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Research Article

INFLUENCE OF PLANT COMPOSITION ON METHANE EMISION FROM MOSZNE PEATLAND

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ABSTRACT
Methane is the second most important man-made greenhouse gas after carbon dioxide. For more than the last 20 years the increase of the rate of CH_4 emission has been varying dramatically each year. This trend is common worldwide, though in different parts of the world unevenly intense, conditioned by the amount of emissions from natural and anthropogenic sources. Peatland ecosystems are one of the natural methane emitters, responsible for about 24% of the total CH_4 emissions. Methane emission from wetlands is the balance between the processes of methanogenesis and methanotrophy with an active role of wetlands plants composition. Participation of vegetation in the reduction the emissions by 30-35% was confirmed. Association of methanotrophic bacteria with plants has been already recognized by Raghoebarsing and colleagues, who showed that methanotrophic bacteria, as endosymbionts and epibionts, live both inside and outside the cells of *Sphagnum* sp.
The main aim of this study was to estimate methane emissions from Moszne peatland, dominated by: *Sphagnum* sp., *Eriophorum vaginatum, Carex nigra* and *Vaccinium uliginosum*.

Keywords: methane, methanotrophic bacteria, peatland vegetation.

INTRODUCTION

Wetlands, as the main natural source of atmospheric methane, contribute to the increase in the greenhouse effect. It is estimated that wetlands emit 145 Tg CH_4 annually, which corresponds to about 10-30% of the total emission from all sources On the other hand, they also effectively capture CH_4 and retain CO_2 formed after CH_4 oxidation and accumulate as a product of photosynthesis [1, 2].

Methane emissions from peatlands result from the imbalance between the processes of methanogenesis (forming of methane) and methanotrophy (oxidation of methane) [3]. Although CH_4 is produced by methanogens under anaerobic conditions, plant cover can influence this gas production by its consumption and transport in wetland ecosystems [4]. Plants may inhibit methane production by oxygen transport to the rhizosphere or promote methane emission by means of gas exchange through a micro- and macrodiffusion. In some ecosystems plants play a predominant role in controlling the quantities of methane emitted to the atmosphere. It has been reported that 55–85% of methane emissions from peatlands are plant-mediated [5, 6].

Particular attention should be paid to the marshland vascular plants, due to high methanogenic potential of their habitat. Recently, it was found that they play a dual role in methane cycling. They not only stimulate methane emission to the atmosphere, but may also contribute to hampering this process by providing oxygen, through internal transport to the subsurface, where CH_4 oxidation occurs in the rhizosphere [7]. In addition, methanotrophic bacteria present inside the plant tissue may utilize methane flowing through the plant as a source of carbon and energy.

Previously, it has been shown that methane emissions are lower in areas that are covered by *Sphagnum*. Raghoebarsing et al. have shown that this is caused by the methanotrophic bacteria, which live inside (entophytes) or on submerged *Sphagnum* (epiphytes), with especially high methane oxidation rates in submerged *Sphagnum cuspidatum*. It was confirmed that *Sphagnum* peat forming species are involved in the reduction of CH_4 emissions by about 30-35% [8].

The associated methanotrophic bacteria have the ability to oxidise not only methane, but also other hydrocarbons. Due to this feature, they may also find an application in bioremediation. An enzyme found in methanotrophs responsible for oxidation of CH_4 is methane monooksygenase (MMO), which catalyses the conversation of methane to methanol in the first step of methane oxidation to CO_2. MMO occurs in two forms: a membrane-bound, particulate (pMMO) and a cytoplasmic soluble (sMMO). The distinct expression of the two enzymes is dependent on the availability of copper ions in the growth medium. In case of high enough copper amount available to the bacterial cells a pMMO is synthesized, but when copper availability is limited sMMO is produced by some methanotrophs [9].

This work is an attempt to estimate methane emissions from Moszne peatland in which autochthonous flora: *Sphagnum* sp., *Eriophorum vaginatum*, *Carex nigra*, and *Vaccinium uliginosum* dominate.

MATERIALS AND METHODS

The research was conducted in Moszne transitional moor (*Sphagno-Caricetum rostratae*), located in the north-western part of the Poleski National Park (PPN) (51° 23' N, 23° 63' E) (Fig. 1) situated in the province of Lublin, in the Polish part of Polesie. PPN is a part of the West Polesie Biosphere Reserve, protected under the Ramsar convention as an important wetland site with distinguish values of nature.

Characteristic composition plant cover of Moszne peatland was determined on the basis of the phytosociological analyses that were performed according to the criterion of phytocenose homogeneity [10]. The diversity of plant species (accounting the herb and moss layers) was based on a quantitative surface coverage in 10-point Braun-Blanquet scale. Then, within the previously selected for photosociological research vegetation patches, randomly marked out the research points dominated by: *Sphagnum* sp., *Eriophorum vaginatum*, *Carex nigra*, and *Vaccinium uliginosum* has been selected.

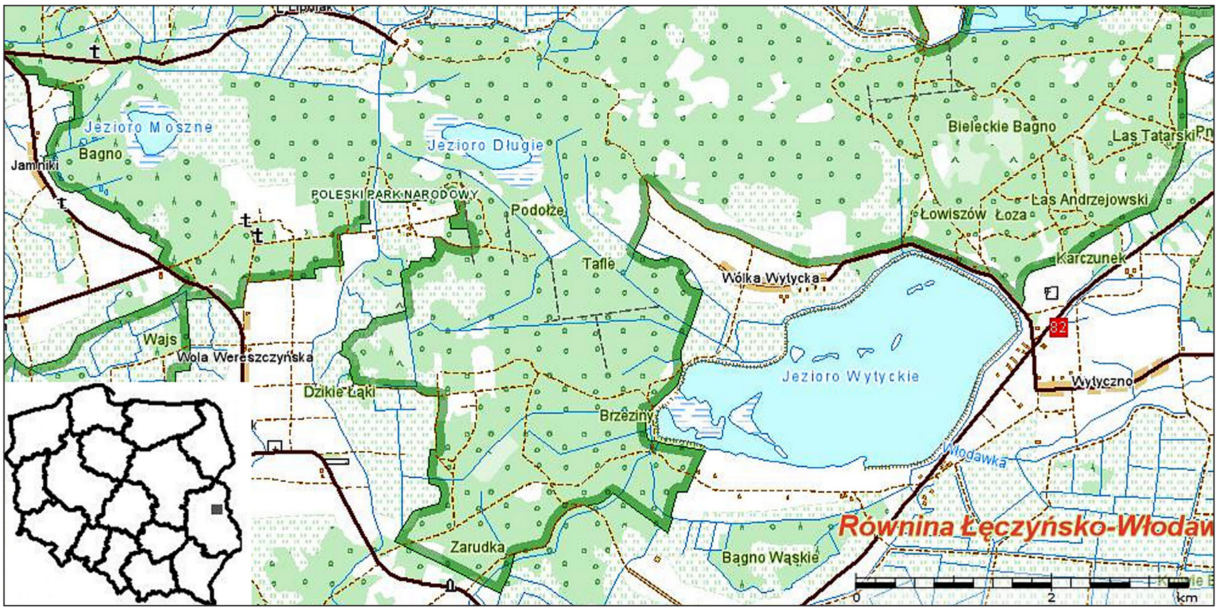

Fig. 1. Localization of Moszne peatland (after [19] modified)

In situ methane emission rates from the selected points of Moszne peatland were analyzed in 2011 in three growing seasons (spring, summer, autumn) in order to determine the influence of temperature and plant cover on methane fluxes. Samples of gases emitted from the surface were collected during stationary measurements using the chamber method [11]. The sealed chambers were set in the tested points (Fig. 2). The gases were delivered through the rubber septa placed at the top of the chamber using a gas tight syringe and transferred to the vented vials (20 ml). The triplicate gas samples were collected after 0 (control), 30 min and 60 min. Concentration of CH_4 was analysed using gas chromatograph (SIMADZU, GC 2010) equipped with a flame ionization detector (FID), after CH_4 calibration. To estimate the contribution of plants in methane emissions form the Moszne peatland, in each investigated point gas sampling were conducted from the surface with the cover by native flora and after its removal.

Fig. 2. Chamber technique for collecting gases samples *in situ*

RESULTS AND DISCUSSION

In this study, methane emissions were calculated in the range of 0.014±0.01 - 6.36±0.8 g CH_4 m^{-2} h^{-1}. This variation depended on environmental conditions such as temperature, water table and changes in atmospheric pressure [12] and also on plant species composition. The participation of vegetation in the reduction the emissions by 30-35% was confirmed by Chen and Murrell [13], who demonstrated that the interior of the plant may be an ecological niche for the methanotrophic bacteria, thus lead to the oxidation of transported methane, reducing its release into the atmosphere.

It was found that in the points dominated by *Vaccinium* sp. and *Carex* sp. the plant cover positively affected methane flux to the atmosphere. Its emission (adapted to low nutrient availability) from plant-covered measurement points was higher by 26% and 2%, for *Vaccinum* sp. and *Carex* sp. respectively, compared to places where vegetation has been removed. This may be due to the poorly developed root system, which reduces the oxidation of CH_4 in the root zone. On the other hand, some plants such as *Carex* sp. have only a passive mechanism of gas diffusion [14] which can increase CH_4 transport. The opposite trend was observed in points with *Eriophorum* sp. and *Sphagnum* sp. dominance, where the methane emissions were lower by 25% and 10%, respectively in comparison to points with natural plant cover, which indicated the active role of the methanotrophic endo- or epiphytic bacteria in methane oxidation in the analyzed plots. In addition, well-developed root system and the release of oxygen from roots to the rhizosphere can lead to the inhibition of methanogenesis and oxidation of CH_4 to CO_2. Association of the methanotrophic bacteria with plants has been already recognized by Raghoebarsing and colleagues [8], who showed that methanotrophic bacteria such as endosymbionts and epibionts live both inside and outside the cells of *Sphagnum* sp. Until now, however, there is no recognition how the methanotrophic bacteria are associated with vascular plants.

In spring methane oxidation was intensified in all of the tested points (with the exception of *Carex* sp.) while in summer and autumn registered methanogenesis and methanotrophic fluctuations depended on the position (Table 1). The seasonal changes in vegetation composition participated in the reduction of methane emissions from peatland were influenced not only by lowered temperature but also the physiological state of the plants. Weaker condition of plants, related to ending the growing season created less favorable conditions for the activity of plant associated with methanotriphic bacteria. This relationship was particularly observed in the case of *Vaccinium* sp. and *Eriophorum* sp.

The research conducted by Kölbener and colleagues [15] in the peatlands of southern Sweden have also shown the relationship between the emissions of methane and vegetation covering the area of research. They found that methane emission was up to five times higher from the peat cores with *Eriophorum latifolium*, *Potentilla*

Table 1. Methane emission in the different part of year

Vegetation	Methane emission [$gCH_4\,m^{-2}h^{-1}$]											
	Spring				Summer				Autumn			
	Carex sp.	*Eriophorum* sp.	*Vaccinium* sp.	*Sphagnum* sp.	*Carex* sp.	*Eriophorum* sp.	*Vaccinium* sp.	*Sphagnum* sp.	*Carex* sp .	*Eriophorum* sp.	*Vaccinium* sp.	*Sphagnum* sp.
Present	0.252	0.195	0.169	0.068	6.365	0.004	0.113	1.222	0.039	0.072	1.153	3.267
Absence	0.231	0.210	0.225	0.531	5.644	0.139	0.215	1.226	0.642	0.014	0.699	3.303
ΔCH_4/h	+0.02	-0.02	-0.06	-0.46	+0.72	-0.14	-0.10	-0.004	-0.003	+0.08	+0.45	-0.04

palustris, *Carex rostrata*, *Anthoxanthum odoratum*, *Carex elata and Carex acutiformis* than from control cores without plant. This study indicates of the participation of *Carex* sp. in the plant compositions on the higher methane emission. The other recent investigations of CH_4 flux in peatlands indicate that *Sphagnum* mosses may play a role in controlling of CH_4 oxidation. The studies have shown differences in CH_4 flux from sedge-dominated areas versus *Sphagnum* dominated areas [16] indicating that these microenvironments could be responsible for either the facilitation or mitigation of CH_4 emissions respectively. Our results show a reduction in CH_4 emission with *Sphagnum* sp. to 13%, while with *Carex* sp. this increase was to 12% during summer season.

Thus, peatland flora composition is able to affect the emission of methane, acting as an effective biofilter. This also underlines the importance of these studies and their contribution to recognition in the environmental protection and climate changes. Identification of relationship between peatland plants and methanotrophic activity, as well as exploitability of microorganisms often reveals their great potential in engineering applications.

As described above, MMO can participate in the biotransformation and bioremediation of substances such as: alkanes, alkenes, aliphatic and aromatic substances or their derivatives such as TCE (trichlorethylene) [17]. The fact that the Moszne peatland plants are hosts for MMO synthesizing methanotrophic bacteria can be used to design plant covers to remediate post-mining subsidence areas or to create methane-capturing landfills covers. This could have large importance for Bogdanka coal mine located in the vicinity of the PPN. Plant species derived from wetlands ecosystems may also serve for the construction of biological sewage purification systems [18]. Further research on peatland plant compositions and their participation in the greenhouse gases emissions by their interaction with methanotrophic bacteria may be helpful in designing wastewater treatment beds.

CONCLUSIONS

1. It was found that methane emissions depend on the composition of peatland vegetation.
2. The highest and independent of season methane biofiltration capacity was observed in the composition of vegetation with dominance of *Sphagnum* sp. The contribution of *Carex* sp. increased methane emissions during the whole growing season. The role of *Vaccinium* sp. and *Eriophorum* sp. in the methane emissions depended on the season.
3. The potential ability of the plant - methanotrophic bacteria systems to reduce the methane emission was demonstrated at the level from 0.01 to 77%, depending on season and the of the host plant.

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