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Temperature and water potential of grey clays in relation to their physical, chemical and microbiological characteristics and phytocoenology within the scope of the Radovesice Dump

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Abstract

Radovesice Dump is a part of brown-coal Most basin, which is situated in the northern part of the Czech Republic. Grey clays are the anthropogenic substrates, which have been used here as a reclamation material in most cases. Water potential of these substrates corresponds to their physical properties, annual precipitation, soil temperature and terrain exposition. All of these characteristics are the limiting factors of soil water, which is available to plants. Area left to spontaneous succession and reclaimed area served as the serviced ones. Water potential was studied in three depths (10, 20 and 30 cm) of soil profile and the evaluated values showed significant difference between individual depths as well as exposition. As far as chemical analyses are concerned, the highest values were recorded in case of reclaimed area, whereas the levels of soil moisture here were medium. On the other hand, area left to spontaneous succession showed the lowest values in this sense, however specific representation of vegetation was much large-scale. As far as microbiological characteristics are concerned, the concentrations of phospholipid fatty acids were relatively low in both cases. To the dominant herb species belonged *Calamagrostis epigejos*, *Urtica dioica*, *Alopecurus pratensis* and *Astragalus glycyphyllos*. It was found that spontaneous succession was more variable as far as the specific representation of vegetation is concerned, though favourable soil physical and chemical properties were provided by technical reclamation too..

Keywords: Radovesice Dump, grey clays, soil water potential, soil moisture, soil temperature, phytocoenology

Introduction

Radovesice Dump, the outer dump of Bílina Mine, occurs at the altitude of 350 m a. s. l. and was created between 1964 and 2002 (Řehoř et al., 2011). It is formed by grey and yellow Miocene clays mixed with quaternary sands. Its particle-size structure is very variable, even within the scope of small areas. Grey and yellow clays are rich in nutrients, above all magnesium, potassium and calcium. Phosphorus is in default. As far as clays are concerned content of humic substances is relatively high and pH is usually neutral (Dimitrovský, 2000; Řehoř and Ondráček, 2012). Clays are loose after filling; however they lie down and become compact in the process. All this mean that substrate chemistry is favourable for plant growth, nevertheless soil physical characteristics are not so positive.

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Problems of eccession were carried out by Pyšek et al. (1997, 2001), Hodačová, Prach (2003) and Prach et al. (2009a, 2009b, 2009c, 2010), who described primary succession on these substrates, where annual plants appeared in first five years, perennial plants occurred between the fifth and the tenth year and woody plants rose till the tenth year. Complete coverage (100 %) with dominating species *Calamagrostis epigejos*, *Festuca rupicola*, *Poa angustifolia*, *P. trivialis*, *Arrhenaterum elatius*, *Cirsium arvense*, *Populus tremula*, *Fraxinus excelsior*, *Acer pseudoplatanus* etc. was reached after the tenth year. Woch et al. (2013) compared vegetation cover of spontaneous succession and technical reclamation in relation to physical and chemical soil properties. The impact of reclamation processes on the vegetation colonization was studied by Ninot et al. (2001), who found that the management of planting did not influence the quality of phytocoenosis, while the selection of appropriate plants could contribute to weed presence (e.g. *Festuca arundinacea*, *Dactylis glomerata*, *Lotus corniculatus*), which disposes of negative influences (uptake of soil moisture and nutrients, shading etc.).

Soil chemistry was studied by Abakumov et al. (2013) who compared post-mined localities of different age and found that soil of reclaimed areas cumulated carbon and nitrogen much faster, which had a positive influence on herb species. The similar relationship was found by Lopez and Fennesy (2002) who confirmed the influence of soil carbon, phosphorus and calcium on the vegetation cover. Moreno-de las Heras (2009) used physical, chemical and biochemical indicators, for example soil aggregates stability, soil enzymes activity etc., for 18 years and found that soil forming processes and related soil aggregate size significantly affected vegetation representation. He also emphasized the necessity to incorporate organic substances into soil when reclaiming of areas affected by mining activities. Graham and Haynes (2004) used carbon content in soil and in microbes as well as microbial activity of soil flora to indicate effectiveness of sand dunes reclamation. The relationship between soil carbon and nitrogen and soil fauna activity was also studied by Frouz et al. (2013). Phospholipid fatty acids (PLFA) in terms of post-mining sites were dealt with Šnajdr et al. (2013), who studied the importance of trees´ presence and found that higher amount PLFA was under the trees because of the litter.

Soil physical properties in relation to vegetation cover were studied by Krümmelbein and Raab (2012), who evaluated the availability of anthropogenic substrates within the scope of agricultural reclamation. They found that rare cultivation improved soil permeability and hydraulic conductivity. Lehmann et al. (1998) or Polak and Wallach (2001) were concerned with soil water potential and they found significant differences within the depths as well as within selected species.

The main aim of this study was to evaluate soil water potential and temperature on anthropogenic affected soils and to find out their physical, chemical and microbiologic properties in relation to occurring phytocoenosis.

Material and Methods

Areas of Interest

The areas of interest were chosen from two different ecological types of habitats. Their brief characteristics are mentioned in the table below (Table 1). The first locality was left to spontaneous succession. It is 14 years old and represented by a crater, which was created by incomplete strewing of material during the dump building. Four various collecting areas were found here; to be more specific these were the top and base of southwards oriented slope and the top and base of northwards oriented slope. Their gradient was ~45°. This locality was situated at the Radovesice Dump No. XVII.B. The second locality was a reclaimed area, situated at the Radovesice Dump No. VII. It is 6 – 10 years old and the slope gradient is 5°. This locality was reclaimed by marline placement, 0.3 m below the substrate surface in order to improve soil properties. The locality was grassed and forested within the scope of reclamation works.

Table 1. Areas of interest characteristic

Area Number	Area Name	Abbreviation	Altitude (m a. s. l.)	GPS Coordinates
1	Top of southwards oriented slope	S top	390	50°32'01.67" N 13°50'11.63" E
2	Base of southwards oriented slope	S base	380	50°32'00.91" N 13°50'11.24" E
3	Top of northwards oriented slope	N top	390	50°31'59.01" N 13°50'09.70" E
4	Base of northwards oriented slope	N base	380	50°31'59.13" N 13°50'10.98" E
5	Reclaimed area	R	390	50°31'57.30" N 13°50'05.75" E

Samples Collection and Analyses

Samples used on soil moisture determination were collected in a form of undisturbed ones, into so-called Kopeckého sample rings. They were collected from the depth of rooting (approximately 0.2 m below soil surface) in 14-days interval during the whole vegetation season (from April to October 2013). Soil moisture was determined by gravimetric method according to ČSN ISO 11 465 (1998) methodology in a laboratory of the Department of Natural Sciences, the Faculty of the Environment UJEP.

Soil water potential was determined on succession areas only. The reason is that the authors wanted to focus on the situation in the crater, which they found much interesting. It was determined by gypsum blocks MicroLog ERi. They were put into various depths below the soil surface (10, 20 and 30 cm) at the beginning of the vegetation season and were taken out at the end of the vegetation season. They were located on both slopes of succession crater. Soil water potential was measured in bars (1 mm conventional water column = 0.009807 bar). Soil temperature was measured simultaneously with soil water potential in a depth of 10 cm. It was measured by means of datalogger.

As far as other soil characteristics are concerned, particle-size analysis, mineralogical analysis and soil chemical analysis (nitrogen content [N_c], oxidable carbon content [C_{ox}], calcium carbonate content [$CaCO_3$], soil reaction [pH/H_2O], nutrient content [P, K, Mg] and sorption capacity) were proceeded. The samples were collected at the end of August 2013 and they were analysed in the certified laboratory of The Brown Coal Research Institute j. s. c. Samples for microbiologic analyses (PLFA determination) were taken simultaneously. The analyses were carried out in a laboratory of the Department of Technical Sciences, the Faculty of the Environment UJEP and the Research Institute of Inorganic Chemistry, Inc.

Phospholipid fatty acids were analysed according to the adopted methodology of Zelles (1995) as described previously (Kuráň et al. 2014, Trögl et al., 2013)

Phytocoenology Survey

The phytocoenology survey was carried out according to Braun-Blanquet scale of abundance and dominance (Moravec et al., 1994) in the first half of the vegetation season, on the 22nd June 2013. Rounded areas with the diameter of 8 m were selected for the purpose of the research. All species were unified according to the methodology of Kubát et al. (2002). Phytocoenology survey was proceeded to uncover the occurrence of constant plant species on selected localities. Sørensen index of resemblance (Moravec et al., 1994) was calculated for each survey.

Methods of Statistical Evaluation

All the results were evaluated by means of MS Excel 2007. Relationship among soil water potential, soil temperature and air temperature was determined in terms of Statistica 12 Software. To be specific, ANOVA, regression coefficient and Pearson´s correlation coefficient at the significance level $p < 0.05$ were used. As far as PLFA is concerned, Bonferroni tests at the significance level $p < 0.05$ was calculated via Statistica 10 Software.

Results and Discussion

Soil moisture

When we consider selected localities, the highest values of soil moisture were recorded in a case of the reclaimed area (11.0 % on average. On the other hand the lowest values were measured on succession areas (7.0 % on average). It was also found that the base of northwards oriented slope disposed of lower average moisture than its top. This can be explained by lower retention capacity of sand, which prevailed on the slope base. It was possible to evaluate the relationship between soil moisture and average daily temperature from the graph below (Figure 1). There is a significant correlation which level varies a lot; it is stronger as far as the succession areas are concerned and weak in case of the reclaimed area.

Within the scope of soil water potential (Figure 2) and soil temperature (Figure 3), no significant relations were found. The lowest values of soil temperature were recorded on the northwards oriented slope, which is given by its position (lower exposition to sunlight). The extreme conditions of spoil-heaps were described by Pyšek et al. (1997), Dimitrovský, (2000); Hodačová, Prach (2003); Prach et al. (2009a); and Řehoř and Ondráček, (2012). Our results show that these soils are rich in nutrients but poor in soil moisture. There is such more significant difference between southwards and northwards oriented slopes which corresponds to vegetation cover (e.g. *Urtica dioica* was found on the northwards oriented slope as well).

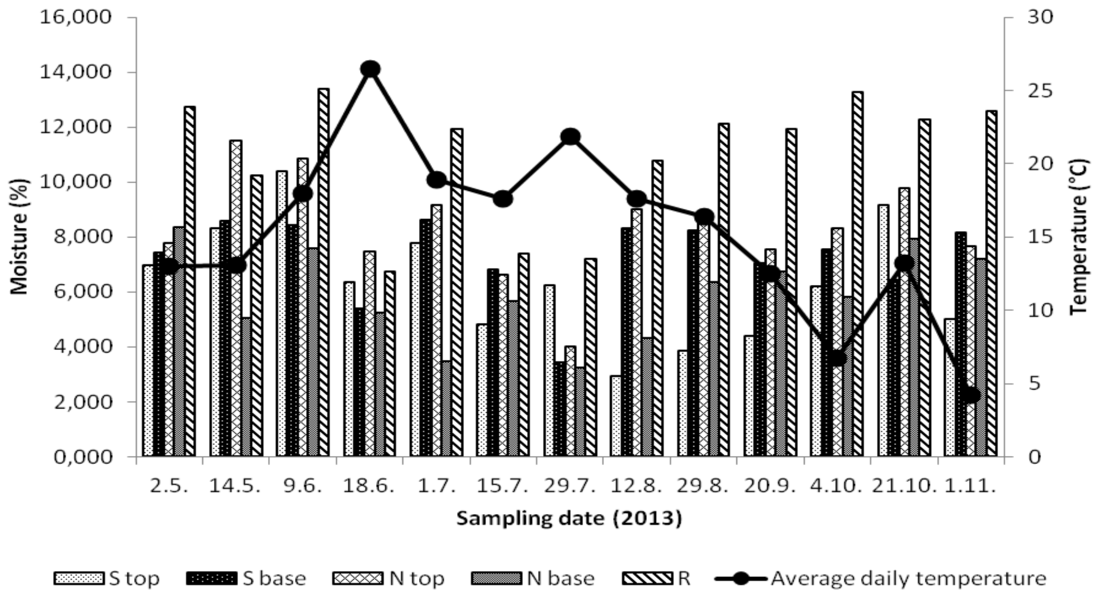

Figure 1. Relation of soil moisture on average daily temperature

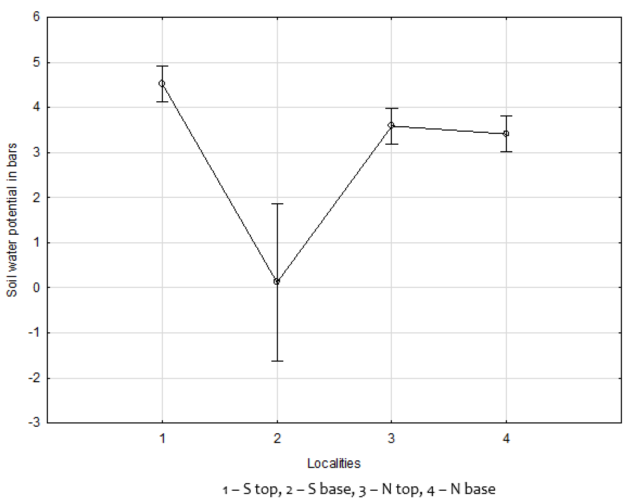

Figure 2. Soil water potential on selected localities

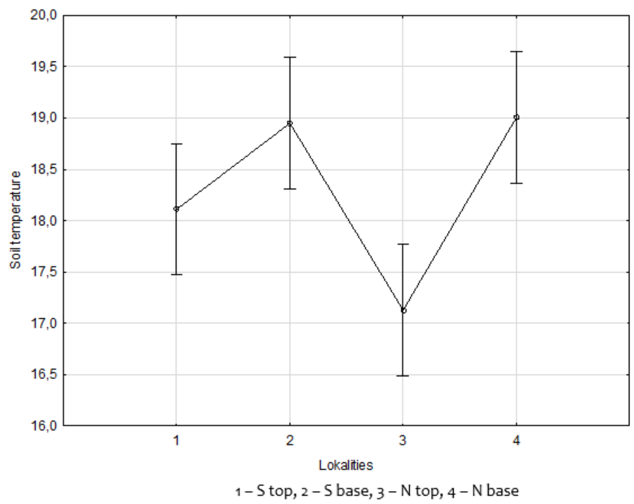

Figure 3. Soil temperature on selected localities

Soil Analyses

Soil of individual localities was classified as loamy after the particle-size analysis had been carried out. As far as mineralogical analysis is concerned, soil base consists of silica, kaolinite and illite. Kaolinite and illite are in a form of aid at the top of both slopes; on the other hand reclaimed locality is enriched by calcite.

Soil of the reclaimed area disposes of much better properties when compared with areas of spontaneous succession. It is obvious (Table 2) that the amount of calcium carbonate is almost three times higher within the reclaimed locality. The similar situation stands for the amount of carbon (C_{ox}). This fact can be explained by the presence of grey clays and marlite in the soil. They are rich in calcium, magnesium and potassium and they were put into the soil during the reclamation processes to improve its properties (Řehoř and Ondráček, 2012). On the other hand succession localities were left to spontaneous development without any amendments, which is the reason of poor soils. Similar results were obtained by Buczko et al. (2001) and

Frouz et al. (2011). Total nitrogen occurs only on reclaimed area which corresponds to the plant species that were found here (*Urtica dioica*, *Alopecurus pratensis*, *Arrhenatherum elatius*, *Galium aparine*). Wilson (1943) found that nitrogen is present up to 1.6 % in sufficiently moist soils, which confirm our results, too.

Table 2. Representation of selected elements in soil

Locality	$CaCO_3$ (%)	C_{ox} (%)	N_{tot} (%)	pH/H_2O
S top	0.9	0.9	0.0	6.7
S base	1.0	1.0	0.0	6.7
N top	0.8	0.8	0.0	6.6
N base	0.4	0.7	0.0	6.4
R	2.1	1.9	0.1	6.9

Almost the same situation stands for the amount of soil nutrients (Table 3). The amount of phosphorus was not significant on reclaimed area. This fact is also connected with the presence of grey clays and marlite which are lack in phosphorus (Řehoř and Ondráček, 2012). The same results were presented by Zoubková et al. (2013).

Table 3. Content of selected nutrients in soil

Locality	K (mg/kg)	Mg (mg/kg)	P (mg/kg)
S top	151	475	1
S base	187	455	0
N top	163	428	1
N base	118	325	0
R	220	749	2

Phospholipid fatty acid (PLFA)

According to the results (Table 4) the soil on all localities was poor in living microbial biomass as detected by total PLFA. All four succession sites were comparable and significantly lower to reclaimed site. The values for succession were even lower to deserts (Bailey et al., 2002) and comparable to similar clays (Baldrian et al., 2008) while the R site was comparable to poorer agricultural soils (Bailey et al., 2002). Ratios between fungal and bacterial PLFA (F/B) were also lower than in mature soils (Kaur et al., 2005). Ratios between grampositive and gramnegative bacteria (G^+/G^-) were in all cases significantly lower than 1, common in mature undisturbed soils (Kaur et al., 2005). This indicates that G^- bacteria are more successful in the early stages of primary succession. Levels of *trans/cis* PLFA were significantly higher than 1 in all cases, indicating microbial stress. Generally we can say that there was no significant difference between reclaimed areas and areas left to spontaneous succession. The possible reason can be that in both cases we are speaking about anthroposoils, which are usually poor in microbial activity. The *cy/pre* ratio, indicator of transition of microbial community to stationary growth/phase, were higher than in normal soils (Kaur et al., 2005). Nevertheless in such poor localities this can be affected by many factors (e.g. nutrient levels, water activity, pH, presence of microbial inhibitors etc.) that more data from more similar localities are needed in order to interpret them properly.

Table 4. Soil phospholipid fatty acids (PLFA) characteristics

Locality	$PLFA_{tot}$	F/B	G^+/G^-	*trans/cis*	cy/pre
S top	7.54	0.21	0.54	0.23	0.27
S base	1.71	0.12	0.57	0.29	0.33
N top	1.40	0.09	0.50	0.39	0.28
N base	1.83	0.37	0.41	0.30	0.33
R	2.44	0.17	0.52	0.29	0.27

$PLFA_{tot}$ – total phospholipid fatty acids, F/B – ratio of fungal/bacterial PLFA, G^+/G^- – ratio of indicator PLFA of gram-positive and gram-negative bacteria, *trans/cis* – stress indicator based on the ratio of *trans* and *cis* monounsaturated fatty acids (Kaur et al., 2005), *cy/pre* – stress indicator based on the ratio of fatty acids with cyclopropyl ring and their metabolic precursors (Moore-Kucera and Dick, 2008).

Letters denote overlaping of 95%-confidence intervals. 0 denotes the value is statistically (t-test, α=0.05) comparable to zero (i.e. not significant).

Phytocoenology survey

All four layers were present on the Radovesice Dump, whereas the most dominant was the herb one. The coverage of tree layer gets about 5 %. Trees (*Betula pendula* and *Populus nigra*) occurred only within the scope of succession localities. Juvenile tree species were found mostly at the bottom of both succession slopes, which can be explained by well-balanced water conditions. The most dominant juvenile tree species were (*Salix caprea* juv., *Acer pseudoplatanus* juv. and *Populus tremula* juv.). All these species occurred on the northwards oriented slope, which confirms results of Landhausser et al. (2010) and Frouz et al. (2011).

The most dominant shrub species were *Fraxinus excelsior*, *Tilia cordata* and *Populus tremula*, which were found only on the reclaimed area. The reason is that they were planted here as a consequence of technical reclamation and they are under strict management (regular cutting etc.) nowadays. It is obvious from the above mentioned trees and shrubs that *Picea* spp. is no more the key species as far as the reclamation processes are concerned. It is much more often to plant out species such as *Fraxinus excelsior*, *Acer platanoides*, *A. pseudoplatanus* or *Alnus glutinosa* on the areas affected by mining activities (Hodačová and Prach, 2003; Prach et al., 2009c).

As far as the herb layer is concerned, the most dominant species were *Calamagrostis epigejos*, *Cirsium arvense*, *Lathyrus pratensis* and *Trifolium pratense*. *Calamagrostis epigejos* disposes of very good adapting ability and it was present with the coverage over 37 % on all localities. The highest abundance of herb layer was found on the top of northwards oriented slope, where *Calamagrostis epigejos* and *Lathyrus pratensis* belonged among the most dominant species. On the other hand the lower abundance was on the reclaimed area, even the soil properties were the best here. Within the scope of succession localities the most dominant species were, except the above mentioned *Calamagrostis epigejos* and *Cirsium arvense*, *Astragalus glycyphyllos*, *Tussilago farfara*, *Lathyrus pratensis* and *Melilotus officinalis*.

The only species from the moss layer was *Rhytidiadelphus squarrosus* which occurred on the northwards oriented slope.

The level of resemblance ranges between 12.8 – 62.2 %. The highest resemblance index recorded succession localities. Contrariwise the lowest values were found between reclaimed and succession areas (12.8 %). In this case shrub layer outplanting on the reclaimed area plays the crucial role as well as the management on the reclaimed area. Analogous results can be found in the article of Zoubková et al. (2013).

Conclusion

Such a low values of soil water potential, which correlated with soil temperature, were measured within the scope of the areas of interest. As far as the statistical point of view is concerned, slope orientation have almost no impact on occurring phytocoenosis. To be sure in this statement, it is necessary to proceed long-term survey. Spontaneous succession is much diversiform as far as phytocoenosis is concerned, although much more favourable chemical and physical soil characteristics provides technically modified and enriched reclaimed soil. Microbiologic characteristics are rather poor on both types of localities, that is why we can make a conclusion that anthropogenic affected soil are poor in microorganisms and consequently in their activity.

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