The Release of Dissolved Organic Carbon in Paddy Soils Under Contrasting Redox Status

Jiajiang Lin, Yan He, Jiachun Shi, Xingmei Liu, and Jianming Xu

Abstract The objectives of this study were to examine the release of dissolved organic carbon (DOC) from soils under contrasting redox environments induced by various water content and application of different ionic electron acceptors and redox materials. Under flooded conditions, the release of DOC in soils was significantly decreased by addition of $FeCl_3$ and enhanced by addition of $NaNO_3$. Significant amount of DOC was produced only under constantly flooded conditions or alternate wetting and drying cycles. By contrast, the release of DOC when incubated aerobically was independent on soil water content. The addition of Na_2SO_4 at the concentration of 7 g kg^{-1} significantly inhibited DOC release. As soil redox potential gradually decreased with the addition of redox materials, more and more DOC were released at the end of incubation.

Keywords Dissolved organic carbon (DOC) • Water content • Oxidant/reductant • Redox potential

Introduction

The concentration of dissolved organic carbon (DOC) in soils is dependent on their release rates from soil organic matter and consumption by soil organisms. Previous studies indicated that anaerobic decomposition of soil organic matter is slower than aerobic (Minamikawa and Sakai 2007), while some other studies proved DOC release enhanced under flooded conditions. Also, there is now a large body of research exploring the effect of inorganic ion on the sorption of DOC (Monteith et al. 2007; Kerr and Eimers 2012). However, there is less information in the

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literature examining the effect of external oxidant and reductant on DOC concentrations under flooded conditions. The objectives of the study were to (1) compare the release of DOC from soils under aerobic and flooded anaerobic conditions regulated by different soil water content and (2) determine the effect of contrasting redox status on DOC release in soils when flooded by addition of different ionic electron acceptors in the form of Na_2SO_4, $NaNO_3$ and $FeCl_3$ and redox materials in the form of $K_3[Fe(CN)_6]$ and dithiothreitol (DTT).

Materials and Methods

Two soils utilized in this study were a clayey illitic thermic typic umbraqualf (soil 1) and a silty clay loam Argiustoll (soil 2). Soil samples were taken from the surface layer (0–20-cm depth). They were air-dried, ground and sieved less than 1 mm prior to use. The aerobically incubated soils were adjusted to 60% water hold capacity (WHC) by addition of Milli-Q water. The anaerobically incubated soils were flooded, with a 2-cm water layer covering the soil surface. Na_2SO_4 (2.8 g kg^{-1}), $NaNO_3$ (1.7 g kg^{-1}) and $FeCl_3$ (13.5 g kg^{-1}) were applied to study their effect on DOC release in two soils under flooded condition.

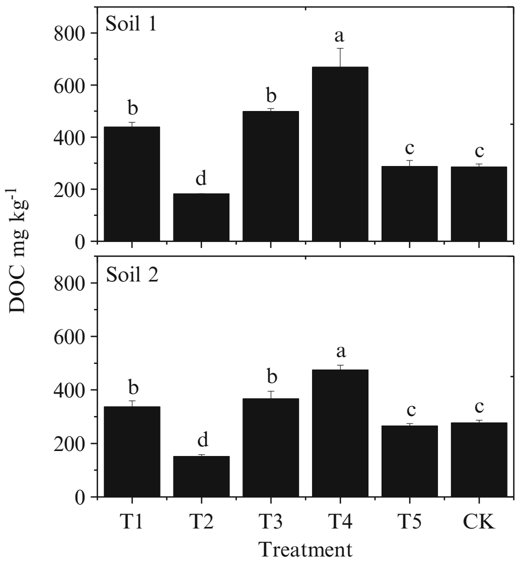
Soil 1, a typical paddy soil in China, had been chosen for further study. The effect of water content and the addition of different redox materials (including weak sulphate and strong $K_3[Fe(CN)_6]$ oxidants, and dithiothreitol (DTT) reductant) on DOC release in soil 1 was investigated. Five water content levels include 30% (W1), 50% (W2) and 100% (W3) WHC, as well as flooded (W4) and alternate flooded wetting and 50% WHC drying cycles (7-day (DW1) and 15-day (DW2) intervals). The addition levels of Na_2SO_4 were 0 g kg^{-1} (S0), 0.7 g kg^{-1} (S1), 2.8 g kg^{-1} (S2), 7.0 g kg^{-1} (S3) and 14 g kg^{-1} (S4). Another batch of initial redox potentials (0 mV (M1), 100 mV (M2) and 600 mV (M3)) was set up by addition of DTT or $K_3[Fe(CN)_6]$, respectively, and the treatment without addition (M0) was used as control. All treatments with three replicates were incubated at 25°C in the dark.

Results and Discussion

No changes in DOC concentration occurred when incubated aerobically with 60% WHC (T5) (Fig. 1). By contrast, the release of DOC in soils was significantly changed when incubated flooded (T1), which increased up to 50% and 20% as compared to initial concentration for soil 1 and soil 2, respectively.

The release of DOC under flooded conditions following the addition of Na_2SO_4, $NaNO_3$ and $FeCl_3$ was also shown in Fig. 1. In general, $FeCl_3$ addition significantly inhibited the release of DOC. The addition of $FeCl_3$ significantly decreased the soil pH and inhibited the reduction reaction in soils (data not shown), thereby inhibited

Fig. 1 DOC concentrations after 120 days incubated in two soils under contrasting redox status. CK, T1 and T5 refer to initial concentration, variation in control and 60% WHC; T2, T3 and T4 represent variation in presence of Fe (III), sulfate and nitrate, respectively. The same lower-case letters within incubation time indicate no significant difference, and different ones indicate significant difference at 5% level



the release of DOC. The addition of nitrate significantly increased the release of DOC. Nitrate is the first prior electron acceptor reduced when oxygen depletion under flooded condition. Nitrate-reducing bacteria may be activated by the addition of nitrate, using soil organic matter as electron donor and therefore further releasing DOC.

The DOC concentration decreased as the water content increased from 30 to 100% WHC. However, the differences were not statistically significant ($P < 0.05$). Incubation both when flooded and with short wetting-drying cycles (DW1) same were to produce more DOC than with long wetting-drying cycles (DW2). Although there was no significant relationship between DOC concentration and water content, the differences between flooded and unflooded conditions were significant. In addition, alternate wetting and drying cycles may facilitate decomposition of refractory materials.

The increased addition of sulphate from 7.0 g kg^{-1} (S3) to 14.0 g kg^{-1} (S4) decreased significantly the release of DOC (Fig. 2b). DOC release may be limited at a much higher redox potential condition after the application of sulphate than control treatment without application.

The release of DOC following the addition of strong oxidant ($K_3[Fe(CN)_6]$) and reductant (DTT) was shown in Fig. 2c. Both oxidant and reductant added increased the release of DOC significantly and decreased the soil redox potential at the end of experiment (data not shown). Even though the role of $K_3[Fe(CN)_6]$ for decreasing soil redox potential was unclear, our results indicated that the release of DOC was enhanced at low redox potential.

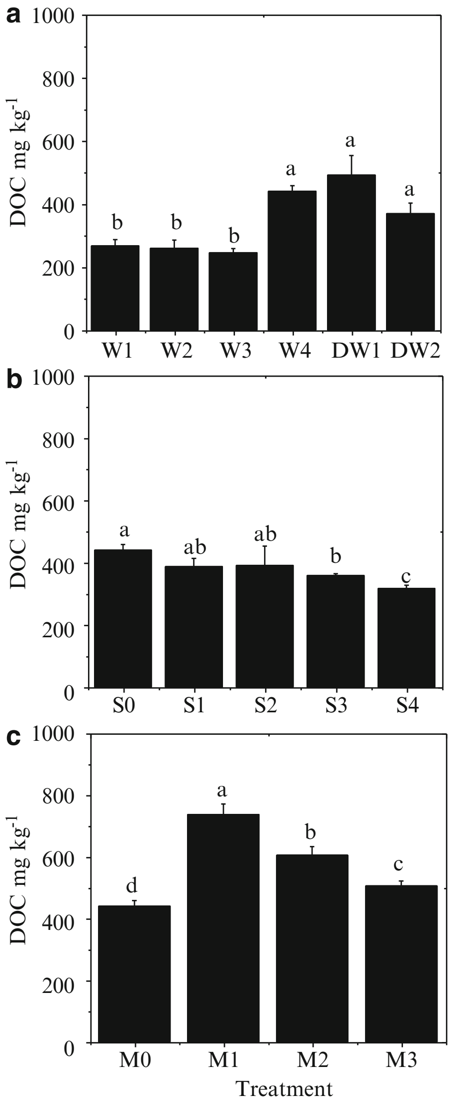


Fig. 2 Effect of water content (**a**) as well as addition of sulfate (**b**) and strong oxidant and reductant (**c**) on DOC concentrations after 120 days of incubation. The same lower-case letters within incubation time indicate no significant difference and different ones indicate significant difference at 5% level

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