3.2 The abiotic and eco-physiological parameters of biological soil crusts of ash-slag and ore-waste sedimentation basins

KATEŘINA ČERNÁ

INTRODUCTION

Human activities such as ore-mining or ash-slag depositions greatly influence soil abiotic and ecophysiological characteristics. High concentrations of toxic metals connected with low nutrient availability lead to specific characteristics of such soils and development of specific bacterial communities that are able to survive in these unfavourable conditions.

MATERIALS AND METHODS

Samples of biological soil crusts including just the upper 0,5 cm-layer of soil were collected on the study sites in spring of 2006. Laboratory analyses were carried out by the Analytical Laboratory of the Section of Plant Ecology of the Czech Academy of Science in Třeboň. Soil samples were sieved through a 2-mm mesh and air-dried (Zbíral 1995, ISO 11464). Soil pH was determined with a glass electrode in a 1-to-5 (w/w) soil-to-deionized water mixture (5M KCl, respectivelly) (ISO/DIS 10390). Electrical conductivity was measured in a 1-to-5 soil-to-water mixture at 25 °C (ISO/DIS 11265). The concentrations of nitrate ions (NO_3-N), ammonium ions (NH_4-N) and dissolved reactive phosphorus (DRP) in the soil suspension were determined colorimetrically with a continuous flow analyser (FIA-STAR, Tecator, Sweden). The gas diffusion method was used for the estimation of the concentration of NH_4-N (Karlberg & Twengström 1983). The concentration of NO_3-N was determined after its reduction to nitrite in a Cd-Cu column and the subsequent reaction of nitrite with sulfanilamide and N-(1-naphthyl)-ethylenediamine. Standard phosphomolybdenum complex method was used for the DRP estimation (Parsons et al. 1984). Total nitrogen (TN) and total phosphorus (TP) concentrations were determined as NO_2-N and DRP respectively, after mineralization of the samples by persulphate (Grasshoff et al. 1983). Basal respiration of microbial assemblages was determined after incubation of soil samples in 25 °C for 24 hours. Samples were incubated in air tight jars along with 10 ml of 1 M NaOH. The CO_2-C evolved was determined by titration by HCl (Anderson 1982). Soil incubation was also used for determination of ammonification and nitrification rates. Soil samples (10 g of soil each) were moistened to 60% of max WHC and incubated for three weeks at 20 °C in aerobic conditions. NH_4-N and NO_3-N were extracted before and after the incubation and their concentration was determined with continuous flow analyzer. The ammonification and nitrification rate was computed from the differences in the concentration of NH_4-N and NO_3-N at the beginning and at the end of incubation. Fluorescein diacetate (FDA) hydrolysis rate was estimated as described in Schnürer and Rosswall (1982) using an incubation period of 1 h at 28 °C. To determine the heavy metals concentration soil samples were firstly digested with NO_3 and HCl in ratio 1-to-3 (w/w). Then samples were subjected to atomic absorption spectrometry and the concentration was determined by FAAS using air acetylene flame.

RESULTS

We attempted to identify soil parameters that influence the development of biological soil crusts at studied localities. We found no difference in soil pH/H_2O (measured in soil-water mixture). Soil pH values between 7.77 and 8.24 were measured at all localities (Fig. 3.2.1), the highest value of pH was found in Dvůr Králové. Differences in pH/KCl values (measured in soil-KCl mixture) were found – the values of pH were lower than those measured in soil-water mixture. The range of measured values was detected from 6.47 to 8.06 the highest value was measured in Dvůr Králové. We detected differences in measured values of electrical conductivity in localities. The highest electrical conductivity was measured at the locality in Dvůr Králové (280 μS/cm) the smallest conductivity was measured at the locality in Měděnec (27.5 μS/cm). The highest measured value was ten times higher compared to the lowest one (Fig. 3.2.1). Measured concentrations of NH_4^+ differed between studied localities. The highest concentration was detected in Radvanice (0.0217 mg/g) which exceeded many times the concentration in other places (Fig. 3.2.2). In Ostrov the concentration of NH_4^+ was lower than 0.0001 mg/g. Concentrations of NO_3^- in all localities were low, the highest value was measured in Měděnec (0.00092 mg/g), in Ostrov and Dvůr Králové the concentrations of NO_3^- were lower than 0.0001 mg/g. The amount of PO_4^{-3} in the soil of studied localities ranged between 0.000116 to 0.00052 mg/g, the highest value measured in Ostrov (0.00052 mg/g). Differences in the amount of total nitrogen and total phosphorus in soils of studied localities were detected (Fig. 3.2.3). The

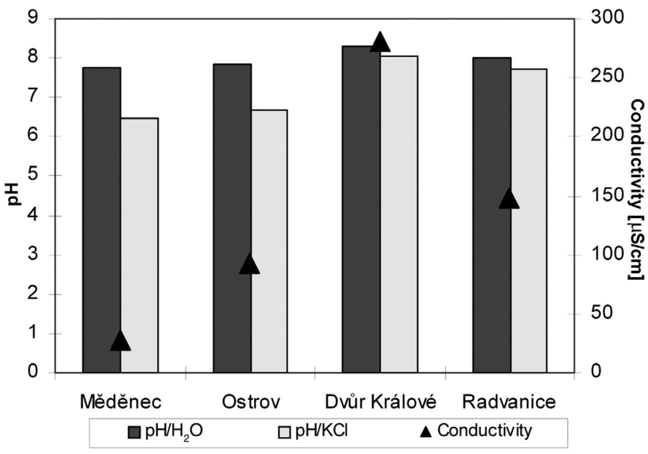

Fig. 3.2.1 The values of pH and chemical conductivity measured at studied localities.

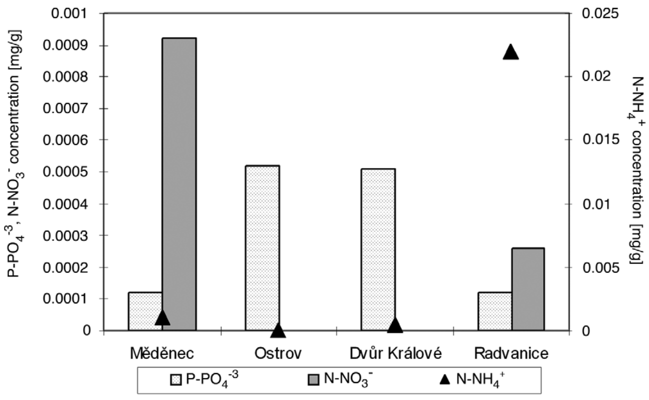

Fig. 3.2.2 Concentrations of NH_4^+, NO_3^- and PO_4^{-3}(DRP) measured at studied localities.

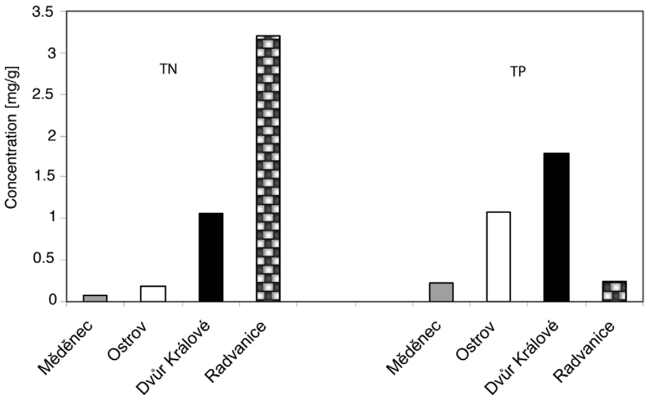

Fig. 3.2.3 Total concentrations of nitrogen and phosphorus at studied localities.

concentration of total nitrogen ranged between 0.08 mg/g in Měděnec and 3.2 mg/g in Radvanice. Concentration of total phosphorus was high in Ostrov (1.08 mg/g) and Dvůr Králové (1.8 mg/g). In Radvanice and Měděnec, measured concentrations were low (0.24 mg/g, 0.23 mg/g, respectively). Measured ammonification and nitrification rates showed that at localities where the rate of ammonification was higher, the rate of nitrification was low. The highest rate of ammonification was measured in Ostrov (0.067 µg/g·d). The highest rate of nitrification was measured in Radvanice (3.35 µg/g·d), this rate was many times higher than in other localities (Fig. 3.2.4). Studied localities differed in measured values of basal respiration and hydrolysis FDA (Fig. 3.2.5). In Měděnec and Ostrov these values were low in both cases of measured parameters. The lowest value of basal respiration was measured in Ostrov (0.66 µg C-CO_2/g·h), hydrolysis FDA was lowest in Měděnec (0.21 A/g·h). By contrast, in Dvůr Králové and Radvanice, high values of basal respiration and hydrolysis were detected. The highest value of basal respiration was measured in Radvanice (11.64 µg C-CO_2/g·h) some twenty times higher than in Ostrov. The highest hydrolysis FDA was detected in Dvůr Králové (0.36 A/g·h) and was more than ten times higher than in Měděnec. The concentrations of heavy metals illustrated the Radvanice locality as the most toxic-loaded site among the investigated sedimentation basins (Tab. 3.2.1). However, in the Dvůr Králové ash sedimentation basin the highest concentrations of Al and SO_4^{2-} were detected.

Table 3.2.1 The concentrations of heavy metals at the studied localities. (Highest values are highlited in bold-italics.)

	Měděnec	Ostrov	Dvůr Králové	Radvanice
Al [mg/g]	19.9	31.3	***36.5***	7.09
Fe [mg/g]	46.8	23.6	18.6	***77.8***
SO_4^- [mg/g]	1.08	9.69	***14.9***	10.8
Mn [mg/g]	0.42	0.3	0.31	***5.46***
Cu [mg/g]	0.04	0.19	0.23	***0.53***
Zn [mg/g]	0.06	0.08	0.17	***1.04***
Cd [mg/g]	0.0014	0.0015	0.0023	***0.0055***
Pb [mg/g]	0.017	0.023	0.062	***0.128***

DISCUSSION

Substrates of ash-slag deposits have been proved to have generally higher pH values. Their alkalinity is derived from the chemical qualities of deposits which contain high Mg, K and Ca concentrations (Townsend & Hodgson 1973). The pH values of ore sedimentation basins substrates is mainly influenced by the type of mineral originally mined and tends to be mostly acidic (Choi & Wali 1995). However, as gradually the acidic compounds are washed out from the upper layer of the substrate so pH values increase (Slavíková 1986). This could be the case of our sedimentation basin localities with higher pH/H_2O value. The higher pH could be connected with the relatively long time since mining termination – in Radvanice the ore-mining activities were terminated in 1965, in Měděnec in 1997. We assumed that the high conductivity level of the Dvůr Králové ash sedimentation locality could be connected with a regular deposition of ash-slag that brings diluted salts to the locality. The low concentrations of ammonium and nitrate ions in the Dvůr Králové and the Ostrov localities could be explained by the generally low amounts of nitrogen in ash-slag deposits (Kolář 1969) and the lower activity of soil microbiota in an unstable environment in still-active industrial sedimentation areas. On the other hand, high amounts of phosphate comes with ash-slag deposits (Kolář 1969). In Měděnec and Radvanice, concentration of ammonium and nitrate ions was higher and we can see that despite the high toxic metal concentrations in these localities, specific crust communities nevertheless developed. The biotic parameters of substrates at the investigated localities (basal respiration, hydrolysis FDA, ammonification and nitrification rates) indicated a relatively low activity of microbial communities in comparison with the literature records (Yuan et al. 2007; García-Gil et al. 2004; Boyle et al. 2007). The nitrification rate reflected substrate nutrient concentration at all the localities. In Radvanice there was the highest nitrification rate and a high initial concentration of NH_4^+. As there was no obvious limitation of any other nutrients or pH and the lowest concentrations of aluminium were measured, we can expect a well developed community of nitrifying bacteria. We assume that microbial activity at our localities is influenced mostly by non-availability of nutrients, phosphorus especially, in basic conditions. Phosphorus requires a pH between 6.0 and 7.0 and becomes chemically immobile outside this range, forming insoluble compounds with calcium (Ca) in calcareous soils. In addition, high concentrations of toxic metals could be also ascribed to low microbial acitivity. But, in conditions of pH higher than 7.0 toxic metals are non-available and constitute insoluble compounds. In conclusion, microbial activity of biological soil crusts of anthropogenic substrates is mostly influenced by low availability of nutrients and the unstable condition of ash-slag deposits. High concentrations of toxic metals in the studied localities are connected with mining history in Měděnec and Radvanice or with ash-slag chemical parameters, but in current conditions their influence is not as important.

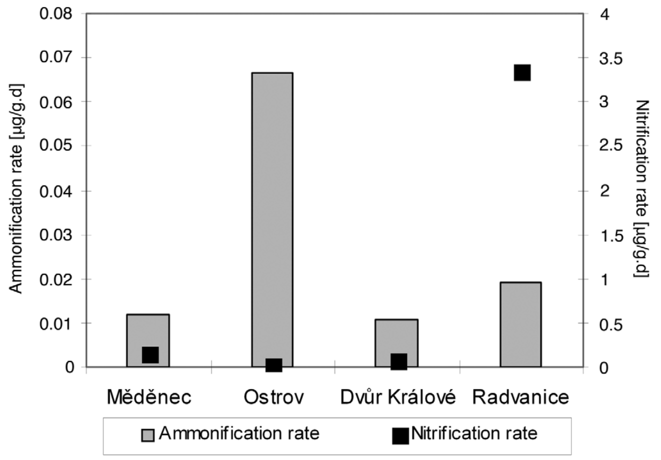

Fig. 3.2.4 The values of ammonification and nitrification rates at studied localities.

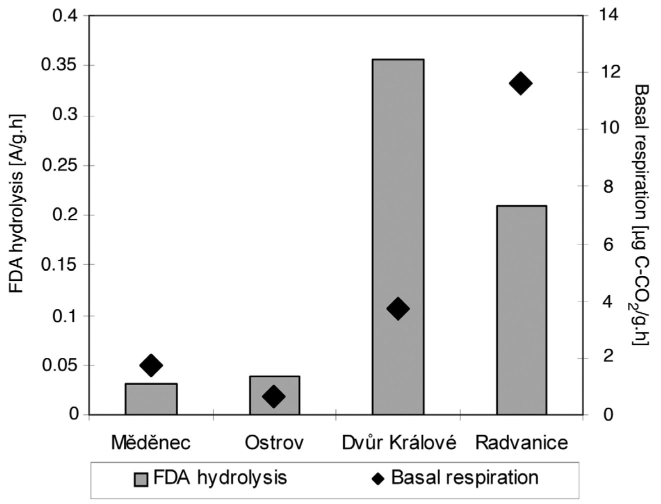

Fig. 3.2.5 The values of hydrolysis FDA and basal respiration at studied localities.

CONCLUSIONS

The anthropogenic substrates of ash-slag deposits and ore-sedimentation basins are characterized by high concentrations of toxic heavy metals, mostly higher pH values (but see chapter 4.5) and the generally low nutrient concentrations. We conclude that these characteristics lead to development of specific microbial communities that are able to sustain in these conditions and to diminution of vascular plant competition.