Contemporary Problems of Management and Environmental Protection
Vol. 2, 2009. Wetlands - Their Functions and Protection: 125-138

Chapter VII

Paweł Nicia

Characteristics and problems of mountain and submontane fens protection

INTRODUCTION

Only several hundred years ago almost all territory of Poland was covered by extensive forests among which wetlands and bogs spread out. As settlements developed the wetland area became diminishing rapidly. At present various types of wetlands occupy only about 14% of the area of Poland (DEMBEK et al. 2000). There are 1 307 000 ha of peatbogs, constituting 4.4% of country territory. Peat cover is larger in the northern part of Poland, which is associated with glacial surface features, and is diminishing slowly toward the south (ILNICKI 2002). Peatbogs are most numerous in the Pomorze (Pomerania) region, where their number reaches between 25 and 50 per 100 km^2. In southern Poland on average there is less than one peatbog per 100 km^2. However, in some mountain regions, in places of the underground waters seepage onto the surface, wetlands covering small areas are quite common. Such wetlands where mucking process of organic matter accumulation is visible at various depth of peat layer are called fens (*młaki*) in the local dialect (TOMASZEWSKI 1970).

CHARACTERISTICS OF FEN WATERS AND SOILS

The most frequently encountered wetlands in the mountain area comprise among others low sedge fens (eutro-, mezo- and oligotrophic), marshy meadows, tall-herb fens with *Chaerophyllum*, *Aconitum*, *Adenostyles alliariae* and *Caltha palustris* but also spring peatlands commonly encountered in places of ground water seepage onto the surface (MATUSZKIEWICZ 2001).

The occurrence of all hydrogenic habitats, including mountain fens is connected with water presence in their soil profiles. In conditions of high humidity a mucking process may occur involving deposition of variously decomposed remnants of vegetation covering the wetlands. Organic soils formed in this way may be characterized by various chemical and physical properties. The factor which definitely determines the properties of organic soil developed in conditions of high moisture is the type of hydrological water feeding. The amount of water and its properties, such as mineralization, oxygenation and ionic composition determine the effect on chemical and physical properties of fen soils (GĄSIOREK, NICIA 2007; NICIA, NIEMYSKA-ŁUKASZUK 2008; NICIA, MIECHÓWKA 2007; NICIA, MIECHÓWKA 2004).

A majority of mountain fens which formed in the slope horizons reveal soligenous type of hydrological feeding. These comprise among others low sedge mountain fens, alder wetlands and tall-herb fens. Frequently, specific physiographic conditions in which mountain fens occur cause that not only waters seeping from the aquifers contribute to their feeding but also surface runoffs and more seldom water of mountain streams. In case of fens with soligenous type of hydrological feeding, waters seeping from various aquifers are characterized by specific chemical properties depending on chemical properties of the rocks, through which they flow. Feeding the soils, they enrich them in components which were present in the rocks of aquifers. Depending on the chemical composition of rocks building the underground water reservoirs, water may be characterized by a greatly diversified mineral contents, from about 100 to over a thousand mg $\cdot dm^{-3}$. In case of water feeding low sedge eutrophic mountain fens located in the Pieniny National Park and partly in the Orawsko-Nowotarska Basin, mineralization of their feeding waters is on average from 300 to 1000 mg $\cdot dm^{-3}$ (NICIA, MIECHÓWKA 2007). These waters flow out of the underground water reservoirs built of readily soluble limestones. Waters feeding low sedge mezotrophic mountain fens from the area of Babiogorski National Park are characterized by a much lower mineralization (NICIA 2008). They flow out of water reservoirs built of flysch sandstones of the Magura strata. Minerals contained in feeding waters, particularly Ca and Mg ions directly affect chemical properties of fen soils causing mineralization of acid products of organic matter breakdown, which influences the direction of plant succession and prevents the dystrophy limiting plant development (GĄSIOREK, NICIA 2007). The soils of soligenous fens (e.g. eutrophic fens) (Photo 1) fed by water where mineralization exceeds 500 mg $\cdot$ dm^{-3} reveal high pH values (7.4) and high $CaCO_3$ content even exceeding 650 g $\cdot$ kg^{-1} (Table 1) (NICIA, MIECHÓWKA 2004). Carbonate content in these fen soils is so high that during longer periods of rainless weather carbonate precipitations are visible on their surface as so called calcareous sinter (Photo 2).

Fens with ombrogenic type of hydrological feeding reveal different properties of both water and soils. They often constitute the next development stage of soligenous fen, in which the thickness of deposited organic matter is so big that it looses contact with groundwaters. These wetlands are primarily fed with rain waters with very low content of minerals. As in the case of soligenous fens also surface runoffs have some share in their water feeding.

Mineralization of ombrogenic fen waters generally does not exceed several dozen mg$\cdot$ dm^{-3}. Low content of minerals, including Ca^{2+} and Mg^{2+} ions which would neutralize acid products of organic matter breakdown influences these soils' pH. The soils of fens with ombrogenic type of hydrological feeding reveal very acid pH and total lack of carbonates (Table 1).

Water feeding fens affects not only the reaction and contents of carbonates but also mineral contents, i.e. the content of mineral components in fen waters. The highest contents of mineral elements are characteristic of mountain fens with soligenous type of hydrological feeding. Their feeding water flows through accumulated organic matter and enriches it with minerals it carries, increasing its mineral content. Also mineral components washed out of soils situated above the fens and supplied with waters flowing down the slope may enter soligenous fens. Mineral content in fens with the ombrogenic type of hydrological feeding, which are fed with waters with low content of minerals is much lower. Lower organic levels of ombrogenic fens situated immediately on mineral bedrock, within the groundwater range, reveal higher content of minerals in comparison with the surface horizons due to their enrichment in mineral elements through the contact with bedrock on which they formed.

The origin of fens with soligenous type of hydrological feeding might have occurred as follows: at the first stage when water from the aquifer outlet started seeping onto the surface, the area which it flooded became overgrown with higrophylic vegetation. Remnants of these plants, primarily roots were deposited in conditions of high moisture, enriching the mineral surface horizons in organic matter. Hardly permeable mineral horizons on the surface level became a mineral substratum, on which peat deposited, formed primarily from sedges, moss, trees covering the fens and organic matter (e.g. tree leaves), which found its way to fen surface from the adjoining areas. With growing depth of organic horizons, soligenous fens may gradually lose contact with groundwater and may change to ombrogenic type of hydrological feeding.

The genesis of fens fed with rainwaters looks different. They may form in the areas where precipitations are higher than transpiration. At the initial phase of development they may be fed also with surface runoffs and water seepage which collects on flattened fragments of the slopes. In such conditions hydrophilous vegetation developed and at high moisture its dead remnants became deposited as organic horizons. Organic horizons deposited as peat rapidly lose contact with groundwaters. With increasing depth of organic horizons formed in result of mucking process the type of hydrological feeding changes into typically ombrogenic.

Some of the mountain fens, e.g. spring peatbogs develop on slope locations along surface runoffs giving rise to mountain streams. The properties of waters feeding this type of habitats may be described as intermediate in relation to hydrogenic habitat waters with soligenous and ombrogenic type of hydrological feeding. Depth of organic horizons at the first stage of these fen formation is small and does not exceed several centimetres. High speed of water flow and inclination of slopes on which they occur do not favour organic matter accumulation.

A characteristic feature of most non-degraded mountain fens at the organic matter accumulation stage is the uplift of the middle parts of fens in relation to the edge part (Fig. 1). Their middle parts may be characterized by a faster rate of organic matter accumulation, which may be explained by a greater moisture of the middle part of the fen in comparison with its boundaries. Depth of the deposited organic matter in mountain fens is greatly diversified, from several centimetres to even 2 metres. The rate of organic matter deposition in the soils of these habitats is greatly diversified and depends in the first place on physiographic conditions in which they are situated, erosion processes washing out the accumulated organic matter beyond their surface, degree of organic matter decomposition and on the inflow of allochtonic organic matter originating from the areas immediately adjoining the fens. Slope inclination on which fens developed greatly affects the depth of organic horizons. Fens formed on almost flat terrain, where inclination does not exceed 3^o are characterized by the highest depth of organic horizons. Depth of organic horizons of both meadow and forest wetlands formed on slopes with small inclination reaches even 2 m. In case of mountain fens developed on slightly steep slopes with inclination over 15^o the depth of deposited organic matter generally does not exceed 0.30 m (NICIA, MIECHÓWKA 2004). Depth of organic horizons occurring in the upper parts of fens is generally lower than in their bottom parts (Fig. 1).

Intensity of erosion processes occurring on the fen surface is connected with the inclination of slopes on which they formed. During heavy rainfall water flowing down the slope on the fen surface may wash out amorphous particles, originated in result of organic matter humification, beyond its area. The greater intensification of erosion processes is characteristic for surface horizons of fen soils with higher level of organic matter decomposition where plant cover limiting the rate of erosion processes was destroyed by rooting up wild boars and other wild animals.

Different degrees of organic matter decomposition are characteristic for mountain fen soils. In majority of them the degree of decomposition decreases with the depth of the soil profile, which is associated with anaerobic conditions in deeper situated organic horizons (NICIA, NIEMYSKA-ŁUKASZUK 2008; MAZUREK, NICIA 2006; NICIA, MIECHÓWKA 2004). The agent stimulating organic matter breakdown process is soil oxygenation. It may occur through the fen feeding waters or in result of fluctuations of groundwaters. The highest degree of organic matter decomposition is observed in fen soils with soligenous type of hydrological feeding, in which feeding water, in the form of a spring, seeps to the surface above fen and only later overflows the slope, becomes oxygenated and feeds the fen. In soligenous fen soils, fed with seeping underground waters with low efficiency during draught periods, the groundwater level may lower by several centimeters, which also affects oxygenation of the soil profile. Oxygenation of fens with ombrogenic type of hydrological feeding and the degree of organic horizon decomposition in these soils are much lower in comparison with oxygenation of waters feeding soligenous fens (Table 1).

The highest degree of organic matter decomposition characterized fens situated on slopes with small inclination, with surface covered with vegetation, whereas the degree of organic matter decomposition is not high. The rate of organic matter accumulation in the soils of eutrophic, mezotrophic and oligotrophic low sedge fens, estimated on the basis of field observations in the years 2000-2009 is between 0.1 and 0.5 mm yearly. However, in the case when vegetal cover of the fens is damaged, the depth of the accumulated organic matter may diminish due to erosion processes causing washing out of decomposed organic matter beyond the fen area. Erosion processes of this type may occur also on the soils where vegetal cover is undamaged, e.g. in soils of *Caltho-Alnetum* biotopes. This process is favoured by the conditions in which such biotopes occur (they also usually situated on slopes with high inclination) and the soil properties (high degree of organic matter decomposition).

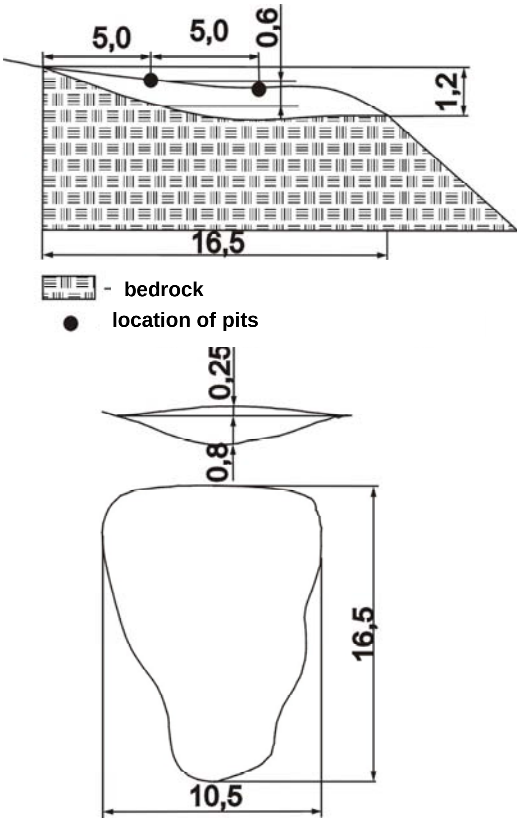


Fig.1. Field sketch of low sedge eutrophic fen situated in the Pieninski National Part (Franka Fen); Dimensions were stated in metres (P. Nicia)

Table 1

Basic properties of surface horizons of mountain fen soils and their feeding waters

Basic properties of soils and waters	Type of hydrological feeding	
	Soligenous	Ombrogenic
Soil pH	5.0 - 7.5	2.5 - 5.0
$CaCO_3$ content [$g \cdot kg^{-1}$]	0 - 700	0
Mineral contents [%]	25-75	6-30
Water mineralization [$mg \cdot dm^{-3}$]	>100	0 - 100
Water oxygenation [$mg\ O_2 \cdot dm^{-3}$]	0.5 - 5.0	0.1 - 1.0
Peat decomposition degree after von Post	H_5 - H_{10}	H_1 - H_5

Depending on the depth of deposited organic matter, chemical properties of soils and the direction of plant succession, mountain fen soils with natural water regime may be counted (according to Systematics of Polish Soils, PTG 1989) to ground-gley peat-gley soils (Photo 3), low peat soils (Photo 4), transitory peat soils (Photo 5) and high peat soils. The Systematics of Polish Soils (PTG 1989) counts the soils of drained wetlands covered by mucking process to muck soils (Photo 6).

THE IMPORTANCE OF MOUNTAIN FENS

Fens may be counted to specific fresh water ecotones, whose properties are inevitably linked to water presence in their soil profiles. Their area is relatively small and as a rule covers between several and several hundred square meters. Despite the fact, they are crucial for mountain ecosystems to a considerable degree affecting their greater biodiversity. Owing to high water capacity of organic deposits, fens have a serious influence on shaping hydrological relationships. Fen soils are saturated with water. One cubic meter of fen organic soil retains, depending on the degree of decomposition and silting, between 300 and 900 millimeters of water. Soils of the fen whose mean depth of organic horizons is 0.5 m and which covers the area of 100 m^2, constitute a natural reservoir holding even over 40 000 dm^3 of water. During drought period this water may seep and feed the directly adjoining areas.

Water presence in fen soil profiles, considerable amount of accumulated organic matter but also moisture of the adjoining soils causes that these areas are settled by strictly stenotypic plant and animal species which are characterized by a very narrow margin of tolerance for habitat conditions. These species may undergo the full or a part of their life cycle in the mountain fen soils. Among the species settling mountain fens are rare, often vanishing or endangered plant and animal species, many of which have been mentioned in the Polish red data book of animals (2001) and Polish red data book of plants (2001). Some of them have been counted to the species determined in the Directive 92/43/EWG of 21 May 1992 on protection of natural habitats and wild fauna and flora (Habitats Directive) as the priority ones. Numerous malacofauna, with a great variety of taxons, comprising from several to many species, is present in eutrophic fen soils. Among the molucs species, particular attention should be paid to *Pupilla alpicola* occurring in eutrophic fen waters fed by strongly mineralized waters. Frequently encountered species settling both mesotrophic fens, *Caltho-Alnetum* or some tall-herb fens are *Salamandra salamandra*, *Tritus montandoni* and *Carabus variolosus* (Photos 7, 8, 9). Also numerous species of enthomogenic nematodes parasitising insects (Photo 10) and fungi occur in the mountain fen soils (ROPEK, NICIA 2005, 2008).

Fens are greatly important for the development of various insect species many of which are forest pest parasites. Frequently wild animals treat fens as their sanitation facilities where they treat their wounds and get rid of parasites.

From among plant species which occur in fens one should mention among others *Droseria rotundifolia* and *Pinguicula vulgaris*. Vegetation covering fens provides a source of food for herbivores. Water-logged, swampy meadows constitute also an important landscape element, characteristic for the Carpathian Mountains.

Photo 1. Eutrophic fen in Pieniny National Park (photo by P. Nicia, 2004)

Photo 2. Calcareous sinter on the surface of low sedge eutrophic fen in the Pieniny National Park (photo by P. Nicia, 2004)

Photo 3

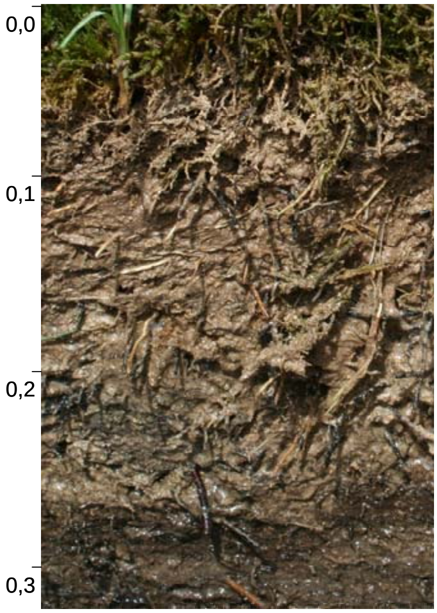


Photo 4

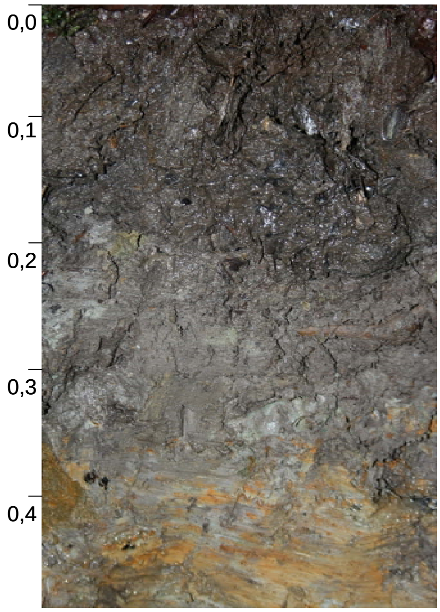


Photo 5

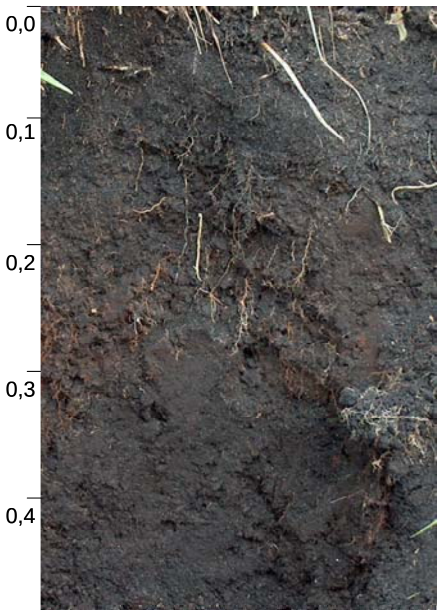
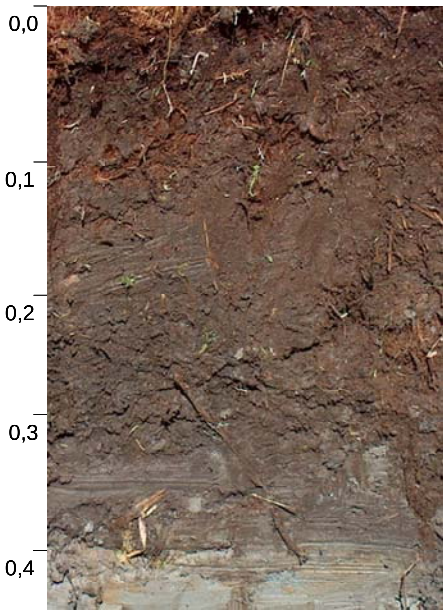


Photo 6



Photos 3-6. Mountain fen soils: 3 – ground-gley peat-gley soil, 4 – low peatbog soil, 5 – transitory peatbog soil, 6 – muck soil (photo by P. Nicia, 2006)

Photo 7. Spotted salamander (*Salamandra salamandra*) (photo by P. Nicia, 2008)

Photo 8. Carpathian newt (*Triturus montandoni*) (photo by P. Nicia, 2009)


Photo 9. Ground-beetle (*Carabus variolosus*) (photo by P. Nicia, 2009)

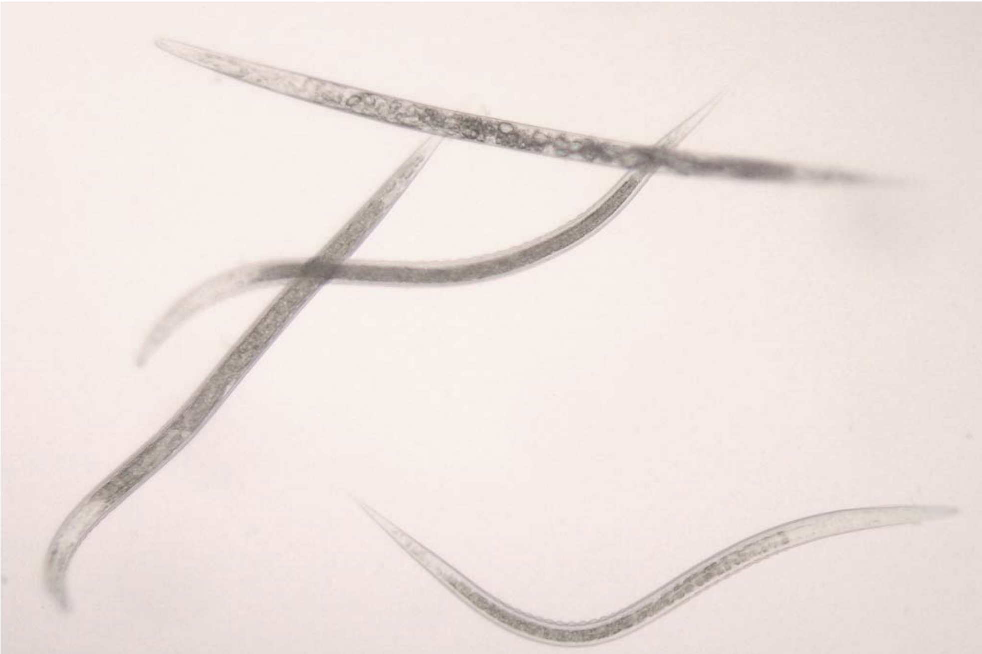


Photo 10. Enthomopathogenic nematodes (*Steinernema feltiae*) (photo by D. Ropek 2007)

PROBLEMS OF MOUNTAIN FENS PROTECTION

A considerable part of hydrogenous habitats, also those situated in the submontane zone have been degraded and devastated over the recent years. Since the year 1894 the peatbog area in the Orawsko-Nowotarska Basin diminished by 34%. Large patches of peatbogs with low peat depth most probably vanished even at the beginning of farmer colonization of this area in the 18th and 19th century due to their grazing and burning for arable fields. In the 19th and at the beginning of the 20th century intensive excavation of peat for farm animal bedding, for field fertilization and for heating purposes was conducted. The "State Enterprise for Peat Exploitation" was established in 1949, which was exploiting high peatbogs on an industrial scale leading to devastation of considerable areas of high peatbogs in the submontane regions (ŁAJCZAK 2006). Due to relatively low depth of peat deposits, mountain fen soils were not exploited by industrial methods in order to obtain peat. However, attempts were made to use them as meadows and pastures and in some cases as arable lands, whereas in case of forest fens, new tree species with greater use value were introduced to replace the species previously present in these areas. These measures were inevitably connected with their drainage. In case of mountain fens even a slight decrease in groundwater level and influx of biogenic components from the fen neigbouring areas may lead to a change of the direction of pedogenic process and plant succession on this terrain. In result of changes in water relationships, organic soils may pass from accumulation to decession stage at which mucking intensifies and water retention diminishes. Parallelly to decreasing peat soil moisture also habitat conditions change – the development of plant species characteristic for peat soil is inhibited, including also those which belong to vanishing or endangered species. Drainage disturbs dynamic equilibrium in the fen soils, which causes "falling out" of stenotypic, rare and vanishing species from these areas.

One of hydrogenous habitats whose large areas were degraded and devastated in result of drainage works conducted in the seventies of the previous century is *Caltho-Alnetum*. Prior to coming under legal protection in 1997, most patches of *Caltho-Alnetum* from the terrain of today Babiogorski National Park underwent reclamation works conducted in the seventies by means of between 0.3 to 0.9 m deep drainage ditches placed between several to many meters apart, according to the forest management directive of 1957. In case of *Caltho-Alnetum* the ditches drained the fen feeding water directly from he aquifer outlet preventing its flooding the slope surface. Such rapid cutting off the inflow of fen feeding water led to fen entering the decession stage at which mucking process takes place. Drainage works aimed at lowering the underground water level which would make possible introducing other tree species to these areas, of better than black alder use values (e.g. ash or spruce). Some other patches of *Caltho-Alnetum* were degraded in result of breaking off the aquifers feeding them during local road construction works.

Another frequent cause of mountain fen degradation is their location in the vicinity of tourist routes or ski routes which may cause a change in water regime, chemical properties of feeding waters and intensify soil erosion. Mountain fens situated close to farms are usually used as local illegal waste dumps.

Degradation of mountain fens may occur also in result of anthropogenic metal bearing dusts deposition on their surface. These dusts emitted by industries and power plants may move for long distances and become deposited on the mountain massif slopes (NICIA et al. 2004; NICIA et al. 2006). The source of heavy metal pollution in fen soils located close to traffic routes is also vehicle transport (NICIA et al. 2007).

Organic soils of mountain fens are to greater degree threatened with heavy metal pollution than mineral mountain soils. Heavy metal affinity with humus favours their accumulation in organic soils. Research conducted in the mountain areas confirm that zinc, lead and cadmium concentrations in soil depends considerably on their contents of organic matter. Heavy metal accumulation in eutrophic fen soils is also enhanced by the neutral or alkaline pH of these soils (NICIA et al. 2004; NICIA et al. 2006). Despite the occurrence of conditions causing immobilization of heavy metals in organic soils with neutral pH, there is always a risk of disturbing this balance, e.g. through increase in soil acidification or mineralization of organic substance in effect of its drainage.

CONCLUSIONS

Currently many environmentally valuable hydrogeonous habitats are among the priority habitats mentioned in the annex to I Habitats Directive of the European Union and their protection is a particular responsibility of the member states. In compliance with the Regulation of the Minister of the Natural Environment of the Polish Government of 16 May 2005 on the types of natural habitats and plant and animal species requiring protection in the form of Natura areas designation (Dz. U. nr 94, poz. 795), the following habitats: mountain tall herb-fens, transitory peatbogs and bogs, mountain alkaline peat-bogs, limestone springs, fens, *Caricetum caespitosae* alliance, coniferous forests and other forests and alder wetlands were covered with protection. The expected consequence should be undertaking measures for maintaining or reconstruction of the proper state of these natural habitats. Unfortunately, lack of plans of protecting the Natura 2000 areas prevent any protective measures or which is even worse, inhibits further realization of previously set goals which did not consider the importance of this type of natural biotopes. There are well known instances of continuing reconstruction of tree stands in the areas of hydrogenous habitats under protection where several hundred square meter or even or many-hundred square meter patches of degraded *Caltho-Alnetum* occur but no re-naturalization measures have been undertaken to restore them, moreover new species are introduced which are not characteristic for this habitat.

Only the detailed inventory of mountain hydrogenous habitats comprising the determining of: species composition of vegetation covering them, localization, analysis of the soils and their feeding waters properties would help to determine which of them occur in natural state or close to natural and in which re-naturalization measures are still possible to conduct. However, to make the protection of these specific habitats efficient, a close cooperation is crucial between the key managers of various forms of nature protection and interdisciplinary research teams focused on forest site science, but also acceptance of the re-naturalization endeavours by the local communities.

Exemplary activities aimed the restoration of natural water relationships in the hydrogenous habitats under legal protection is an attempt at re-naturalization of degraded biotopes of *Caltho-Alnetum* alliance in the Babiogorski National Park. In result of cooperation between the Department of Soil Science and Soil Protection of the University of Agriculture in Krakow and Babiogorski National Park research plots were established on several degraded patches of *Caltho-Alnetum.* The groundwater level is slowly raised on these plots through obstructing the water flow in the draining ditches in order to restore the natural pedogenic process, which should occur in this area. Constant monitoring of physical and chemical soil properties, as well as species composition of covering vegetation has been conducted.

REFERENCES

Dz. U. nr 94, poz. 795. Rozporządzeniem Ministra Środowiska z dnia 16 maja 2005 r. w sprawie typów siedlisk przyrodniczych oraz gatunków roślin i zwierząt wymagających ochrony w formie wyznaczenia obszarów Natura 2000. [Journal of Laws. No. 94, item 795. Regulation of the Minister of the Environment dated 16 May 2005 on types of biotopes and plant and animal species requiring protection in the form of Natura 2000 areas].

DEMBEK W., PIÓRKOWSKI H., Rycharski M. 2000. Mokradła na tle regionizacji fizyczno-geograficznej Polski. Biblioteczka Wiadomości IMUZ, 97: 1-121. [Wetlands against the background of physico-geographical regionalization of Poland]

GĄSIOREK M., NICIA P. 2007. Phosphorus forms in soil and water of fens with various trophicity. Polish Journal of Environmental Studies, 17(2C): 34-38.

ILNICKI P. 2002. Torfowiska i torf. Wydawnictwo Akademii Rolniczej w Poznaniu. Peat-bogs and peat. Agricultural University of Poznań Publishers: 408 pp.

ŁAJCZAK A. 2006. Torfowiska Kotliny Orawsko-Nowotarskiej. Rozwój, antropogeniczna degradacja, renaturyzacja i wybrane problemy ochrony. [Peatbogs of Orawsko-Nowatarska Basin. Development, human impact, renaturalization and selected problems of protection]. Polish Academy of Sciences, W. Szafer Institute of Botany, Kraków: 147 ss.

MATUSZKIEWICZ W. 2001. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Wydawnictwo Naukowe PWN, Warszawa, 537 pp. [Guidebook for classification system of plant communities of Poland]

MAZUREK R., NICIA P. 2006. Micromorphological properties of low sedge mountain fen soils. Polish Journal of Environmental Studies, 15(5D): 80-85.

NICIA P. 2008. Ionic composition of low sedge mesotrophic mountain fen waters. Polish Journal of Environmental Studies, 17(2C): 26-29.

NICIA P., MIECHÓWKA A., ZALESKI T. 2007. The influence of Krakow-Zakopane road on chemical properties of waters and soils of the fen near Klikuszowa. Zeszyty Problemowe Postępów Nauk Rolniczych, 520: 159-166.

NICIA P., MAZUREK R., NIEMYSKA-ŁUKASZUK J. 2006. Heavy metals in soils and waters of mesotrophic mountain fens. Polish Journal of Environmental Studies, 15(5D), Part I: 321-326.

NICIA P., MIECHÓWKA A. 2004. General charasteristics of eutrophic fen soil. Polish Journal of Soil Science, 37(1): 39-47.
NICIA P., MIECHÓWKA A. 2007. The effect of human activities and atmospheric conditions on ionic composition of low sedge mountain eutrophic fen waters. Polish Journal of Environmental Studies, 16(2A) Part II: 337-341.
NICIA P., MIECHÓWKA A., GĄSIOREK M., ZADROŻNY P. 2004. Heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) in the mountain eutrophic fen soils**.** Chemia i Inżynieria Ekologiczna, 11(8): 755-760.
NICIA P., NIEMYSKA-ŁUKASZUK J. 2008. Ogólna charakterystyka gleb torfowych mezotroficznych młak górskich. Roczniki Gleboznawcze. Annals of Soil Science, 59(1): 155-160. [General characteristics of peat soils of mountain mezotrophic fens]
Polska czerwona księga roślin. Polish red data book of plants. 2001. Kaźmierczakowa R., Zarzycki K. (Eds.), Polish Academy of Sciences, W. Szafer Institute of Botany, Institute of Nature Conservation, Kraków, 664 pp.
Polska czerwona księga zwierząt. Polish red data book of animals. 2001. Głowaciński Z. (Eds.), Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 449 pp.
ROPEK D., NICIA P. 2005. Entomopatogenic fungi and nematodes in soil of mountain eutrophic fens. Ecological Chemistry and Engineering, 12(10): 1140-1145.
ROPEK. D., NICIA P. 2008. Entomopathogenic fungi and nematodes in oligotrophic low sedge fen soils. Ecological Chemistry and Engineering, 15(1-2): 133-137.
Systematyka Gleb Polski. 1989. Roczniki Gleboznawcze. Annals of Soil Science 40(3-4): 1-150. [Taxonomy of the Soils of Poland]
TOMASZEWSKI J. 1970. Młaki górskie. Czasopismo Geogroficzne. Geographical Journal, 41(4): 27-32. [Mountain fens]

Paweł Nicia
University of Agriculture in Krakow
Department of Soil Science and Soil Protection
al. Mickiewicza 21
e-mail: rrnicia@cyf-kr.edu.pl