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METHANE EMISSION FROM PEAT SOILS OF THE ŁĘCZYŃSKO-WŁODAWSKIE LAKE DISTRICT UNDER FLOODED CONDITIONS

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Abstract. The aim of the study was to investigate the rate of methane emission from natural and drained peat soils, flooded with water in model experiment for predicting gas emission changes during renaturalization process. The subjects of study were peat soils taken from the Łęczyńsko-Włodawskie Lake District. The laboratory incubation was conducted in darkness for 126 days at room temperature. Each week the redox potential (Eh) and the pH of the collected solutions were measured, and gaseous samples were drawn in which CH_4 and CO_2 concentrations were tested. The maximal emission of CH_4 (35.27 mg CH_4 m^{-2} d^{-1}) was observed for the drained peat soil after 76 days of incubation at Eh – 66.3 mV. Significant emission of CH_4 was recorded after 34 days, from drained peat soil (14.77 mg CH_4 m^{-2} d^{-1}) and after 62 days (7.53 mg CH_4 m^{-2} d^{-1}) from natural peat soil. Significant correlation between methane emission and redox potential was found for both natural and drained peat soil.

Keywords: peat soils, methane emission

INTRODUCTION

To restore the original air-water conditions of the soils of hydrogenic areas, numerous projects of soil water logging have been created in recent years. Temporal soil flooding resulted in the formation of greenhouse gases such as CO_2 and CH_4. Methane is an important greenhouse gas thought to contribute to the global warming. On a global scale the contribution amounts to roughly 2 per cent of the total equivalent emission rate of all greenhouse gases [1,2,4,5,11].

During the past 200 years the methane concentration increased dramatically because of imbalance between global sources and sinks. Methane concentration reached 1.72 ppmV in 1994 with an average annual increase of 0.6% [6,9].

Annually, about 540 Tg of CH_4 is emitted to the atmosphere from the biosphere. Methane production from soil is associated with wetlands (natural wetlands emit 100-200 Tg $year^{-1}$), paddy rice production, termites and landfills [8].

Peatlands are generally a source of CH_4 which is produced by methanogenesis in the peat profile. Because of their extensive coverage, peatlands and other wetlands play a significant role in the regulation of the atmospheric concentration of these gases [10].

Methane emissions from wetlands are highly variable and are determined by complex interactions among the chemical, physical, and biological properties of the local environment [7]. Methane efflux from peatland is a function of the rates of CH_4 production and consumption in the different parts of the profile, as well as transport mechanism to the atmosphere [10]. The main controllers of methane emission from peatlands are water level, temperature, redox potential and the availability of substrate for fermentation. The level of reduction in submerged soils is normally measured by determining Eh. Oxidized soils have a characteristic Eh in the range of +700 mV, whereas flooded soil exhibit Eh as low as –300 mV [7].

The aim of the study was to investigate the rate of methane emission from peat soils (natural and drained) irrigated with water in a model experiment for the prediction of gas emission changes during peat soils renaturalization process.

MATERIALS AND METHODS

Peat soils were collected in June 1999 on the territory of the Łęczyńsko-Włodawskie Lake District in the central part of eastern Poland:

Natural peat soil. The natural peat soil from which the samples were collected is situated in the territory of the Poleski National Park, in the vicinity of the reserve of "Lake Moszne." It is a high peat-bog with organic matter up to 2.5 m thick. The bottom constitutes a thin layer of peated gyttja which passes to sedge-moss peat. The surface of the peat-bog, abundant in peat holes, is covered by pine wood with birches, black alders and trembling poplars.

Drained peat soil. The drained peat from which the samples were collected is situated near the village of Pieszowola. Melioration of low peat-bog, performed in 1968, resulted in a decline of the ground water table. Peat-bogs have been transformed into postpog soils, which caused a decrease of their ecological function. Now the peats are used as meadows.

The peat soil samples were transported to the laboratory and placed in plastic containers of 5 dm^3 capacity. A schematic of the incubation containers is presented in Figure 1. In each of the containers the following elements were installed: 3 platinum electrodes to measure the redox potential and an agar bridge

closing the circuit during Eh measurements. Rubber membranes fixed in the covers of the containers were used to draw gaseous samples. To each container 500 ml water was added and the containers were tightly closed. The incubation was conducted in darkness for 126 days at room temperature. Each week redox potential (Eh) was measured and the drawing of gaseous samples was performed.

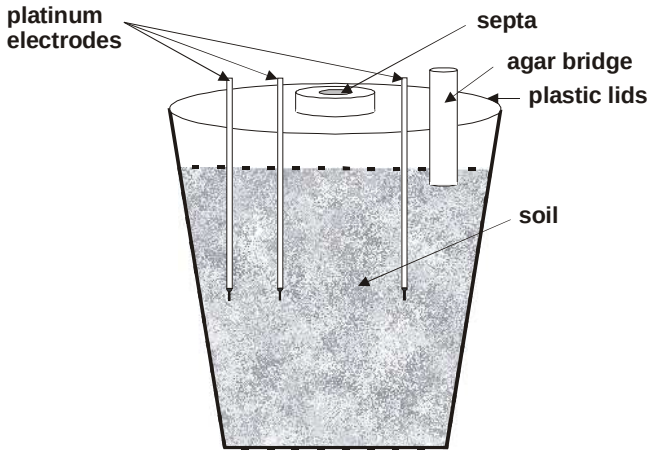

Fig. 1. Schematic of the incubation containers

Redox potential (Eh) was measured with platinum electrodes in relation to the calomel electrode used as a reference electrode (placed in the agar bridge).

Gaseous samples were analyzed by means of a GC14 gas chromatograph (Shimadzu) equipped with thermal conductivity (TCD) and flame ionization (FID) detectors. In the gaseous samples CH_4 and CO_2 concentrations were determined.

RESULTS AND DISCUSSION

The composition of analyzed air released from flooded soils changed significantly with time. The dynamics of CH_4 emission during the incubation is presented in Figure 2. Just after the first days of flooding, the concentration of CH_4 in the headspace air of the natural and drained peat soils was found on the level of dozens ppm. In Chang and Yang [3] study, the atmospheric methane concentration in Kang-du wetland, Kang-nan wetland and Kang-nan lake area (Taiwan) was 0.8-2.7, 0.7-1.6 and 0.8-1.7 ppm, respectively. During the subsequent days of drained peat incubation, the amount of CH_4 increased, and after 76 days reached the maximum emission of 35.27 mg CH_4 m^{-2} d^{-1}. After the maximum, the

CH_4 emission decreased. Experiments with natural peat soil showed a significant increase of CH_4 emission (7.53 mg CH_4 m^{-2} d^{-1}) after 62 days. After the next ten days, the methane emission increased up to 29.63 mg CH_4 m^{-2} d^{-1} and remained at this level to the end of the incubation. Le Mer and Roger [8] found that methane emissions by cultivated and natural wetlands was a median on a level lower than 10 mg CH_4 m^{-2} h^{-1}. Average methane emission from wetlands in Taiwan was established as 1.82, 0.14 and 0.23 mg m^{-2} h^{-1} in Kang-du wetland, Kang-nan wetland and Kang-nan lake area, respectively [3]. Significant CH_4 emission was recorded after 34 days of incubation (1.22 mg kg^{-1}) in drained peat and after 62 days of incubation (0.72 mg kg^{-1}) in natural peat.

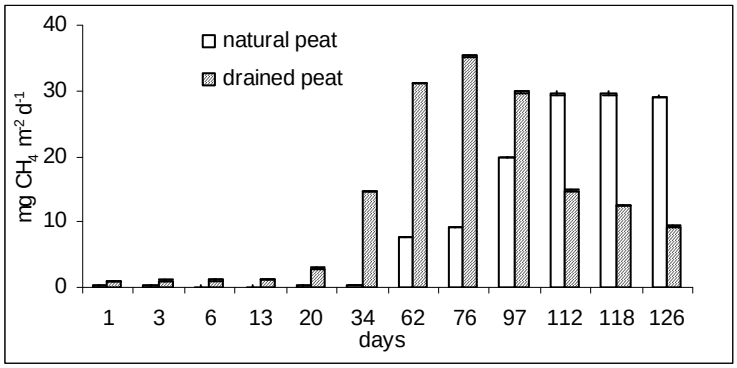

Fig. 2. The emission of CH_4 from natural and drained peats under flooding

The emission of CO_2 from the soil in both the peat soils is presented in Figure 3. The maximal emission was observed in natural and drained peat soils (103.61 mg CO_2 m^{-2} d^{-1} and 114.92 mg CO_2 m^{-2} d^{-1}, respectively) after 2 days of incubation. Later, the CO_2 emission was decreasing and after 126 days of incubation the CO_2 emission in natural peat soil reached 8.78 mg CO_2 m^{-2} d^{-1} and 7.09 mg CO_2 m^{-2} d^{-1} in drained peat soil.

Relation between redox potential and methane emission for natural peat is presented in Figure 4, and in Figure 5 for drained peat. During the incubation, soil redox potential decreased from 176 mV to –73 mV (natural peat) and from 142 mV to –146 mV (drained peat). Significant emission of methane was observed at Eh level of about – 60 mV and about Eh – 0 mV, respectively, for natural and drained peat soil. Stępniewski and Stępniewska [12] affirmed that the beginning of CH_4 production in a soil starts below 50 mV, with maximum emission at the level of –150 mV. Kludze and DeLaune [7] observed maximum CH_4 production at –300 mV.

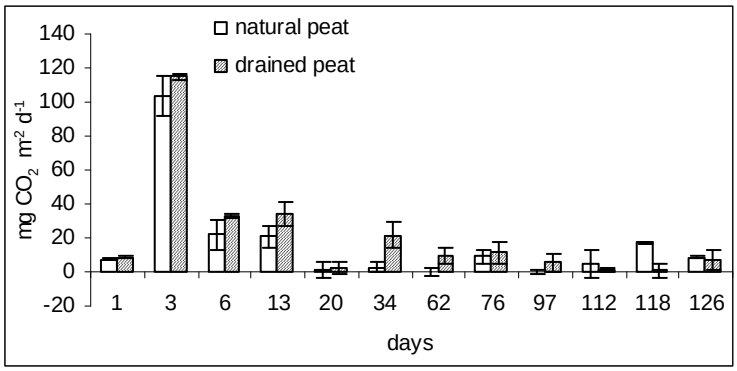

Fig. 3. The dynamics of respiration in natural and drained peats under flood conditions

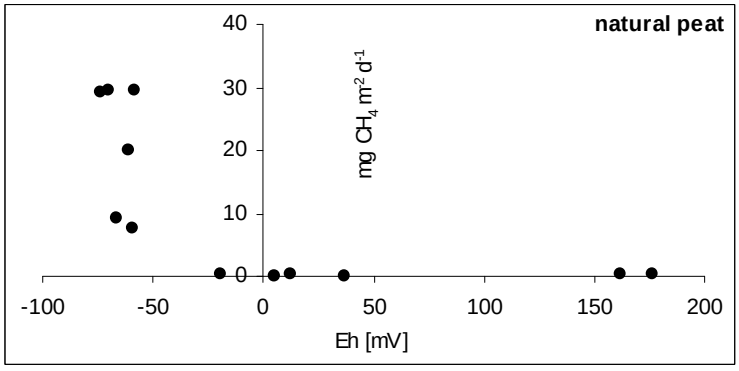

Fig. 4. Emission of CH_4 as a function of Eh values in natural peat under flood conditions

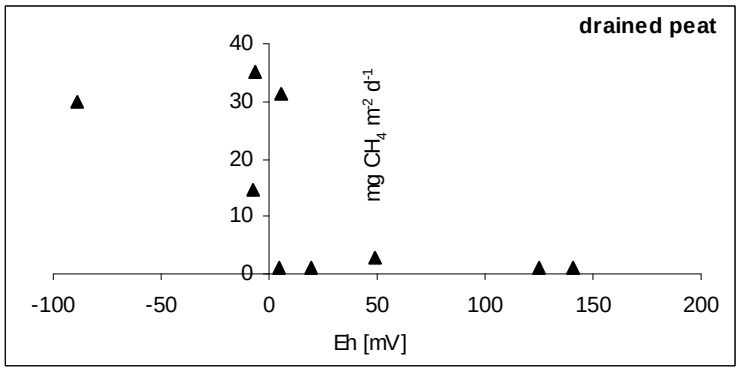

Fig. 5. Emission of CH_4 as a function of Eh values in drained peat under flood conditions

At the beginning of the incubation, the reaction of the soil solutions studied oscillated at the levels of pH 5 and pH 7 for natural and drained peat, respectively. In the course of the study, slight fluctuations in the reaction were observed with a declining tendency to around 1 at the end of the incubation. Zehnder [13] showed that the optimum pH level for the activity of methanogenic bacteria is between 6.8 and 7.4, while the production rates decrease sharply at pH values of about 6.5.

CONCLUSIONS

1. Maximal emission of CH_4 (35.27 mg CH_4 m^{-2} d^{-1}) from the drained peat soil was observed after 76 days of incubation at Eh –66.3 mV.
2. Experiments with natural peat soil showed an increase of CH_4 emission to the level of about 29 mg CH_4 m^{-2} d^{-1} after 112 days.
3. Significant emission of CH_4 from drained peat soil (14.77 mg CH_4 m^{-2} d^{-1}) was recorded after 34 days of incubation, and after 62 days incubation in the case of natural peat soil (7.53 mg CH_4 m^{-2} d^{-1}).
4. Significant correlation between methane emission and redox potential was found for both natural and drained peat soil.

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EMISJA METANU Z GLEB TORFOWYCH POJEZIERZA ŁĘCZYŃSKO-WŁODAWSKIEGO W WARUNKACH CAŁKOWITEGO ZALANIA WODĄ

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Streszczenie. Celem pracy było zbadanie emisji metanu z naturalnych i drenowanych gleb torfowych, w eksperymencie modelowym, po zalaniu wodą. Gleby torfowe zostały pobrane z Pojezierza Łęczyńsko-Włodawskiego. Inkubacja była prowadzona w laboratorium, w ciemności, w temperaturze pokojowej, przez 126 dni. Każdego tygodnia mierzono potencjał redox inkubowanych gleb torfowych, pH pobranych roztworów oraz pobierano próbki gazowe, w których określano zawartość CH_4 i CO_2. Znaczącą emisję metanu odnotowano po 34 dniach z gleb torfowych drenowanych (14,77 mg CH_4 $m^{-2} \cdot d^{-1}$) i po 62 dniach z gleb torfowych naturalnych (7,53 mg CH_4 $m^{-2} \cdot d^{-1}$). Maksymalną emisję CH_4 (35,27 mg CH_4 $m^{-2} \cdot d^{-1}$) zaobserwowano z gleb torfowych drenowanych po 76 dniach inkubacji, przy Eh – 66,3 mV. Korelacje pomiędzy emisją metanu a potencjałem redox obserwowano zarówno dla gleb torfowych naturalnych jak i drenowanych.

Słowa kluczowe: gleby torfowe, emisja metanu