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δ^{34}S values and S concentrations in native and transplanted *Pleurozium schreberi* in a heavily industrialised area

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ABSTRACT

Sulphur is an element found in surplus in anthropogenic areas and one of the minerals responsible for the development of acid rains. The analysis of stable S isotopes provides a powerful tool for studying various aspects of the biogeochemical circulation of sulphur. δ^{34}S values and S concentrations were determined in a 90-day experiment with the native moss *Pleurozium schreberi* from rural, urban and industrial sites in Upper Silesia in southern Poland. At the same time *P. schreberi* from a control site was transplanted to the same rural, urban and industrial sites and the δ^{34}S values and S concentrations were determined in the same 90-day experiment. ^{34}S enrichment (up to 4.7‰) in the mosses tested indicates that these plants responded to environmental pollution stress. Sulphur isotopic composition in the transplanted *P. schreberi* was related to S concentrations in this species after 90 days of the experiment. Higher δ^{34}S values and S concentrations were noted in native mosses than in those transplanted from rural and urban sites while an opposite situation was reported in industrial sites. The transplanted *P. schreberi* was a better sulphur bioindicator than the native moss in more polluted industrial sites and worse in less polluted rural and urban sites.

1. Introduction

Bioindication is a very useful way to assess the existence of environmental pollutants by measuring the levels of contaminants in plants (Markert et al., 2011). Mosses may be classified as the most effective organisms with ability to intercept, hold and accumulate xenobiotics (Fernándèz et al., 2000a, Fernándèz and Carballeira, 2001). Due to lack of cuticle and the presence of efficient cation exchange sites on their cell walls, shortage of a real root system or water-conducting tissues, they take most of the elements from airborne fallout being therefore a suitable tool for controlling atmospheric pollution (Galsomies et al., 1999; Fernándèz et al., 2000b; Gerdol et al., 2000, Carballeira and Fernándèz, 2002; Zechmeister et al., 2003). Mosses may be used in passive biomonitoring, i.e., using native species, and in active biomonitoring, using transplants in case of the absence of native mosses in the study areas (Fernándèz and Carballeira, 2001). However, plants have a capacity to adapt to certain environmental conditions. Therefore, it should be expected that native mosses accumulate less metals than the same species transplanted to polluted sites (Boquete et al. 2014). Thus native mosses may lead to underestimation of pollutant deposition. Complementary biomonitoring with native and transplanted mosses testing their response to sulphur deposition has not been studied so far. Therefore an experiment was set up based on the simplified and modified bioindication method of Fernándèz and Carballeira (2001) to compare the bioconcentration of sulphur and its stable isotope between the native moss *Pleurozium schreberi* from an industrial area with the bioconcentration in the same species transplanted from uncontaminated sites and equally exposed. Sulphur is one of the elements found in surplus in anthropogenically impacted areas, whose main sources are combustion of fossil fuels, processing of sulphur-containing ores, industry and less so vehicle exhaust emissions. Both anthropogenic and natural sources of

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atmospheric sulphur are distinguished by their stable isotopic signatures and expressed as δ values in units of per mille (‰) with respect to the Cañon Diablo Troilite (CDT or VCDT) international meteorite standard according to the following equation where $R={}^{34}S/{}^{32}S$:

$$\delta^{34}\,S=\left[\frac{(R_{sample})}{R_{standard}}-1\right]\times 1000$$

(Wiseman and Wadleigh, 2002; Wadleigh, 2003). Approximately 95% of S in the environment occurs as the stable ^{32}S isotope, while 4.2% occurs as the heavier stable ^{34}S isotope. If an artificial source of S, such as air pollution, differs from the natural background levels in the relative amounts of these two isotopes, it provides a distinctive signature of this source when combined with the measured concentration of sulphur (de Caritat et al., 1997; Wadleigh, 2003; Sanborn et al., 2005; Derda et al., 2006). Therefore, the analysis of stable S isotope supply is a powerful tool for studying various aspects of the biogeochemical cycling of this element (de Caritat et al., 1997). Wadleigh (2003) studies illustrate the potential of combining stable isotopes with concentration measurements for lichen biomonitoring of atmospheric sulphur. Since mosses receive the bulk of their nutrients directly from wet and dry deposition, their sulphur isotopic composition should reflect that of the atmosphere (Krouse and Case, 1981). The present study compares the concentrations of total sulphur and the $\delta^{34}S$ isotope values of *P. schreberi* transplanted from a control site to rural, urban and industrial sites and the same species growing naturally at the same sites. According to Ares et al. (2012) the technique where live moss samples are exposed is frequently used to estimate the level of adaptation of native moss to contamination in a selected area. This helps with questions which arise when utilising native moss in which genotypic and/or phenotypic adaptation may develop in polluted environments with modified tissue concentrations of xenobiotics. We tested the hypothesis that the concentration of S in *P. schreberi* transplanted from an unpolluted control site to an industrial area reflects the level of deposited sulphur more closely than the same parameter in the native *P. schreberi*.

2. Materials and methods

2.1. Description of the investigated area

Investigations were carried out in one of the most polluted urban regions of Poland, in Upper Silesia (Fig. 1) characterised by

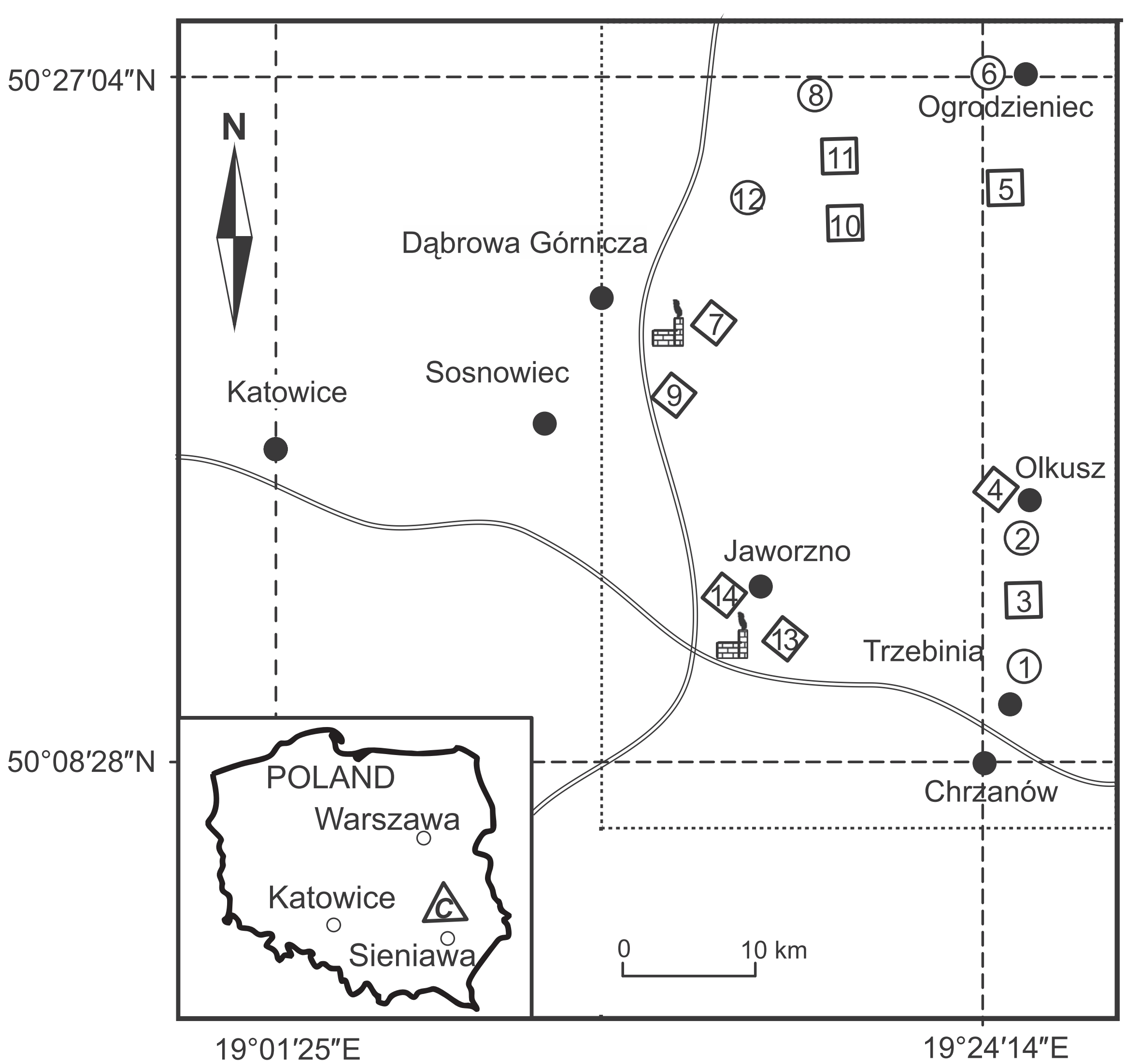

Fig. 1. Location of the investigated area. Symbols refer to: circle = urban, square = rural, diamond = industrial, triangle = control, ═══ highways or national roads; -------- study area border; smelter or power station.