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Environmental factors and dissolved organic carbon content in a Jinchuan peatland

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ABSTRACT

Dissolved organic carbon (DOC) is an important biologically active substrate for microorganisms that has major effects on the biogeochemical nutrients cycles. The loss of DOC through hydrological processes is a major outcome of the carbon content of wetlands being involved in the carbon flux. There has been very little research on the dynamics of DOC and the factors influencing it in wetland ecosystems, especially in the case of peatlands where the nutrient and pH levels are very low. Using field experiments and laboratory analyses, we studied the temporal (May to October) and spatial (0–20 and 20–40 cm depths) distribution of DOC and environmental factors in 5 typical herbaceous communities (*Phragmites australis–Carex*, *Carex–Deyeuxia angustifolia*, *Carex–Sphagnaceae*, *Carex schmidtii*, and *Carex tenuiflora*) in the Jinchuan peatland of Jilin province. A positive relationship between DOC and microorganism biomass carbon (MBC) was observed in both soil layers. The seasonal dynamics of DOC was similar for all the communities. The DOC concentration in the 0–20 cm depth range was lower during spring and autumn, and higher during the summer, while the DOC concentration in the 20–40 cm depth range decreased throughout the whole period. The DOC concentration in the 20–40 cm depth range was generally higher than in the 0–20 cm depth range (38.73–150.05 and 20.39–115.73 mg/L, respectively), but the difference was not significant in July and August, when the water level was high because of precipitation. DOC concentration in the *Carex–D. angustifolia* community (CD) was significantly higher than that of other communities, which may be due to strong human disturbance. The DOC concentration in the peatland was positively correlated with soil surface temperature, total nitrogen, phosphorous, and pH, and negatively correlated with water level, flooding frequency, and oxidation–reduction potential. The results of a stepwise regression analysis showed that the DOC content in the 0–20 cm depth range was mainly influenced by the surface soil temperature and oxidation–reduction potential, while in the 20–40 cm depth range, water quality factors, such as total nitrogen, were more important. The negative relationship between DOC and oxidation–reduction potential was not consistent with the results from other wetland types, probably because of extremely low pH conditions in this case. Significant negative correlations between DOC concentration and MBC content in both the depth ranges are suggestive of a trade-off. Our results point towards the environmental factors that determine the DOC content in the peatland, which therefore play an important role in the carbon cycle of peatlands.

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1. Introduction

The carbon cycle of peatland ecosystem plays an important role in the balance of global cycling of carbon, but its stability is influenced greatly by global change compared to other ecosystems, such as forests and grasslands [1]. There are generally five main carbon pools in peatland ecosystems: living organism and litter, peat and soil, CO_2 and CH_4, microbial biomass carbon and dissolved organic carbon [2]. Most of the carbon in these ecosystems exists in the form of organic carbon. The initial changes of soil carbon pool mainly occur in the labile organic carbon pool, which is easy to decompose and mineralize, such as soil microbial biomass carbon and dissolved organic carbon [3]. The dissolved organic carbon (DOC) is defined as organic carbon passing through a 0.45 mm-pore-diameter filter [4]. Although the proportion to total carbon is quite small, the dissolved organic carbon is both the important energy source for soil microbial activity and the main driver for biogeochemical cycles of carbon, nitrogen, phosphorus and other nutrient elements [5].

The DOC generally comes from the decomposition of plant litter, releasing exudates from plant roots, soil humic substance and microorganism, etc.[5]. The content and fluctuation of DOC are commonly affected by environmental factors (temperature, humidity and etc), biological factors (microorganism, vegetation and etc.) and their interactions [6]. Although the export of DOC through hydrological process is regarded as one of the main exportation of carbon releasing from wetland [7], which has an important effect on soil carbon flux [8], the studies reported on DOC dynamic change and key factors are limited in wetland ecosystem, especially in peatland [9–11]. The environment of peatland is different from that of other wetland types, with much lower nutrient and pH levels. These environmental factors may result in the different temporal and spatial distribution patterns of DOC in

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peatland. This study described the seasonal and the vertical variations of dissolve organic carbon in different peatland herbaceous communities and explored the influences of the biological and environmental factors on the content of DOC, based on the investigation in several typical herbaceous communities in Jinchuan peatland of Jilin province. Our research will provide some basic data to help understand the biogeochemical process of the carbon element in peatland ecosystem and its response to environmental change. Furthermore, there were some theoretical implications on illustrating and predicting the response of carbon sequestration function of peatland ecosystems to the global changes of climate and land utilization, as well as on improving peatland ecosystem service management.

2. Materials and methods

2.1. Study area

The field site is at the Jinchuan peatland (126°20′12.5″ E,42°20′55″ N) located in Longwan National Nature Reserve, Jilin Province, China. It belongs to the north temperate continental monsoon climate, with an average annual temperature of 4.1 °C, the highest annual average temperature of 5.1 °C and the lowest of 3.1 °C. The average yearly rainfall is 704.2 mm, 61% of which occurs in summer. The evaporation is 1276.1 mm. The annual average illumination is about 2550 h, frost-free period is 110–120 days. Peatlands in this area are waterlogged whole year, or seasonally in some sites. Because of the differences of micro-topography and human disturbance, there are apparent water level gradients in the peatlands, resulting in different communities dominated by different species. Five typical herbaceous communities (*Phragmites australis–Carex*,PC; *Carex–Deyeuxia angustifolia*,CD; *Carex–Sphagnaceae*,CS; *Carex schmidtii*,Cs; *Carex tenuiflora*,Ct)were chosen to study the temporal and spatial distribution of DOC content and environmental factors. The environmental conditions in different communities were shown in Table 1.

2.2. Research methods

From May to October in 2013, the ground temperature and water level were automatically recorded every 30 min by button thermometers (Dallas) and CTD-Diver, which were placed in the five typical herbaceous communities randomly.

Plant roots commonly distribute within 0–40 cm soil layer. Plant litter accumulates within 0–20 cm soil layer where the soil microbial decomposition actively occurs, and DOC could be leached from this layer into 20–40 cm soil layer where closely related to the changes of DOC content in this system. Therefore, water and soil samples were collected at the middle of each month from May to October to study the temporal and spatial distribution of DOC at depth of 0–20 cm and 20–40 cm, respectively.Three PVC tubes have been randomly set up in each community. Water samples were pumped by syringes from PVC tubes and kept in polyethylene plastic bottles transported in an incubator. All the water samples were stored at 4 °C in laboratory until several measurements below were finished. The contents of DOC were measured by Shimadzu TOC-VCPN after water samples were filtered with 0.45 μm filters. The pH value of water was measured by pH meter. Soil nitrogen and phosphorous contents were measured using potassium persulfate oxidation-molybdenum blue colorimetric method. The contents of microbial biomass carbon (MBC) of soil were measured by chloroform fumigation–extraction method [12]. Oxidation reduction potential of soil was measured using SX712 on the same day when samples were collected. In total, there were three randomly selected samples repeatedly measured three times for each community.

2.3. Data analysis

The data were detected the normalization and suitable data transformation was conducted to follow normal distribution if necessary. Analysis of variance (ANOVA) was used to determine whether there were significant differences of DOC contents among different communities, months and soil layers. Multiple comparisons were tested by LSD method with a significance level of 0.05. Linear correlation and regression analyses were used to determine the relationships of DOC with MBC and environmental factors, respectively. Due to the more or less interactions among environmental factors, stepwise regression analyses were further used to comparing the relative effect of each environmental factor. All the data were analyzed by SPSS19.0 software.

3. Results

3.1. The temporal and spatial distribution of DOC content

3.1.1. Seasonal dynamics of water DOC content in different communities

There were significant differences of DOC contents in different communities, as the DOC concentration in both of the two soil layers in *Carex–D. angustifolia* community (CD) were significantly higher than those of other communities, while there was no significant difference among other communities in most months (Tables 2 and 3).

The seasonal dynamics of DOC content was similar for all communities. However, the seasonal fluctuation of DOC content was different between 0–20 cm and 20–40 cm layers. In 0–20 cm depth, except the *Carex–Sphagnaceae* community (CS) with no significant seasonal fluctuation of DOC content, the DOC contents of other communities firstly increased then decreased, which was highest in July and lowest in October (Fig.1a, Table 2). In 20–40 cm depth, except *P. australis–Carex*

Table 1
Environmental conditions of different communities.

Community	*Phragmites australis–Carex* PC	*Carex–Deyeuxia angustifolia* CD	*Carex–Sphagnaceae* CS	*Carex schmidtii* Cs	*Carex tenuiflora* Ct
Location	Near the river	Near the farmland	Near the brush	The center of the peatland	Near the brush
Human disturbance	Weakness	Strength	Weakness	Weakness	Weakness
Water level(cm)[a]	10.40 ± 0.51	−1.13 ± 0.95	9.05 ± 0.32	8.36 ± 0.37	5.81 ± 0.38
Flooding frequency(%)[b]	95.45 ± 1.13	71.75 ± 4.38	100.00 ± 0.00	97.82 ± 0.55	93.30 ± 1.70
Water total nitrogen(mg/L)	1.38 ± 0.10	2.93 ± 0.31	1.09 ± 0.11	1.07 ± 0.14	0.98 ± 0.09
Water total phosphorous(μg/L)	50.19 ± 7.02	130.27 ± 19.89	49.10 ± 5.25	53.30 ± 8.82	31.96 ± 5.78
Water pH	6.53 ± 0.07	6.91 ± 0.03	6.27 ± 0.06	6.32 ± 0.05	6.25 ± 0.06
Temperature of soil surface(°C)	17.39 ± 0.70	16.74 ± 0.67	18.01 ± 0.75	17.23 ± 0.64	18.29 ± 0.75
Oxidation reduction potential	49.72 ± 4.19	−24.00 ± 5.80	26.14 ± 5.07	55.75 ± 4.96	46.08 ± 3.6
Soil carbon content(g/kg)	364.97 ± 11.27	304.82 ± 13.36	363.72 ± 3.89	373.14 ± 10.31	344.77 ± 9.44
Soil nitrogen content(g/kg)	17.99 ± 0.37	12.48 ± 0.47	13.17 ± 0.09	13.43 ± 0.09	14.56 ± 0.18
Soil phosphorous content(g/kg)	0.91 ± 0.02	1.27 ± 0.01	0.89 ± 0	0.85 ± 0.01	0.95 ± 0.01

[a] Using CTD Divers automatically recorded water level every 30 min. The monthly mean water level was calculated with the mean value of 30 days, and the negative value indicates the water level below soil surface.
[b] Flooding frequency (%) = (water record number / total number of records) × 100%.

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