogeneity; geostatistics.

Introduction
Large-scale open-cast mining of brown coal is a commonly used method of mining. It leads to formation of permanent dumps of sterile rock. An effort is concentrated on landscape reclamation and revitalisation of these sites in the northern parts of the Czech Republic. In order to make either agricultural or forest exploitation possible, it is necessary to reclaim the dumpsite earths. They are usually sterile rocks, often very clayey, with no or very low organic matter content and sometimes also with unfavourable soil reaction. One reclamation measure consists in covering soil with natural topsoil (Bell 2001; Bořůvka and Kozák 2001). It should increase organic matter content and improve nutrients status. Physical properties, particularly soil structure, are often improved (Valla *et al.* 2000). Moreover, topsoiling should increase biodiversity of the newly created soils (DePuit 1984; Schladweiler *et al.* 2005).

The spatial heterogeneity of those anthropogenic soils is usually high, as the deposited material is very heterogeneous, including sterile rock with variable composition and from different depths, remains of brown coal carbon, and possibly added material rich in organic matter. This variability did not develop naturally as a result of pedogenic processes and natural spatial distribution, as it is the case in natural soils, but it is the result of human activities (Bořůvka and Kozák 2001; Rohošková *et al.* 2006). The time of the development of reclaimed dumpsite soils is too short for the factors to manifest fully (Sencindiver and Ammons 2000). Nevertheless, temporal changes of reclaimed soils even at the initial stages of their development are very important (e.g. Šourková *et al.* 2005).

The aim of this study is to evaluate the effect of natural topsoil cover on soil properties of two dumpsites in Northern Bohemia and to assess the heterogeneity of the reclaimed soils.

Methods
Studied areas and sampling
Two dumpsites of the Severočeské doly, a.s., mining company were selected: Libouš and Pokrok. Both are formed by clays. Soil samples were collected on both areas using a sampling scheme shown on Figure 1. 45 soil samples were collected on each site from the depths of 0 to 20 cm. The sampling scheme was placed on each dumpsite on the border between areas with and without topsoil cover so that approximately half of the sampling points were located on the area with natural topsoil cover, half of the points were on the area without the cover.

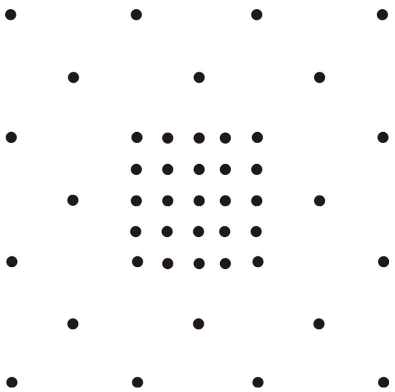

Figure 1. Sampling scheme applied on both dumpsites. The size of the big square was 90x90 m at the Libouš dumpsite and 120x120 m at the Pokrok dumpsite.

Soil analyses

Selected basic soil characteristics were determined by commonly used methods. Exchangeable soil pH (pH_{KCl}) was measured potentiometrically in 0.2M KCl extract (1:2.5; w:v; Zbíral 2002). Oxidisable (mainly organic) carbon content (C_{ox}) was determined oxidimetrically by a modified Tyurin method (Pospíšil 1964). Humus quality was assessed by the ratio of absorbances of sodium pyrophosphate soil extract (1:20; w:v) at the wavelengths of 400 and 600 nm (A_{400}/A_{600}; Pospíšil 1981). Content of carbonates was determined volumetrically after reaction with 10% HCl. Particle size distribution was determined by the areometric method. Available nutrients (Ca_{av}, Mg_{av}, K_{av}, P_{av}) were determined in Mehlich 3 solution (Zbíral 1996). Physical properties (bulk density – $\square_d$, total porosity, capillary porosity) were determined using a common procedure on undisturbed soil samples collected into physical cylinders.

Data treatment

Data were statistically processed using Statgraphics Centurion XV software (StatPoint, Inc.). Spatial variability was described using GS+ geostatistical software (Robertson 2000) and ArcMap v. 9.2 (ESRI Inc.).

Results and discussion

Comparison between areas with topsoil cover and without this cover is shown in Table 1.

Table 1. Effect of natural topsoil cover on chemical and physical properties of reclaimed dumpsite soils of the Pokrok and Libouš dumpsites: mean values and t-test results (t and P values). Differences at P ≤ 0.05 are put in bold.

Characteristic	Pokrok dumpsite				Libouš dumpsite			
	Without cover	With cover	t-value	P	Without cover	With cover	t-value	P
C_{ox} (%)	0.312	1.827	**-12.79**	**< 0.001**	0.721	1.263	**-6.503**	**< 0.001**
A_{400}/A_{600}	4.18	3.76	**3.767**	**0.001**	4.909	3.917	**7.957**	**< 0.001**
pH_{H2O}	6.83	6.17	**4.094**	**< 0.001**	6.365	7.167	**-4.781**	**< 0.001**
pH_{KCl}	6.38	5.88	**3.148**	**0.003**	5.969	6.663	**-4.062**	**< 0.001**
Carbonates (%wt.)	0.042	0.045	-0.130	0.897	0.048	0.078	-0.434	0.666
Ca_{av} (mg/kg)	3744.4	3424.8	1.337	0.187	3851.3	5239.4	**-3.462**	**0.001**
Mg_{av} (mg/kg)	1345.3	534.3	**10.15**	**< 0.001**	1658.3	1336.2	**4.532**	**< 0.001**
K_{av} (mg/kg)	411.0	286.0	**7.838**	**< 0.001**	442.2	253.3	**9.785**	**< 0.001**
P_{av} (mg/kg)	12.19	27.52	**-4.998**	**< 0.001**	13.72	15.01	-0.290	0.774
Clay (%wt.)	56.70	31.17	**11.88**	**< 0.001**	49.46	44.01	1.354	0.183
Silt (%wt.)	34.56	37.00	-1.884	0.066	36.05	35.12	0.397	0.693
Sand (%wt.)	8.74	31.83	**-15.64**	**< 0.001**	14.49	20.87	-1.882	0.067
$\square_d$ (g/cm^3)	1.295	1.327	-0.559	0.579	1.15	1.30	**3.922**	**< 0.001**
Porosity (%vol.)	49.40	46.15	**2.096**	**0.041**	55.06	49.07	**3.922**	**< 0.001**
Capillary porosity (%vol.)	44.85	35.27	**7.500**	**< 0.001**	45.30	40.08	**4.000**	**< 0.001**

On both dumpsites, covering with natural topsoil increased the content of oxidisable carbon and improved organic matter quality indicated by lower A_{400}/A_{600} ratio. It shows that the organic matter from natural topsoil is more mature and humified than the organic matter of dumpsite earths. Moreover, a part of the oxidisable carbon in the uncovered dumpsite earths can be coal waste rather than soil organic carbon (Borůvka *et al*. 1998). The effect of topsoil cover on soil pH was not consistent between the two dumpsites under study; both pHs were lower in covered soils on the Pokrok dumpsite compared to the soils without topsoil cover, while the opposite was true for the Libouš dumpsite. Nevertheless, all pH values are quite favourable, ranging around neutral values, probably thanks to the carbonate content in all soils.

Topsoiling slightly increases the content of available phosphorus that is generally deficient in the dumpsite soils of the region. In contrast, the contents of available calcium, magnesium, and potassium were lower on the covered sites; however, the supply was still very good in soils of both areas.

Natural topsoil cover also decreased the content of clay, particularly at the Pokrok dumpsite. Content of sand was increased correspondingly, which could lead to better physical properties as the dumpsite earths of the area are generally very clayey. However, the bulk density ($\square_d$) increased and total and capillary porosity rather decreased by topsoiling, probably due to the machinery traffic. Nevertheless, the proportion of coarser pores increased on the cover areas, which is a positive sign implicating better aeration and easier infiltration and water transport in the soils with natural topsoil cover.

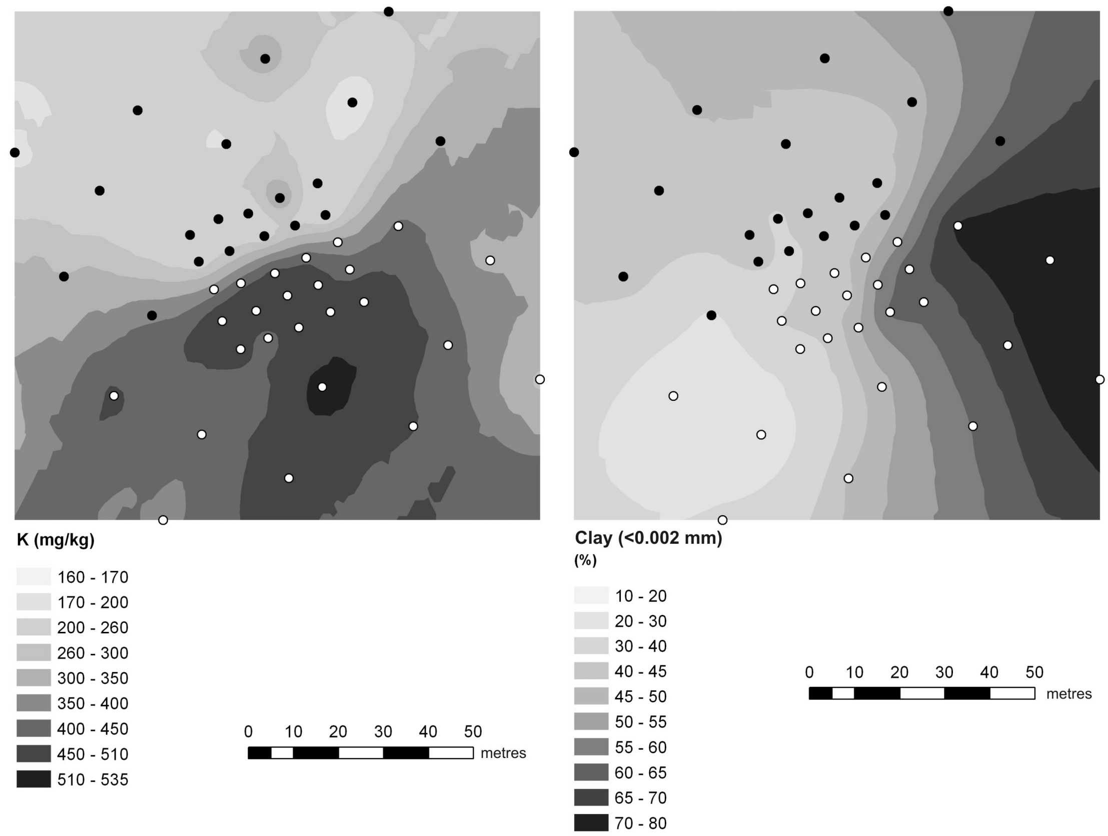

Figure 2. Example of spatial distribution of soil properties: content of available K (left) and content of clay (right) on the Libouš dumpsite study area. White points indicate sampling points without natural topsoil cover, black points those with topsoil cover.

Spatial distribution was assessed by means of geostatistics. Variogram parameters differed between the areas with and without topsoil cover; however, there was not a consistent difference (data not shown). Kriging maps showed spatial distribution and the effect of topsoil cover on the spatial distribution of soil properties. For some soil properties there is a clear shift between the areas with and without cover, as for example in case of available K content in the Libouš dumpsite (Figure 2, left). In contrast, there are characteristics that do not show a clear effect of topsoil cover on their spatial distribution, as for example clay content in the Libouš dumpsite (Figure 2, right).

Conclusion

The natural topsoil cover can generally improve the starting quality of the developing soil. It can facilitate further soil forming process, as well as the exploitation of the soils particularly for agricultural use. Spatial variation and distribution of soil properties is also influenced by the way of reclamation.

Acknowledgement

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