Multiproxy Environmental Studies in Poland Using Peatlands

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Peatlands are a remarkable and interesting archive for investigating past and present changes in the environment. This article is a summary of Polish studies using different methods and types of mires.

Keywords: peatlands, pollen analysis, peat, multiproxy studies.

INTRODUCTION

Peatlands are an essential medium that gives information about past and present changes in the environment. Peatlands are an important reservoir of atmospherically derived metals and other pollutants, stable isotopes, pollens, macrofossils, and others (Tobolski, 2000; 2003). This ability is used to conduct environmental studies using particular types of mires and attracts many specialists since they can study a wide range of issues.

However, peatlands also are very sensitive ecosystems, and it is easy to disturb their delicate balance; therefore, they need to be protected.

Ombrotrophic peat bogs are the most reliable material to monitor heavy metal pollution fluxes as well as other environmental changes in the past (Shotyk, 2002; Bindler, 2006). They are good for investigation of past climate fluctuations using stable isotopes, especially $\delta^{13}C$ (Jędrysek et al., 2003; Jędrysek and Skrzypek, 2005). The problem in this kind of research is to find an undisturbed peat bog with a stable water level and a low degree of decomposition and ash content.

Shotyk (2002) and Monna et al. (2004) have claimed that transitional bogs could also be a good material for retrospective investigations. Transitional mires are more common in the central part of Poland than ombrotrophic peat bogs; hence, that could be an alternative for such analysis. The latter are also useful for assessing the inorganic mineral fraction. Some attempts have been provided by Fiałkiewicz et al. (2008).

It is a long-term tradition to use pollen analysis as an important basis for other environmental studies; many spectra of floristic composition were examined using Polish peatlands (Tobolski, 2003). Some of the results, with detailed descriptions and publications, are included in the European fossil pollen database (compare Fig. 1).

Many scientists emphasize the great value of interdisciplinary work for interpreting environmental phenomena.

Figure 1. **The fossil pollen database of Poland**
(*http://pollen.cerege.fr/fpd-epd/bibli.do*)

THE DISTRIBUTION AND STATE OF PEATLANDS IN POLAND

Broadly speaking, wetlands occupy 43,460 km^2, nearly 14% of the area of Poland. There are about 51,000 peat bogs covering over 12,500 km^2 (4%)

of the total area of the country. Most of them are fens, constituting 92.4% of the peatlands. Raised bogs and transitional mires constitute 4.3% and 3.3%, respectively (Ilnicki and Żurek, 1996; Ilnicki, 2002).

Large peatlands (both raised bogs and fens) dominate northern Poland, where the easily recognized recent glacial morphology, most suitable for peat accumulation, was shaped by Baltic glaciations.

The occurrence of peatlands generally diminishes with respect to their size and number from the north to the south of Poland (Fig. 2). Pristine raised bogs of high ecological value occur in the mountains of southern Poland and are protected within national parks (Karkonosze National Park, Bieszczadzki National Park, Babiogórski National Park). Four national parks – Polesie National Park, Biebrza National Park, Narew National Park in eastern Poland, and the National Park "Ujście Warty" in western Poland were created mainly for the purpose of protecting large wetland complexes.

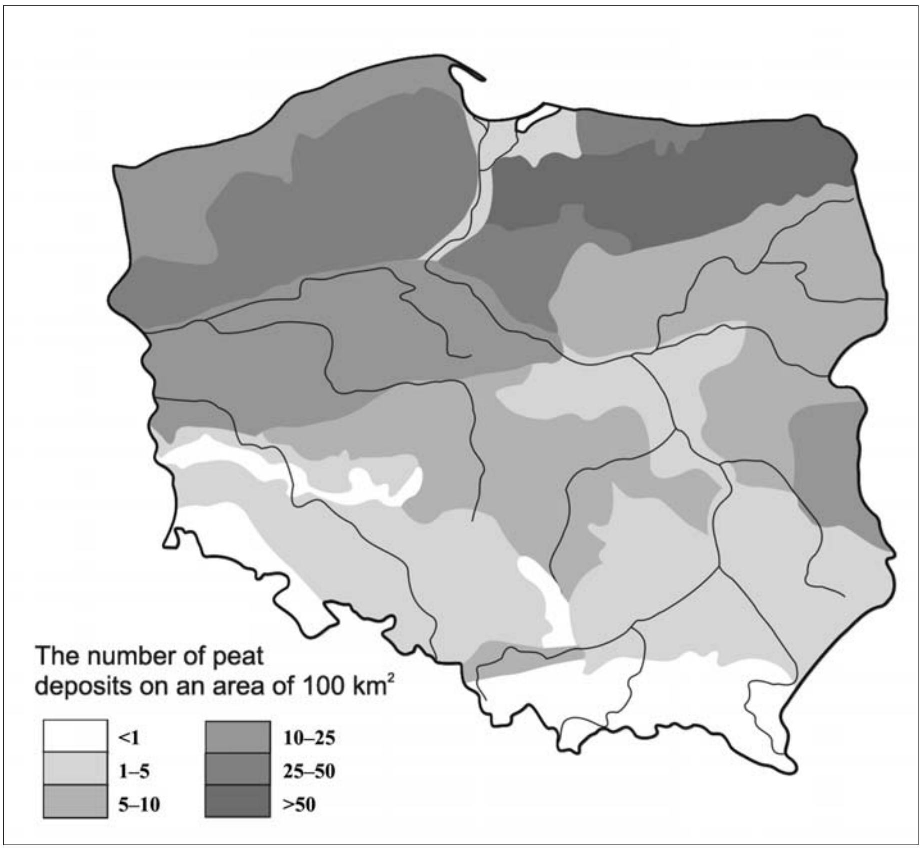

Figure 2. **The extent of peatlands and mires in Poland (Ilnicki et al., 2002; according to Żurek)**

Most of the peatlands in Poland are used for agriculture, mainly as grasslands. The provided data (Table 1) indicate that only 9% have remained in their natural or seminatural state (Mioduszewski, 2006). Due to the intensification of agriculture and land development, many wetlands were totally exploited. The present area of peatlands is thought to cover at least 20% less than the area in the 19th century.

Table 1. **The use of peatlands in Poland (according to Mioduszewski, 2006)**

The type of use	Area, thousand ha	Share, %
Natural peatlands	120.0	8.8
Meadows	960.0	70.7
Forests	120.0	8.8
Post-peat mining	150.0	11.0
Protected peatlands	6.1	0.4
Exploited peatlands (peat dredging)	2.5	0.2
Total	1358.6	100

THE PALEOENVIRONMENT AND CLIMATE CHANGES

The Żabieniec kettle-hole mire located in central Poland (Forysiak et al., 2008) as well as the Stążki mire in northern Poland (Lamentowicz et al., 2008) were successfully used to do interdisciplinary research of past climatic and ecological changes.

The article prepared by Forysiak et al. (2008) demonstrated the interdisciplinary investigations of the Holocene part of the Żabieniec mire conducted by experts in geomorphology, paleobotany, paleozoology, protistology, and archaeology. Up to the medieval times this peat bog was undisturbed by anthropogenic influences. However already at that time, as indicated by pollen analysis, signals related to deforestation connected with developing agriculture were received. The occurrence of higher mineral matter content was interpreted as the result of medieval deforestation and as a consequence of climatic instability related to the Little Ice Age.

The work done by Lamentowicz et al. (2008) is of similar character to the work described above and focuses on differentiating climate influences from human impact using stable isotopes, pollen, plant macrofossils, and testate amoebae. The described Baltic bog was influenced by mixed oceanic and continental climate, which makes this area an interesting subject of research. The results of pollen analysis show that human activity was less important up to the 19th century. The authors also emphasized that it was the first attempt of obtaining direct correlation between testate amoebae and the results of analysis of stable isotopes ($\delta^{13}C$) in Sphagnum stems.

De Vleeschouver et al. (2008) have conducted a detailed study on Słowińskie Błota, a 1300 years old ombrotrophic peat bog located in north Poland using high level analysis of lead isotopes, which helped to recognize particular anthropogenic sources of pollution and distinguish them from environmental impacts. Testate amoebae and plant macrofossils showed significant water fluctuations during the last century. Similarly to the Żabieniec mire, pollen data indicate the beginning of medieval deforestation as a sign of human impact.

Detailed studies on peat bogs Puścizna Mała and Puścizna Krauszowska, located in southern Poland, are in preparation. Physicochemical properties, heavy metal concentration, radiocarbon and lead data, pollen analysis, and stable lead isotopes are used in the studies (Fiałkiewicz, unpubl.).

PEAT AS A COLLECTOR AND ARCHIVE OF POLLUTANTS

Trace Elements

The general inventory of heavy metal pollution in Polish mires was done by Bojakowska and Lech (2008). They investigated the content of 17 trace elements in almost hundred mires throughout Poland using the ICP-MS technique. This research indicates a generally low heavy metal pollution of Polish mires. The maximum heavy metal contents were: copper – 22mg/kg, zinc – 31 mg/kg, arsenic – 7 mg/kg, cadmium – 0.3 mg/kg, nickel – 6 mg/kg, and lead – 9 mg/kg (Bojakowska and Lech, 2008). In the works of Strzyszcz and Magiera (2001a and 2001b), magnetic susceptibility measurements were used as the main method for evaluation of heavy metal concentrations in ombrotrophic peat bogs of Poland.

Increased metal concentrations were revealed in industrial regions as a consequence of anthropogenic contamination. They were also noticed in regions where mineralized rocks are exposed on the earth's surface (Wójcik and Wójcik, 2000; Bogacz, 2003; Ekonomiuk et al., 2006).

The approach of applying peat cores to reconstruct long-term variations of heavy metal deposition in mires and thus atmospheric pollution was rarely used for mires in Poland. The first detailed study was conducted by Holynska et al. (1998) for the ombrotrophic peat bog "Puścizna Rękowiańska" in southern Poland (the Orawa Basin). This study included core dating by the ^{210}Pb method, determination of ash content, geochemistry, and pollen analysis. The researchers determined the total concentration of anthropogenic elements like Pb (36–112 µg/g), Zn (47–200 µg/g), As (4–12 µg/g), Ni (2–9 µg/g), Cu (3–9 µg/g), Cr (6–12 µg/g). It is important that Pb, Zn, and As demonstrate significantly higher concentrations than the material from the surrounding soil and in comparison with peat from clean regions, which indicates the anthropogenic origin of these metals. Analysis of other metals like Ti, Al, Si, V indicated an increasing soil dust deposition. Changes in their concentration correlated with the ash content.

Fiałkiewicz et al. (2008) investigated two hundred years old monoliths from the Bagno Bruch transitional mire (southern Poland) to assess the concentrations (anthropogenic fraction) and sources of heavy metals in the peat deposit. In the bog located in a heavily polluted industrial region, lead, zinc, and cadmium reached their maximum values of 238–401 mg/l, 165–770 mg/l, and 7–31 mg/l, respectively. Similarly to the results from the Puścizna Rękowiańska, the concentrations were several times higher than the metal concentrations determined in forest soils which surround the sampling site (Lis and Pasieczna, 1995). This observation confirms the ability of peatlands to cumulate trace elements and their importance in geochemical circulation. The mineral composition of the highly polluted Bagno Bruch mire was complex. Anthropogenic particles originating from coal combustion and smelting industry dominated detrital minerals. The processes of dissolution and precipitation of mineral phases were documented using the scanning electron microscope (SEM) (Fiałkiewicz et al., 2008). A more detailed article is in preparation.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs constitute a significant group of pollutants in the environment, which has been extensively studied since it was discovered that some of them are carcinogenic and mutagenic. United States Environmental Protection Agency (USEPA) distinguished 16 PAHs as priority pollutants. The PAHs form both in natural and anthropogenic conditions. The anthropogenic PAHs are mainly derived from combustion and processing of fossil fuels and biomass, coke industry, oil refineries, household and communal water, and motor vehicles. The concentration of anthropogenic PAHs in the environment is many times higher than that of PAHs of natural sources (Malawska et al., 2002).

In recent years detailed studies on PAH concentration and composition in peatlands have been carried out mainly in north-eastern and southern parts of Poland. The PAHs listed by USEPA and the naturally occurring perylene were analysed in the peat cores in relation to peat depth, the genetic type and physicochemical properties of peat. The relation to pollution of the regions and the amount of PAHs in plants were also discussed (Malawska et al., 2002; Malawska et al., 2006; Malawska and Ekonomiuk, 2008). The concentration and distribution of PAHs in partially burned peatlands were analysed by Bojakowska and Sokołowska (2003).

Evidence from peat samples indicated that there is a continuous and diffuse PAH contamination throughout Poland (Malawska et al., 2006) without any distinct differences between the more polluted southern Poland and the north-eastern region that is free of heavy industry. The content of PAHs listed by USEPA was 43–439 ng/g in all the analysed peat samples. In 32% of the investigated samples (89 peat samples from 18 mires), the PAH content exceeded the concentration of 200 ng/g (Malawska et al., 2006), which is regarded as the upper limit of natural PAH occurrence in soils (Kabata-Pendias, 1995). A concentration as high as 3746 ng/g was recorded in one fen in the Sudeten Mountains (Malawska et al., 2006). Generally, the PAH concentration decreases with depth. Plants growing on the peat surface contained up to several times higher amounts of PAHs than the underlying peat (Malawska et al., 2002).

Radionuclides

Among the main classes of environmental contaminants, radionuclides tend to be generally less well known and less frequently studied in relation to peat than heavy metals or organic compounds. Extensive studies on radiological contaminations have been carried out in Polish soils and lichens (i.e. Biernacka et al., 1991; Mietelski, 1994; Mietelski, 2003; Komosa et al., 2007). The data show an initial increase of artificial radionuclide concentrations in the environment. In several years the concentrations fell back to the level before the Chernobyl catastrophe. The present contamination observed in soils is solely contributed by global fallout (due to nuclear tests carried out in 1945–1963), the Chernobyl disaster (1986), and the re-entry of satellite SNAP 9A (1964).

Translocation in and radionuclide availability to plants in organic soils differ from plants in mineral soils (Shand et al., 1994). Therefore, knowledge about radionuclide mobility and their pattern of distribution in peat-bog profiles could be a solid basis for developing theoretical transport models and can be used to reconstruct the fallout history. This is true especially for raised bogs whose water systems are based on atmospheric precipitation; hence, any radioactive contamination can only be derived from the fallout. The literature concerning activity and mobility of artificial radionuclides in Polish peat bogs is still limited to a few investigations carried out in southern Poland (Boroń et al., 2001; Gaca et al., 2006) and research on calcareous peat in the eastern part of the country (Komosa et al., 2006).

Activity and mobility of radionuclides ($^{239+240}$Pu, ^{238}Pu, ^{241}Am, ^{90}Sr, ^{137}Cs, ^{40}K, ^{228}Ac) were studied in two peat profiles collected from a raised peat bog (pH 5.1–5.7) located in a valley of the Western Tatra Mountains (Gaca et al., 2006). The results show that high artificial radionuclide activity occurred 15 cm below the surface and that activity tends to increase with depth. The maximum activity concentration of ^{137}Cs was equal to 400 Bq/kg, and of ^{239,240}Pu and ^{238}Pu to 18 and 0.45 Bq/kg, respectively. It was concluded that the Chernobyl disaster gives an important contribution to the radiocesium activity, while the other radionuclides have predominantly originated from the global fallout.

The measurements done for a raised bog (pH 3.4–3.8) located at the southern foothills of the Tatra Mountains detected the highest ^{137}Cs activity concentration, equal to 550 Bq/kg in the first 0–5 cm layer. The highest activity of ^{239,240}Pu and ^{238}Pu was detected in the 15–20cm layer equal to 5.07 Bq/kg and 0.159 Bq/kg, respectively. The traces of plutonium found at a depth of 1 m showed that plutonium can be partially mobile in peat. Similar vertical distribution of radiocesium in the bog indicates that ^{137}Cs is also mobile in a peat environment, and the mixing processes are relatively intensive (Boroń et al., 2001).

CONCLUSION

The provided examples demonstrate the high value of multiproxy studies to interpretation of paleoenvironmental changes, but many problems still remain unresolved.

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