CO_2 emission at transformation processes in peat

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The results of measurement of CO_2 emission at mineralization of peat of different botanical composition are presented. The CO_2 concentration was determined by the chemisorption method and the method of laser photoacoustic gas analysis. Some regularities revealed in the process of peat mineralization are discussed.

Introduction

The carbon cycle is a key problem in the biosphere science and in predicting consequences of the anthropogenic changes in the Earth's global climate. The fact that CO_2 content in the atmosphere increases has been established long ago. In the early 70s, when studying the causes of the growing CO_2 concentration in the atmosphere, it was assumed that this growth is the result of the anthropogenic impact on the continental biota, rather than the consequence of the progressively developing global industry.[1]

The carbon cycle is associated, first of all, with the photoautotrophic absorption of CO_2 by plants and microorganisms. This process annually extracts about 8% of the total carbon from the atmosphere (about 6×10^3 kg/year as indicated in Ref. 2). Almost the same amount of carbon comes back due to the destruction of the organic matter.

Under conditions of increasing content of carbon in the atmosphere, the most valuable biogeocoenoses are those that are capable of absorbing the largest amounts while returning the smallest amounts of CO_2. By accumulation of the organic carbon per unit area, the ecosystems of Russia can be ordered as follows: marshes, steppes, forests.[1] Therefore, growing marshes form a unique ecological system in the land biota, because they fix atmospheric CO_2 for a long time.

According to numerous data (see for example, Ref. 3), the process of marsh formation in the Western-Siberian region is still in progress. Thus, according to Ref. 4, the rate of carbon increase in the peat of the Western Siberia varies from 15 to 65 g/m^2 an year, what gives the annual accumulation of 5 to 20 million ton of carbon in peat bogs. At the same time, it is known that drainage of peat bogs on the European territory of Russia results in the annual loss of 34 million ton of carbon.[5] So, reclamation of peat bogs in Siberia possessing 39% of the world peat affects the current ecological situation not only in the Western Siberia, but in the Earth's biosphere as a whole.

The CO_2 emission into the atmosphere from peat-bog ecosystems is governed by intensification of mineralization processes of the organic matter in peat deposits after drainage. No investigations aimed at predicting the peat transformation under natural conditions depending on the bog properties, genesis, and exploitation conditions have been carried out so far on the territory of the Western Siberia. So, the contribution of bogs of the Western Siberia to the increasing CO_2 concentration in the atmosphere cannot be evaluated. The necessity and importance of such evaluation were emphasized in Ref. 6.

The process of organic matter transformation is very complicated. Besides, each layer of a peat deposit is characterized by its own kinetics of mineralization of the organic matter because of different chemical composition. The integral indicator of the intensity of transformation processes in peat is emission of carbon dioxide from the surface of a peat deposit or from components of the peat deposit.

This paper is aimed at the development of the technique for recording the kinetics of mineralization processes in peat of different botanical composition based on the carbon dioxide emission from peat. Another aim is intercalibration of two methods for measurement of the CO_2 concentration.

Objects of the study and investigation techniques

For the experiment we have taken 24 peat samples from representative peat deposits in the natural state from most peat bog areas of the Western Siberia. The samples were studied under laboratory conditions at the temperature of 20°C and natural humidity. Experiments were repeated three times. The duration of the experiment (16 days) was chosen based for the following reasons. The *in situ* rate of mineralization of the peat organic matter to CO_2 in a peat deposit under the action of microflora (bacteria, actinomyces, fungi)

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is low. That is why we have accepted that under optimal ambient conditions (humidity, temperature, illumination) realized in the experiments the rate of mineralization is significantly increased. So the model experiment can be conducted during short time.

The carbon dioxide outflow from peat samples was determined by two methods: the method of chemisorption which was initially developed to study the kinetics of mineralization of the organic matter in mineral soil[7] and the method of laser photoacoustic gas analysis.[8]

In the case of application of the former method, the weighted samples of humid peat were put in a pre-calibrated open gas-measuring system with a 0.2 n KOH absorber. After certain exposure time, the amount of carbon dioxide diffusing to the absorber surface was determined by titration. The amount of produced CO_2 was calculated by the formula:

$$Q_p = Q_{ex} + (Q_{ex} - Q_r \times K \times K_2)K_2/K \times K_2 - K_1,$$

where Q_p is the amount of CO_2 produced during the exposure time, in mg; Q_{ex} the amount of CO_2 diffusing to the absorber surface in the experimental measurement, in mg; Q_r is the amount of CO_2 diffusing to the absorber surface in the reference measurement, in mg; K is the ratio of the CO_2 diffusion flow through the pipe of the absorbing vessel to the total diffusion flow of CO_2 in the reference measurement system; K_1 is the ratio of the CO_2 diffusion flow in the measurement system to the CO_2 flow in the reference measurement system; K_2 is the ratio of the CO_2 diffusion flows through the pipe of the absorbing vessel in the experimental and reference measurement systems, respectively.

In the case of using the laser photoacoustic gas analysis, the weighted samples of raw peat were placed in hermetically sealed chambers. After some exposure time, the air samples from these chambers were sequentially analyzed in the measurement cell of the photoacoustic detector at the CO_2-laser wavelength of 10.591 μm. Prior to measurements the cell was pumped out to vacuum. The concentration C of carbon dioxide in air samples was determined from the experimentally measured amplitude U of the electric signal of the photoacoustic detector and the power W of the laser source:

$$C = K(U/W),$$

where K is the calibration coefficient of the detector, in (ppm·W)/V or (mg·W)/(m^3·V).

In order to standardize the results obtained and to make them comparable for all kinds of peat, the concentration of produced CO_2 determined by both methods was normalized to the unit mass of dry peat and unit time.

For a comparison of the methods used, some their characteristics are presented in the Table 1.

Table 1

Characteristic	Chemisorption method	Photoacoustic method
Detection limit, ppm	277	7.4
Measurement time	Measurements are conducted at 10-40% saturation of the absorber (0.5–24 hours)	Results are obtained in real time
Error, in %	30	10

Results and discussion

To reveal common regularities in the mineralization of the organic matter in peat, investigations for all kinds of peat were performed in open gasometric systems according to the chemisorption technique. Earlier we have studied[9] the accumulation of CO_2 in different kinds of Western-Siberian peat. It was found that by the value of CO_2 accumulation in the process of bog peat accumulation the peats can be ordered as: sphagnum peat of bog hollows > complex high bog peat > sphagnum-fuscum peat > sphagnum-scheuchzeria > sphagnum-cotton grass peat > scheuchzeria peat > cotton grass peat. Fen peats can be ordered as: hypnum > sedge > sedge-hypnum > marsh trefoil > woody > woody sedge peat. In the current experiments the cumulative emission of CO_2 from peat of these kinds for 16 days of the experiment was measured; it was respectively 133, 106, 101, 74, 73, 63, and 46 mg for the bog peats and 198, 144, 125, 107, 76, and 63 mg for the fen peats.

The process of mineralization of some kinds of fen peat is described by a simple exponential function:

$$I_{CO_2} = I^0_{CO_2} \exp(-kt),$$

where $I^0_{CO_2}$ is the intensity of the CO_2 emission at the beginning of the experiment; k is the mineralization constant; t is the duration of the experiment. Earlier such dependence was obtained for describing decomposition of organic matter in soils.[10] At the same time, in bog peat and some kinds of fen peat the kinetics is of sinusoidal character, so further investigations are needed to describe it.

To check the regularities revealed we have conducted photoacoustic measurements of the CO_2 emission. In the measurement series, two of 24 peat samples were used: bog fuscum peat and fen sedge peat. The mean intensity of mineralization of the organic matter in these two samples measured by both methods is shown in the Figure 1.

A common regularity is seen in the kinetics of CO_2 emission obtained by both methods used. Thus, the intensity of mineralization increases at the beginning of the experiment and gradually decreases toward its end. The sinusoidal dependence is also observed in the bog

peat when measuring by both methods; in the fen peat such a regularity is detected only when measuring by the photoacoustic method of gas analysis. It should also be noted that the intensity of CO_2 production measured by the chemisorption method is significantly higher and five to eight times exceeds the values obtained using optical gas analysis. This discrepancy can be caused by the fact that the measurements of the kinetics of CO_2 emission from peat were conducted under different conditions for the two methods.

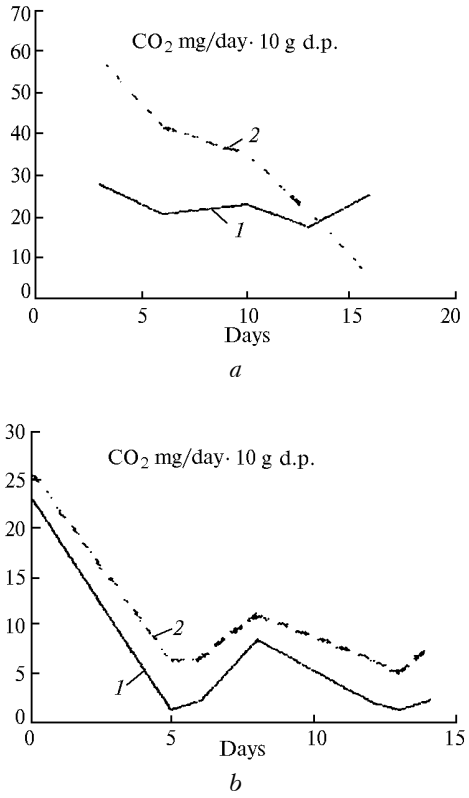

Fig. 1. Kinetics of CO_2 emission from peat measured by the chemisorption (*a*) and photoacoustic (*b*) methods: bog peat (*1*) and fen peat (*2*) peat.

Peat was sampled during the field campaigns in 1992–1993, and until the experiment was started the samples were stored in a peat storehouse under conditions maximally close to the natural ones. In such a case, we can say that the strict anaerobic requirements were not fully met. The experiments with calibrated volumes were performed earlier. So, then used samples were less transformed. It is just this fact that is most likely represented by the discrepancy in the results of measurements of the CO_2 emission. However, the splash of microbiological activity which manifested itself in the increase of the CO_2 emission at the beginning of the measurement cycle was recorded by both methods. So, more experiments are needed before the final conclusion on the causes of the discrepancy in absolute values of the CO_2 emission can be drawn.

Thus, the experiments on studying the kinetics of CO_2 emission conducted with the use of two independent methods have allowed us to study the CO_2 emission from peat of different botanical composition, supported the regularities of transformation of the organic matter in peat, and demonstrated the applicability of both these methods. The goal of our further investigations is to develop a model of transformation of the organic matter in peat to predict the destruction of peat components of a peat deposit. To do this, we should continue detailed study of the dynamics of organic matter transformation in Western-Siberian peat based on the model laboratory experiments. Thus, we could predict the CO_2 inflow into the atmosphere from peat bogs of the Western Siberia in the case of their reclamation based on the rate of mineralization of peat of different chemical composition under anaerobic and aerobic conditions.

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