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Research Institute for Soil Science and Agricultural Chemistry, Hungarian Academy of Sciences
Herman O. u. 15, H-1022 Budapest, Hungary

Tibor Filep

Changes in DOC, DON content and DOC/DON ratio of acidic arenosol during two growing periods in pot experiments

ABSTRACT. Dissolved organic matter (DOM) participates in numerous processes in soils, e.g. mineral weathering and transport of nutrients and pollutants. Nevertheless, DOM can be regarded as an easily mineralizable nutrient source not only for plants, but also for microorganisms. The C and N content of DOM (dissolved organic carbon, DOC and dissolved organic nitrogen, DON) is also important parameter of soils from point of view carbon and nitrogen cycling. Changes in DOC and DON content, as well as DOC/DON ratio of an acidic Arenosol were investigated in a pot experiment during two growing periods using oat as indicator plant. Six soil samples were taken during the investigation: in May, June and July in 2000, and in 2001, respectively. The results can be summarized as follows: (i) The DOC concentration monotonous decreased in the first year from 274 mg/kg to 159 mg/kg, whereas in 2001 the highest DOC content was measured in June (362 mg/kg). (ii) There was a decrease in DON content of the soil: the initial value (5.9 mg/kg) declined to 4.4 mg/kg in June, and 5.0 mg/kg in July in 2000. Similar to this in 2001 in the beggenning of the growing period the DON concentration was 5.6 mg/kg which reduced to 3.8 mg/kg. (iii) The DOC/DON ratio was the highest in June in both years – 58 and 91, respectively. It may be because that the N mineralization rate the highest in June, too. In May and July the values of ratio were 45 and 35 in 2000, and 32 and 43 in 2001.

KEY WORDS: dissolved organic matter, DOC, DON, liming, pot experiment, acidic soil

Dissolved organic matter (DOM) participates in numerous processes in soils, e.g. mineral weathering and transport of nutrients and pollutants. Nevertheless, DOM can be regarded as an easily mineralizable nutrient source not only for plants, but also for microorganisms. The C and N content of DOM (dissolved organic carbon, DOC and dissolved organic nitrogen, DON) is also important parameter of soils from point of view carbon and nitrogen cycling.

Physical, chemical and biological factors and/or the combination of this control the DOM content of soil [Kalbitz et al. 2000]. Changes in soil pH by the use of liming materials result in physico-chemical changes and microbiological alteration in soils and these changes have an influence on DOM concentration. In addition to changes in DOM quantity, there may be an alteration in the composition of dissolved organic matter, e.g. the carbon and nitrogen content of that (dissolved organic carbon, DOC and dissolved organic nitrogen, DON) changes after liming.

The objectives of this study were: (i) to investigate the changes in DON, DOC concentrations and DOC/DON ratios in a pot experiment during two growing period.

METHODS

The soil used was a Luvic Arenosol (according to FAO classification) from Kisvárda. The samples were taken from the 0–20 cm layer, air-dried and passed through a 2 mm sieve. Soil pH was measured in aqueous suspension following 24 h sedimentation at room temperature. CEC was determined, using non--buffered $BaCl_2$-$MgCl_2$ solution [Houba et al. 1989]. Hydrolytic acidity (y_1) was determined by means of titration of 50 g soil extracted with Ca-acetate (pH 8.2). The total carbon and nitrogen content of the soil were analysed using an Elementar Vario EL CNS analyser based on the dry combustion method. The selected properties of the soil were: pH (1:2.5 soil/H_2O) 4.38; CEC 2.67 cmol (+)/kg; y_1 12.6; C 3.65 g/kg; N 0.47 g/kg; C/N 7.8. The 11 kg previously sieved (2 mm) soil was dispensed into each pot. The oat seeds (*Avena sativa* L.) were sown on 7th April 2000. Water content was set to 75% of the field water capacity. Water loss via evapotranspiration was determined by weighing and was replaced with deionized water. At the end of the first vegetation period the remainder pots were no watered till next year. In 2001, the oat seeds were sown 10th on April.

The experimental design was randomised complete block with 7 treatments and 9 replicates. The treatments applied are shown in Table 1. The liming materials have been mixed thoroughly with the soil. Lime doses were calculated from the hydrolytic acidity of the soil [Balogh 1992; Filep 1999]. Treatments were performed with the same amount 90.9 mg/kg soil of N, P and K (introduced in a mixture of NH_4NO_3, $NH_4H_2PO_4$ and KCl).

Table 1 Treatments of the experiment

Treatment	Lime doses g/kg	Remarks
Control	0	
C_1	1	calcite, a half lime dose calculated
C_2	2	calcite, lime dose calculated
C_3	3	calcite, 1.5 fold lime dose calculated
D_1	0.92	dolomite, a half lime dose calculated
D_2	1.84	dolomite, lime dose calculated
D_3	2.76	dolomite, 1.5 fold lime dose calculated

Soil samples (3-3 replicates) were taken three times during the growing period: 6, 10 and 15 weeks after planting, respectively. DOC and DON concentrations were measured in 0.01 M $CaCl_2$ extracts for 2 h with 1:10 soil:solution ratio [Jászberényi et al. 1994]. DOC was measured by ICP-OES. DON was determined by measuring the difference between total dissolved nitrogen and inorganic nitrogen (NO_3^-+NH_4^+) as described by Houba et al. [1994]. The dynamics of DOC and DON concentration was evaluated by the mean of treatments for the given sampling time.

RESULTS

The DOC concentration was 274 mg/kg at the beginning of the growing period in 2000. This value diclined to 159 mg/kg at the third sampling. Compering the value at 3rd sampling in 2000 to the 1st one for 2001, it is seen a slightly increase in DOC concentration. A considerable increase was measured at the next sampling. After this increase there was a decrease in DOC content of the soil again (Fig. 1).

We measured the highest DON concentrations (5.9 and 5.6 mg/kg, respectively) at the beginning of the vegetation period in both years investigated. The rest of part of the growing period the DON content decrease to a certain extent – from 3.8 mg/kg to 5.0 mg/kg DON (Fig. 2).

Similarity was found between the dynamics of DOC/DON ratio comparing 2000 with 2001. In both years, there was a peak of that ratio in the middle of the growing period (Fig. 3). The lowest values were get at the end of the plant life: 35 and 43, in 2000 and 2001, respectively.

Changes in DOC and DON content of the soil during the vegetation period were resulted in the effect of several physical, chemical and biological process. Changes in pH, ionic strength, microbial activity may cause alteration of that parameters with time.

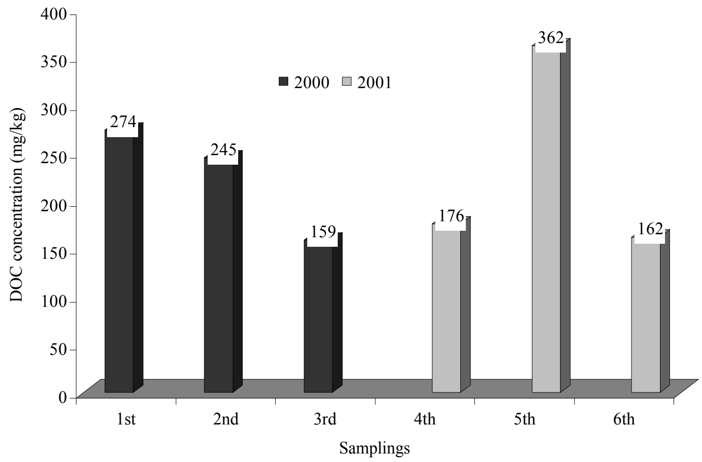

Figure 1. Changes in DOC concentrations of the soil during two vegetetion periods

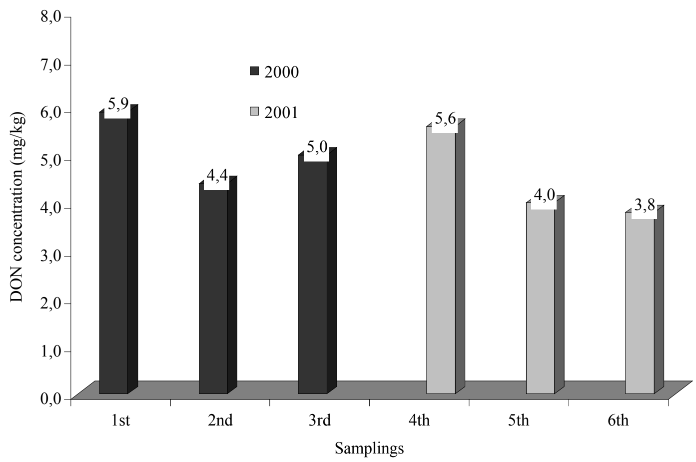

Figure 2. Changes in DON concentrations of the soil during two vegetetion periods

The main external factors influencing DOM (and DOC) solubility are pH and ionic strength [Tipping, Woof 1990]. Increasing pH, the net negative charge of the molecule increased, leading to a steric conformation change of that. At high pH, DOM molecules are in an expanded structure [Rice et al. 2000], because charges endeavour to situate themselves as far apart as possible. Owing to the expanded structure and the net negative charge, the molecule can be penetrated fully by water [Tombácz, Rice 1999], therefore it become hydrophilic.

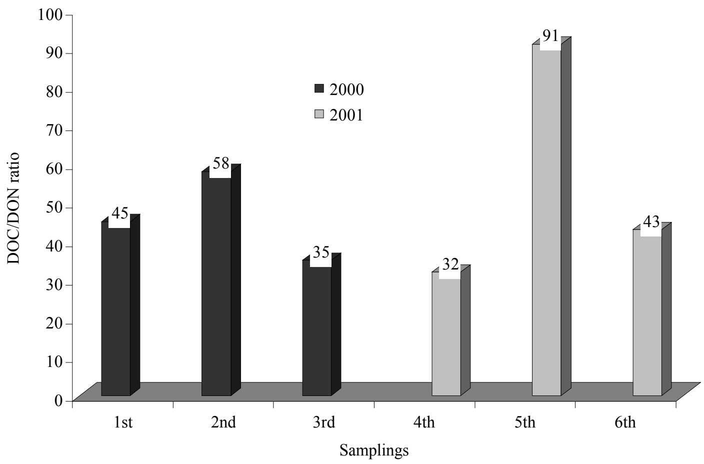

Figure 3. Changes in DOC/DON ratio during two vegetetion periods

It also can be taken account that changes in pH involve the alteration of adsorption/desorption conditions of DOC. In most studies [Jardine et al. 1989, Gu et al. 1994] the increased pH resulted in DOC desorption as a consequence of the decrease in positive charge of clay minerals and Al-, Fe-hydroxides.

In addition to these abiotic controls on DOC concentration, there has also been a biotic influence. The degradation rate of organic matter increased, as the microbial activity in the soil increased with increasing pH [Higashida, Takao 1986], which results in low molecular weight, water-soluble materials.

There was a difference in DON contents with time: the initial 5.9 and 5.6 mg/kg mean value declined to 4.4 and 4.0 mg/kg at the second samplings. The explanation of that substentied decrease is the initial addition of N fertiliser, which promotes the DON quantity in the soil [McDowell et al. 1998]. However, the ratio of DOC and DON did not change during the growing period, because there is no significant changes in pH during the growth (data not shown) and because changes in DOC/DON ratio are considerably pH dependent.

In literature there is some confusion, whether DON decay is faster than DOC? According to Qualls and Haines [1992] the DON degradation rate is not higher than that of DOC. In contrast to this, Scherrer et al. [1992] found that DON was more biodegradable than DOC. It seems to be the rate of the biodegradation processes differs in our study. Although the amount of dissolved organic matter increased, its N content decreased by degradation processes, which changed the C/N ratio in DOM.

In addition to above mention, there may be an other reason for an increase in the DOC/DON ratio. Liming increased the amount of nitrogen poor hydrophobic compounds more than the amount of nitrogen rich hydrophilic compounds [Andersson et al. 2000]. As hydrophobic compounds have greater selectivity to soil than hydrophilic ones [Andersson et al. 1999], this has caused an increase in the DOC/DON ratio.

CONCLUSIONS

1. Investigating dynamics of DOC and DON in an acidic soil, we can stated that it could be controlled by soil pH and several microbial factors.
2. The microbial control on dissolved organic fraction quality was clearly showed by changes in DOC to DON ratio of soil investigated.
3. The maximum of DOC/DON ratio get in the middle part of the growing period indicating that in this period would be a great microbial N fixation.

REFERENCES

Andersson S., Nilsson I., Saetre P. 2000. Leaching of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) in mor humus as affected by temperature and pH. Soil Biol. Biochem. 32, 1–10.

Andersson S., Nilsson I., Valeur, I. 1999. Influence of dolomitic lime on DOC and DON leaching in a forest soil. Biogeochemistry 47, 297–317.

Balogh I. 1992. Improving Mg supply with chemical melioration. In: The importance and source of magnesium. (Eds. T. Fazekas, B. Selmeczi and P. Stefanovits). Akadémiai Kiadó. Budapest, 113–115. (in Hungarian)

Filep G. 1999. Soil amelioration. (in Hungarian). In: Soil science. (Eds. P. Stefanovits, G. Filep and G. Füleky). Mezőgazda Kiadó. Budapest, 347–362.

Gu B., Schmitt J., Chen Z., Liang L., McCarthy J.F. 1994. Adsorption and desorption of natural organic matter on iron oxide: Mechanisms and models. Environ. Sci. Technol. 28, 38–46.

Higashida S., Takao K. 1986. Relations between soil microbial activity and soil properties in grassland. Soil Sci. Plant Nutr. 32, 587–597.

Houba V.J.G., Novozamsky I., Temminghoff E. 1994. Soil and plant analysis. Part 5A. Soil analysis procedures extraction with 0,01 M $CaCl_2$. Wageningen Agricultural University. Wageningen, 12–22.

Houba V.J.G., van der Lee J.J., Novozamsky I., Walinga I. 1989. Soil and Plant Analysis, a series of syllabi. Part 5. Wageningen Agricultural University. Wageningen, 6/1–6/7.

Jardine P.M., Weber N.L., McCarthy J.F. 1989. Mechanism of dissolved organic carbon adsorption on soil. Soil Sci. Soc. Am. J. 53, 1378–1385.

Jászberényi I., Loch J., Sarkadi J. 1994. Experiences with 0.01 M $CaCl_2$ as an extraction reagent for use as a soil testing procedure in Hungary. Commun. Soil Sci. Plant Anal. 25, 1771–1777.

McDowell W.H., Currie W.S., Aber J.D., Yano Y. 1998. Effects of chronic nitrogen amendments on production of dissolved organic carbon and nitrogen in forests soil. Water Air Soil Pollut. 105, 175–182.

Qualls R.G., Haines B.L. 1992. Biodegradability of dissolved organic matter in forest throughfall, soil solution and stream waters. Soil Sci. Soc. Am. J. 56, 578–586.

Rice J.A., Guetzloff T.F., Tombácz E. 2000. Investigations of humic materials aggregation with scattering methods. In: Humic substances. Versatile components of plants, soil and water. (Eds. E.A. Ghabbour and G. Davies). The Royal Society of Chemistry. Cambridge. 135–141.

Scherrer H.W., Werner W., Rossbach J. 1992. Effects of pretreatment of soil samples on N mineralization in incubation experiments. Biol. Fertil. Soils 14, 135–139.

Tipping E., Woof C. 1990. Humic substances in acid organic soils: Modeling their release to the soil solution in terms of humic charge. J. Soil Sci. 41, 573–586.

Tombácz E., Rice J.A. 1999. Changes of colloidal state in aqueous systems of humic acids. In: Understanding humic substances. Advanced methods, properties and applications. (Eds. E.A. Ghabbour and G. Davies). The Royal Society of Chemistry. Cambridge, 69–78.