SOIL AND SOIL BIOTA IN RECLAIMED AND NON-RECLAIMED POST MINING SITES[1]

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Abstract. This contribution summarizes long term research of soil formation, soil chemistry, microstructure and soil biota in unreclaimed post mining sites and sites reclaimed by forest plantation in Northwest Bohemia. Spoil substrate quality vary substantially however toxic substrates with low pH, high polyphenols content or high conductivity are rare. The most frequent are tertiary clays, which support fast development of vegetation. Tree canopy closed in 15-20 years old plantations. Non reclaimed sites, were covered by willow (*Salix caprea)* shrubs about 15-20 years after heaping and young birch and poplar (*Betula pendula* and *Populus tremula*) forest appeared 25-30 years after heaping. Humus layer development in 25-35 years old plots was generally faster in plantation of deciduous trees than in conifers with unreclaimed sites being somewhere in middle. Two chronosequences of sites, one covered by alder plantations and the second unreclaimed, both covering age from 1-41 years were studied in detail. In non-reclaimed sites macrofauna abundances were lower and appear in higher densities in 25-30 years old sites, testacea amoebae and oribatid mites, densities in these sites were high, similar as in natural forest habitat. Microbial respiration was similar to reclaimed sites. Thick fermentation layer developed on soil surface of 15-20 year old plots, in 25-30 year old sites humus layer developed. Enclosure experiment indicated low soil mixing in unreclaimed sites. In alder plantation macrofauna was more abundant dominated by Diptera larvae Diplopoda, and earthworms. In the contrary, meso and microfauna displayed lower densities. Presence of earthworms resulted in more intensive soil mixing, which appear in rapid formation of humus layer.

In conclusion spontaneous succession may be in some cases a sensible way to restore post-mining sites. Soil formation seems to be strongly affected by soil biota development namely earthworm colonization. Maintaining conditions, that support soil fauna development, may accelerate soil formation.

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Introduction

Open cast coal mining causes massive disturbance of ecosystems. For example, the total area which will be disturbed at the end of mining activities (around 2036) in the Sokolov coal mining district (one of two major mining districts in the Czech Republic) will reach more than 6,000 ha. The majority of this area (75 %) is dedicated for forest reclamation. Spoil material overlying the coal layer is removed and deposited in heaps. The largest heaps are thousands of hectares in area and reach elevations of more than 100m above the original terrain. The material excavated from up to 200 m depth differs substantially from normal soils. Reconstruction of soil, soil biota and soil biological functions are important in reconstruction of functional ecosystems in post mining landscape (Bradshaw, 1993). Several studies were dedicated to study of soil and soil biota recovery in post mining sites (Dunger, 1968; Shafer et al., 1979; Dunger 1991; Topp, 1992; Frouz et al., 2001ab; Frouz et al., 2002). However most of these studies were focused on description of soil biota development in reclaimed sites. Little attention was paid on function of individual groups of soil biota in soil formation, particularly in sites that develop under spontaneous succession. The aim of this mini-review is to summarize our research about soil formation, soil biota development and function in soil forming process, in reclaimed and non-reclaimed post mining sites, in the Sokolov coal mining area (Czech Republic) and put it in perspective of research conducted in other post-mining sites in Europe.

Study Area And Environmental Constrains

If not mention otherwise, the studies were carried out at colliery spoil heaps formed by open coast coal mining in the Sokolov coal mining district, in the north western part of the Czech Republic. The altitude of the area is 500-600 m; the mean annual precipitation is 650 mm and the mean annual temperature 6.8°C, for more details see Frouz et al. (2001ab). Spoil substrates in this area are highly variable e.g. pH (H_2O) is ranging from 2.1 to 8.5 (Frouz et al., 2005). Spoil substrates with high conductivity and or low pH and high polyphenol content are toxic for soil biota (Frouz et al., 2005). Fortunately these substrates form only a small fraction of total area. The most widespread are alkaline tertiary clays of the so called cypris formation (Kříbek et al., 1998). These substrates are typically suitable for soil biota, and only exceptionally spots with high salt accumulation were toxic (Frouz et al., 2005). In conclusion prevailing substrates in investigated mining areas were alkaline (pH 8) tertiary clays, consisting from mixture of kaolonite, illite, quartz and limestone (Kříbek et al., 1998) rich in basic nutrients (Šourková et al., 2005). Thus the most common substrates in Sokolov post mining area do not represent major limitation for plant and soil biota development. This is clearly not a universal situation in Europe, e.g. coal and pyrite rich tertiary sand, which create adverse conditions for both soil biota and plant development, are frequent in Cottbus mining area in eastern Germany (Frouz et al., 2001), etc. In Sokolov area vegetation development was rather fast, tree plantation closed their canopy in 15 -20 years after planting (Šourková et al., 2005). On non-reclaimed plots, pioneer herbs and grasses were dominated by *Tusilago farfara* and *Calamagrostie epigeios*, initial development of herb layer was slower, than in another post mining sites in Czech (Prach, 1987). However, 15-20 years old sites are typically covered by willow shrubs (*Salix caprea*) and 25-30 year old unreclaimed sites are usually covered by young forest dominated by *Populus tremula* and *Betula pendula* (Frouz et al., 2001b).

Colonization Of Heaps By Soil Biota

Soil animals that colonize post mining site are mostly ubiquitous eurivalent species common is surrounding landscape (Pižl, 1999; Pižl, 2001; Holec and Frouz 2005). However, in many cases some rare species missing in surrounding landscape can be found on the heaps, these species are typically, mountain species or species characteristic for steps and saline habitats (Holec and Frouz 2005). We can expect that similarly as in another post mining area small arthropods are mostly passively air born, while larger invertebrates fly or crawl from surrounding landscape. Distance from surrounding landscape can by important particularly for colonization of crawlers. For example Frouz (1999) showed that proportion of wingless Diptera significantly decreased from surrounding landscape towards heap center.

We have only little data about migration of microflora on the heap but we expect most of it is airborne. We have found also some viable microflora in fossil spoil heap material (Elhottová et al., in press) but its role on microbial colonization of heaps is not clear.

Development Of Soil And Its Interaction With Soil Biota

We have compared development of humus and fermentation layer in plots reclaimed by planting alder (*Alnus glutinosa*), lime (*Tilia cordata*), oak (*Quercus robur*), larch (*Larix decidua*), pine (mixture of *Pinus silvestris* and *P. nigra*) and spruce (mixture of *Picea omorica* and *P. pungens*). The most rapid development of fermentation and humus layer of soil was found under alder and lime plantations, also larch support fast soil development, on the other hand, the slowest soil development was found under spruce and pine plantations. Sites planted by oak and non-reclaimed sites colonized by natural colonization are somewhere in the middle as concern soil development (Frouz, 2006). Deciduous trees support faster soil formation than evergreen conifers. Soil development in unreclaimed sites is in average comparable to reclaimed ones. Detailed observation of soil development, in two chronosequences of alder plantations and non-reclaimed sites, indicated that the difference between reclaimed and non-reclaimed plots was the most pronounced in intermediate stages of succession. In older plots, this difference decreased as a consequence of earthworm colonization and humus layer formation in non-reclaimed sites (Frouz et al., 2002). Also development of soil biota was compared in these two chronosequences. No apparent differences in microbial parameters were found between reclaimed and unreclaimed sites (Frouz and Nováková 2005; Šourková et al., 2005b). Reclaimed sites harbor higher densities of soil macrofauna, especially earthworms, which were significantly more abundant in reclaimed sites than in non-reclaimed ones. In Diptera, groups that play important role in litter fragmentation dominate on reclaimed sites whereas microsaprophagous groups dominate spontaneous sites. In the contrary, spontaneous sites harbor significantly higher densities of soil micro and mesofauna namely testate amoebae and oribatid mites namely in middle stages of succession (Frouz et al., 2004). In older sites earthworms also start to colonize spontaneous sites, in 40 years sites even endogenous species are present (Frouz et al., 2001b; Frouz et al.,2002; Frouz et al., 2004). Soil macrofauna is sensitive to amount and quality of litter (Lavelle et al., 1997). Higher densities of soil macrofauna in reclaimed sites probably correspond with better quality of litter (lower C/N ratio – Šourková et al., 2005). Beside litter quality non-target inoculation of reclaimed sites by fauna due to transport of soil with seedlings or machinery may accelerate colonization of macrofauna namely earthworms (Frouz et al., 2001). Similar differences were observed also when compared soil fauna in deciduous and in conifer forest in Germany or in German and Czech sites differing in litter quality (Dunger, 1968; Dunger, 1991; Frouz et al., 2001).

Microscopic observation of thin soil section prepared according Rusek (1978) revealed that in reclaimed sites 15-20 years old, litter was converted into fecal pellets very intensively, only very small amount of unconsummated litter was found in topsoil layer. Below fermentation layer massive accumulation of earthworm casts was observed, forming humus layer, the same pattern was observed also in older succession stages (Frouz et al, 2001a; Frouz et al., 2004). In the unreclaimed sites massive accumulation of leaf litter was observed mainly in depressions, deeper in the litter macrosaprophagous mainly millipedes fecal pellets accumulate.

Higher densities of soil macrofauna take part in soil mixing. Soil mixing was more pronounced in reclaimed sites using both soil microstructure analysis and soil microcosms. The importance of soil macrofauna particularly earthworms for soil organic matter mixing was indicated also in other studies (Lavelle and Martin, 1992; Hendriksen, 1997; Frouz, 2002).

Massive mixing of litter into mineral layer and consequent reduction of fermentation layer in reclaimed plots seems to be reason for lower abundance of soil meso and microfauna in reclaimed in comparison to spontaneous sites. Similarly Dunger (1968, 1991) and Frouz et al. (2001) observed decrease in mesofauna and microfauna in latter stages of succession in deciduous forests on post mining heaps. In latter succession stages described in these studies, earthworms become more abundant and also some shift from moder like to mull like form of humus was observed. These changes in soil microstructure namely more intensive soil mixing and removal of fermentation soil layer is postulated to affect negatively communities of some groups of soil meso and microfauna. These results are supported also by using enclosures which were either accessible or non accessible for soil macrofauna, which indicated that amount of litter which is mineralized and lost from the system is similar in both reclaimed and spontaneous sites. Removal of litter from soil surface and soil mixing however differ substantially between both sites. In spontaneous sites majority of litter remain on the soil surface but in the reclaimed sites majority of litter was removed from litter layer and mixed into mineral layer (Frouz 2002; Frouz et al., in press). Shift of dead organic matter from aboveground (litter) to belowground pool is characteristic for more advanced succession stages (Schafer et al., 1979). Organic matter mixed with mineral soil may play important role in alternation of soil physical and chemical properties such as increase of water holding or sorption capacity (Allison, 1973; Frouz et al., in press).

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