

Peatlands represent some of the most important carbon storages in the world. They contain nearly 30 percent of all carbon on the land, while only covering 3 percent of the area. The chemical composition of peats depends on the geobotanical conditions of their formation and on the depth of sampling. Organic matter in peat consists of a mixture of plant and animal products in various stages of decomposition and substances synthesized during the breakdown of these compounds. Peatlands are the source of peat for horticulture, pomology, and floriculture. They also used for forestry and agriculture. The physiological activity of peats is observed in peat-bath therapy for humans. Unfortunately, despite these benefits, peatlands around the world have been heavily utilized or degraded. The agricultural use of peatlands and their exploitation leads to the release of carbon. The long-term cultivation and agricultural use of peatlands has led to a number of effects including lowering of the water table, increased aeration, and changes in plant communities. During these processes the properties of organic matter change from hydrophilic to hydrophobic.

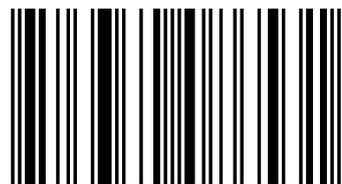
Peat physicochemical properties



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Peat - physicochemical properties

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Chapter 4

MELIORATION OF PEAT SOILS

Lech Wojciech Szajdak, Teresa Meysner, Lydia I. Inisheva, Marek Szczepański,
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The long-term cultivation and agricultural use of peatlands has an impact on their environment such as: decrease of ground water level, changes of aerobic conditions, changes in communities, and root exudates of cultivated plants as well as degradation and mineralization of peat (Grootjans et al., 1985,1986; Lishtvan et al., 1989; Kalbitz et al., 1999; Borys, 2002). Kalbitz et al. (1999) showed that the land use of peatlands effects on fulvic acids (FAs) properties, which account for the major fraction of dissolved organic matter. The above mentioned authors suggested that long-term intensive land use (from 50 to above 200 years) resulted in larger proportion of the aromatic structures and a larger degree of polycondensation of FAs (Kalbitz et al., 1999). However it is unknown what changes in the units of the structure of FAs they cause. Leinweber et al. (2001) reported that in water -soluble FAs, which are the main component (about 60%) of dissolved organic matter, the proportion of carbohydrates and phenols together with lignin monomers increased with increasing intensity of soil tillage, aeration and peat degradation.

A great number of biochemical and chemical processes in peat require aqueous conditions. The drainage as a consequence of agricultural use of peatlands results in intensive changes of biotic and abiotic properties, which leads to the degradation of the peat organic matter. Peat organic matter regulates long-term C storage and the nutrient availability to plants and microbes. The content of moisture, dissolved organic matter (DOM) seems to be closely associated with microbial activity, because this fraction of the organic carbon can be vulnerable to microbial degradation. The quantities of dissolved organic matter are sensitive to land management, especially agricultural use which reduces inputs to the soils organic matter evolution through removal of plant biomass (Marscher & Noble, 1996; Marscher & Bredov, 2002; Inisheva, 2009; Inisheva et al., 2011). The mechanism of the degradation DOM depends on the aromaticity and complexity of dissolved organic matter molecules whereas carbohydrates and amino acids increase this process. DOM degradation results also in a relative enrichment of lignin-derived

moieties, which affects the thermal behaviour of individual compounds classes and increases thermal stability of residual dissolved organic matter.

Peatlands represent some of the most important carbon stores in the world. They contain nearly 30 percent of all carbon on the land, while only covering 3 percent of the area. As one of the largest carbon stores of the world, peat plays a significant function in the regulation of greenhouse gas emissions and global climate. Peat bogs are very important as carbon sinks. Peatlands in several regions revealed actively sequestering carbon. Peat organic matter regulates long-term C storage and nutrient availability to plants and microbes. Peatlands are a source of peat for horticulture, pomology, and floriculture and are also used for forestry and agriculture.

World resources of peat were estimated to be 1.9 trillion tons, of which the Former Soviet Union (FSU) has about 770 billion tons and Canada about 510 billion tons. Domestic deposits of peat occur in all 50 States, with estimated resources of about 310 billion tons or about 16% of the world total (U.S. Geological Survey, Mineral Commodity Summaries, January 1998).

Dispersion or fractional composition of peats is the major index of its colloidal-chemical properties to determine feature of its above-molecular structure. Practically, any mechanical operation on peat production and formation is connected to the dispersion change. However, dispersion of peat in tillage horizon of peat-marshy soils changes essentially. This relates to the processes of organic matter mineralization, to wind and aqueous erosion, and also to the impact of crop - technical activities on the ground (Lishtvan et al., 1989).

Peat represents raw material. The transformation of vegetable matter to peat is a process whose continuation leads to the formation of lignite, coal and anthracite. During peat formation, humification of organic substances takes place. Later steps of diagenesis involve dewatering and compaction. Throughout humification the concentration of hydrogen and oxygen continually decreases and the organic matter increases. The variation of peat arises from the variety of plants whose residues contribute to peat formation, and from environmental conditions in which humification takes place. Peatland formation depends not only on climate but also on land geomorphology (except on the coast and in the highest mountain ranges). Peat comprises relatively unstable substances, whose reactivity contributes to its usefulness. Peat is characterized by colloidal behaviour and by irreversible loss of wettability, produced by drying. The physiological activity of peats is observed in promotion of growth in some plants (Maciak et al., 1977; Szajdak et al., 2011).

Peatlands act in the water regulation. It depends on maintaining the integrity of their special hydrology. Peatlands play a function as biogeochemical barriers in environment. It modifies quality and quantity content of the organic and mineral compounds, and impacts the temporal pattern of water delivery to rivers and lakes. Depending on their function within the hydrological and landscape system, many peat lands also provide the water regulation function with considerable direct value to human society. In addition, peatlands located on floodplains can attenuate flood peaks moving downriver thereby providing a degree of natural flood protection to downstream human settlements.

Peat contains a mixture of organic compounds characterized by high molecular weight - humic and fulvic acids and their salts as well as cellulose, lignite, bitumines, peptides, enzymes and fates. Additionally peat includes low molecular organic compounds like amino acids, alkaloids, purine and pyrimidine bases, carbohydrates, vitamins, sugars, phenols, antibiotics, steroids, triterpenoids, β -sitosterol etc. (Kondo, 1976; Bambalov et al. 2000; Szajdak, 2002). These substances establish colloidal behaviour of peat and lead to loss of wettability caused by drying (Kwak, 1986). The structure, origin and fate of such molecular configurations are thus clearly linked to the water-retention properties of peat (Sokołowska et al., 2005).

The transformation of peat organic matter by chemical, biochemical and biological decay leads to the formation of number of chemical substances. During the peat formation the following principal changes of the organic matter are: decrease of the total water content, increase in specific gravity, increase of compaction, decrease of pore space, increase of the degree of decomposition, colour changes towards dark brown and black as well as increase of the calorific value (Gotkiewicz & Kowalczyk, 1977; Lishtvan et al., 1989; MacCarthy et al., 1990). The variations in peat organic matter arise from the variety of plants whose residues impact the peat formation and from the environmental conditions in which humification takes place (MacCarthy et al., 1990; Seter & Horwath, 2004).

Understanding the processes and mechanisms of the organic matter in peat is a prerequisite for understanding the availability and cycling in nature of nutrients such as derivatives of nitrogen, carbon, sulfur, and phosphorus. Thus, the studying structure and properties of organic substances of such native products as peat, sapropel and brown coal allows revealing essential differences predetermined by their genesis and also permitting to estimate their potential agroecological efficiency and perspective directions of technological processing and use of these valuable organic

materials. In this connection the study of changes in the contents of nitrogen forms in native kaustobioliths as well as in technologically treated ones are of great interest.

Knowledge of the ratio between humified and non-humified materials in natural substrates, such as soils, fertilizers can be considered as very important from agronomical and environmental points of view. Addition of humified materials to the soil is equivalent to the addition of stabilized organic carbon. In contrast, due to biological activities, non-humified materials yield humified compounds and metabolic energy. The actual humification degree in soil is depending on the organic materials applied, soil type, and climatic conditions (Ciavatta et al., 1989). Environmental and economic concerns have prompted agricultural producers and researchers to look for improved nutrient management strategies. Environmental and human health concerns about nutrient management are focused on nitrogen, which is in excess of crop management and might escape from agroecosystems into ground and surface waters (Daniel et al., 1994). Agricultural nutrient management thus aims to balance of nutrient inputs with crop demand and to increase the degree of internal nutrient cycling. Management of soils organic matter has emerged as a major strategy to help achieve these goals because of the central role of soils organic matter plays in storing and cycling nutrients (Skorupanov et al., 1987; Seiter & Horwath, 2004).

Unfortunately, despite these benefits, peatlands around the world have been heavily utilized or degraded. Agricultural use of peatlands and their exploitation lead to the release of carbon. Long-term cultivation and agricultural use of peatlands has led to a number of effects including lowering of the water table, increased aeration, and changes in plant communities. The decline in peat soil moisture content resulting from drainage leads to shrinkage of the peat. Volume change due to shrinkage is the result of several forces acting at micro-scale, and its mechanism and magnitude differ from those in mineral (clay) soils.

Peat soil is drained effectively for practical farming utilizations to be successful and that there is sufficient air space for roots in the soil to allow for gas exchange. The large water retention capacity of peat constitutes a challenge when digging drainage ditches, the drainage capacity of the ditches is not necessarily sufficient to remove enough water from the peat and the drying of the surface soil remains entirely dependent on weather-induced evaporation. The hydraulic conductivity in peat soil may also be slow. The hydraulic conductivity of *Sphagnum* peat is poorer than that of *Carex* peat. Difficulties in drainage are increased when the peat has been degraded and its structure compacted. However, the positive effect of its water retention capacity is that in peat soil there is enough water for the needs of crop plants.

Therefore, there may be many times more easily-available water for the plants than can be found in mineral soil.

Drainage in particular results in a sharp change of biotic and abiotic properties and consequent degradation of peat organic matter. In general, this leads to the progressive differentiation of the hydrophobic and total amino acid contents. The sequential changes in physical and hydraulic properties initiated by drainage for agriculture have an important influence on chemical properties. Aeration of the upper peat layers resulting from drainage and agricultural land use triggers the aerobic decomposition process that causes carbon dioxide emissions from the soil. As results of drained and due to a number of factors including oscillation of ground water level, changes of aerobic conditions, different plant communities, root exudes and products of degradation of rest of plant remains, peat-muck soils may undergo a process of secondary transformation.

The melioration of peatlands led to the biotic and abiotic changes, which implicated the degradation of organic matter and organic compounds. Decrease of water table in peatlands characterizes the differentiation of peptides and amino acids from hydrophilic to hydrophobic (Van Dijk, 1971; Szajdak et. al., 2011). Additionally the degradation and conversion of biologically active substances such as phytohormones (indole-3-acetic acid) and phenolic acids is observed. Indole-3-acetic acid belongs to activators of the processes in soils such as see sprouting and roots growth, but phenolic compounds represent contrary to indole-acetic acid properties. These substances inhibit the physiological processes in soils.

The chemical properties of peat do not provide the best possible conditions for growing of plants. Peat is acidic; therefore the lime needs to be added to the soil. It improves the chemical and physical properties of peats and reduces the risk of phosphorus leaching. However, plants tolerate the acidity of peat soils better than in mineral soils. The detrimental effect of excessive liming is more evident in peat soils. Oats tolerate acidity the best and are therefore the common type of cereal grown in peat soil. A long growth period makes oats susceptible to frost damage, but when used as animal food this is not significant, even if the frost kills the germinative capacity of the seeds.

Sphagnum peat is deficient in all nutrients, whereas *Carex peat* is rich in nitrogen. The rate of mineralization of nitrogen in peat can take at the rate of 210-280 kg h⁻¹ yr⁻¹, which is four times as much as in mineral soils. Due to the large amounts of nitrogen, peat soils are suitable for the production of green material. Leguminous vegetables do not, however, thrive in nitrogen rich soil. By contrast, weeds with lush

growth, such as *Galeopsis* and *Polygonum* species, and couch grass flourish in peat soils, significantly hamper the farming process if they are not controlled. Even though peat soils contain sufficient nitrogen, growth may be disturbed due to the lack of other main nutrients and trace elements.

The characteristics of peat soil do not remain unchanged as it is continually transformed by humification. For various reasons, cultivation accelerates the degradation process. Drainage increases the air space in the soil. Liming and fertilizing increase the nutrient content. Tilling chops up the soil mechanically and mixes in air. All these improve conditions for the decomposer organisms and accelerate the decomposition process. The degradation of peat has an effect on the soil's chemical, physical, biochemical and biological characteristics. The rate of the decomposition greatly depends on the intensity of the farming as well as on the climate conditions. Furthermore peat soils sink physically. The surface level goes down rapidly, especially after damage. Predominantly, the shrinkage is due to compaction of above the ground water level when the mechanical support provided by water disappears. The soil compacts below the ground water level as the soil mass above it increase. Moreover, peat shrinks when it is drying. Peatlands with deep drainage ditches and thick layers of peat will ultimately sink the most.

Limiting cultivation on peat soils is not the way, since stopping all cultivation will not have an impact on reducing environmentally harmful effects. Attempts to reduce these effects include using the peatlands exclusively as grassland.

A number of countries are characterized by rich deposits of organic resources but at the same time the industrial production of organic fertilizers, organomineral mixtures and potting soils based on organic resources (peat, sapropel, and brown coal) is still not satisfied. Using natural organic fertilizers from raw materials such as peat, sapropel and brown coal during last decades increased. Peat extraction for the production of growing substrates and gardening is a multi-million dollar industry in North America and Europe. For instance, the Netherlands import 150 million euro worth of peat every year as a substrate for horticulture.

Soil organic matter represents an equilibrium system, which plays a major role in supplying nutrients to plants grown thereon. Transformation of fresh organic matter to stable humic compounds effect the cation and anion exchange capacity. It is known, that the macromolecules of complex organic compounds under the influence of enzymes, secreted by microorganisms, are exposed by destruction. The degradation products form the heterocyclic compounds, which interact with certain kinds of microorganisms and produce low and high molecular organic substances

such as carbohydrates, and lignin as well as peptides (Schnitzer & Khan, 1978; Bambalov et al., 2000; Szajdak, 2002; Nieder et al., 2003).

Among the chemical properties of organic soils, particularly attention is paid on the nitrogen. Variation in nitrogen gives these soils a specific character. Its content is important as any quantitative and qualitative conversions and also transformations in the nitrogen concentrations are distinctly reflected in chemical and indirectly in the physical properties of soil formations that exert a decisive impact on their fertility. From a large number of works on the peat soil nitrogen it appears that the organic nitrogen occurs in forms that are both easily decomposed and resistant to decomposition (Maciak et al., 1977; Szajdak & Sokolov, 1997; Bambalov et al., 2000; Sławinski et al., 2000; Szajdak et al., 2011).

The cultivation of fens leads to the mineralization and humification of peat. Degradation of mineral and organic carbon or organic nitrogen compounds (peptides, amino acids, amino sugars, amides, alkaloids, plant hormones) to gases products can be carried out by a variety of microbial species. Due to these managements some evolution of greenhouse gasses CH₄, CO₂, NO and N₂O is observed. The evolution of these gases is negative. They are greenhouse gases which cause significant depletion of the Earth's stratospheric ozone layer and contribute to the warming of the Earth's surface. The increase of mineralization processes is accompanied of the biotic system. Many groups of organism inhabiting fens are generally classified, according to their size and structure, into macrofauna, microfauna, mesofauna and microbiota significantly contribute to the physical fragmentation of fen and also nutrient cycling. Its dynamics are affected by the rate of mineralization, immobilization, leaching, root exudates and plant uptake. The following biochemical and chemical processes such as degradation, polycondensation, polymerization and polyaddition of organic substances are responsible for the formation of humic micromolecules, which are characterized by a complex macromolecular structure with aromatic and aliphatic units. They are representing macromolecular polydisperse biphyllic systems including both hydrophobic domains (saturated hydrocarbon chains, aromatic structural units) and hydrophilic functional groups, i.e having amphiphilic character. Various biochemical and chemical mechanisms are involved in the process of the degradation or cleavage of these macromolecules.

Macromolecules - from 100 to 10 000Å.

- Humic and fulvic acids,
- Proteins,
- Nucleic acids,

- Lignines,
- Polysaccharides,
- Waxes/bitumens

The Tyndall effect, also known as Tyndall scattering, is light scattering by particles in a colloid or particles in a fine suspension.

Several physicochemical parameters such as temperature, moisture, the content of oxygen and H^+ , soil density and biochemical activity impact on the conversion of organic matter. This makes the study of organic matter even more important. A conceptual view of biochemical transformation of organic matter in soil concerns the amount of organic matter going through different stages of degradation, from coarse dead plant materials to evolved humified organic matter. Many of the functional groups of organic matter are acidic and deprotonated, resulting in anionic charged matter which facilitates its solubility and ability to complex with metals and biologically active substances. These processes result in quality and quantity changes of physicochemical properties and also to the spatial allocation of mineral post-fer soils. The decrease of the rate of mineralization process and inhibit loss of organic matter quantity, which may have an impact on the availability of nutrients for plant growth, limiting the adverse effects associated with their cultivation (Marscher & Bredov, 2002).

Several investigations dealt with the problem of the changes of amphiphilic character humic substances of peat-muck soils. Amphiphilic properties of humic substances are responsible for their:

- solubility,
- viscosity,
- filtration,
- conformation,
- surfactant-like character,
- dispersion forces,
- electrostatic interaction,
- hydrogen bonding,
- variety of physicochemical properties of considerable practical significance.

These properties are strongly connected with water holding capacity and are depended on secondary transformation of peat muck soils. In particular, the process of secondary transformation of peat muck soils was significantly linked-up with water holding capacity, surface charge and differentiation of bounded amino acids. The amino acids present in the form of protein, peptides, and heterocycles can be

bound to humic substances via hydrogen bonds and/or phenolic products of lignin degradation usually surrounded by protein coats. Therefore, attractive interactions between proteins and amino acids and soils colloids are those (dispersion forces, electrostatic interactions, hydrogen bonding and hydrophobic interaction) of proteins and amino acids with organic colloids.

Different kinds of functional groups have been identified in natural organic matter, including carboxylic, phenolic and hydroxyl groups. Nitrogen- and sulphur-containing functional groups, such as amino, amide, imines, sulfamino, thiol, sulphinic and sulphonic acid groups may also be present in smaller quantities. Functional groups of humic substances play a significant key in the adsorption of water molecules. Therefore, the values of monolayer (or specific surface area) may provide information about these functional groups.

The relative **amphiphilic character** of organic colloids of humic substances can be important in modifying the structure of water films and in affecting the interactions of microorganisms with organic colloids.

Hydrophilic molecule or portion of a molecule is one that has a tendency to interact with or be dissolved by water and other polar substances. Hydrophilic substances can seem to attract water out of the air, the way salts (which are hydrophilic) do.

Hydrophobic molecules tend to be **non-polar** and, thus, prefer other neutral molecules and non-polar **solvents**. Hydrophobic molecules in water often cluster together, forming **micelles**. Water on hydrophobic surfaces will exhibit a high **contact angle** (Table 4.1,4.2, Figure 4.1).

In all organic compounds occur: **hydrophylic-hydrophobic balance between hydrophilic and hydrophobic regions**.

Hydrophilic or hydrophobic regions, which are the result of the presence in the organic matter of lipids, waxes, amines, amino sugars, sugars, polysaccharides, amides, amino acids, aromatic structural units and other moieties, can interact with amphiphilic regions of the microbial surface or may render inorganic particles, such as clay minerals, hydrophobic centers when complexes between these inorganic and organic components are formed. The stabilization and degradation of humus structure depends on biological activity. In response to the formation of soil structure, pores of different size are created and they can reveal different functions.

Peat humic substance (HS) can be considered as a multicomponent system of amphiphilic substances. Hydrophilic fractions are the most reactive and mobile components of HS. They ensure the eluvial and eluvial-illuvial differentiation of the humus profile. Hydrophobic components of peat humus are stable and responsible for

the formation of hydrophobic surfaces, reactions of hydrophobic interactions, the accumulative type of humus profile, and stability of soil aggregates.

Hydrophobic interaction chromatography (HIC) is a perspective method for the study of amphiphilic properties of HS. This method includes the use of hydrophobic interactions between hydrophobic centers of the investigating substance and hydrophobic ligands attached to the uncharged gel matrix. The most hydrophilic components of the sample do not adsorb on the gel and are eluted with a starting buffer. The adsorbed components are fractionated on the basis of successive reducing the strength of their hydrophobic interactions with hydrophobic matrix.

Humic acids (HA) and fulvic acids (FA) from soils of different genesis with the application of HIC were shown to be characterized by different proportion of amphiphilic components, as well as HA and FA from peats of different genesis, peat HA fractions of different chemical maturity, sapropel HA and brown coal HA.

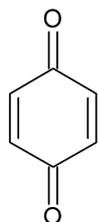
Hydrophobic-hydrophilic properties of HA depend on their chemical composition, structure and conformation. The most chemically mature peat HA fraction was shown to contain the highest proportion of hydrophilic components, whereas a less chemically mature HA fraction was found to contain the largest amount of the most hydrophobic compounds. However, peat FA was nearly completely represented by hydrophilic components. The most hydrophilic components of peat HA obtained by the HIC fractionation were characterized by the highest content of carboxylic groups and the lowest proportion of saturated hydrocarbon chains. In contrast, the most hydrophobic fraction of peat HA contained the largest amount of saturated aliphatic structures and the least percentage of carboxylic groups.

Table 4.1. Hydrophylic functional groups and chemical structures in humic substances

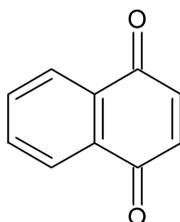
Functional groups	Chemical structures	
carboxylic –COOH	pirene	terpenes
hydroxylic in aliphatic chain –OH	fluorene	isoprene
phenolic –OH	furane	geraniol
sulphydryl –SH	benzofuran	cymene
sulfinyl =SO	tiofurane	limonene
sulfino –SO ₂ H	benzothiofene	menthane
sulfo –SO ₃ H	pirrole	pinane
primary amine =N–	indole	farnesol
secondary amine	chinoline	azulene
tertiary amine	carbazole	carbazole
	xanthene	tropane

Table 4.2. Hydrophobic functional groups of organic matter

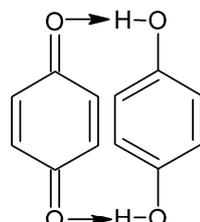
Functional groups	
methyl $-\text{CH}_3$	benzene
methylene $=\text{CH}_2$	naphthalene
methine, methyldine $=\text{CH}-$	diphenyl
methoxyl $-\text{OCH}_3$	anthracene



p-benzoquinone



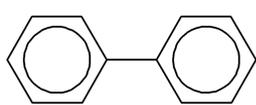
1,4-naphthoquinone



quinhydrone



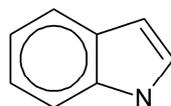
benzene



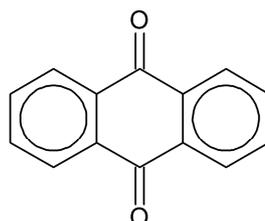
diphenyl



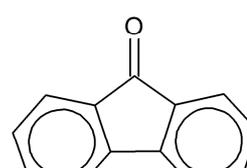
naphthalene



indole



anthraquinone



fluorenone



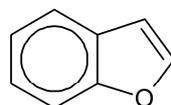
furan



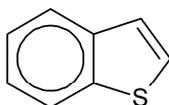
thiophene



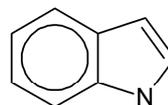
pyrrole



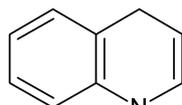
benzofuran



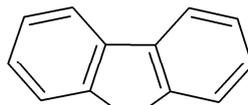
benzothiophene



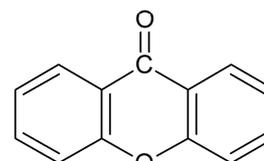
benzopyrrole



quinoline



carbazole



xanthone

Figure 4.1. Hydrophilic and hydrophobic structures in organic matter

Macropores (diameter $>2 \times 10^{-5}$ m) are responsible for drainage and aeration of soils and are characterized by the presence of roots, and live meso- and macrofauna. However, mesopores (1×10^{-7} - 2×10^{-5} m) contain the available plant water, bacteria, fungi, and root hairs and micropores ($<1 \times 10^{-7}$ m) for the adsorbed and intercrystalline water. Finally all these in-depth processes and parameters as soon as properties are focused on load of shrinkage and swelling behavior of peat soils.

The analysis of a peat ecosystems provide a case study in which the balance between production and decomposition of organic matter is the product of a series of past and present environmental factors, particularly geology, climate and topography. Slight variations in time and space in one or other of these factors have resulted in a mosaic of blanket peat with *Calluna*, *Eriophorum* and *Sphagnum* interspersed with grassland swards on a variety of mineral soils. Waterlogging plus the lower temperatures reduced the rate of decomposition and caused an increased accumulation of organic matter which gradually incorporated the remains of the birch woodland. The organic matter accumulation increased the water-holding capacity and acidity of the soil, and with the cool wet climate, bog vegetation of *Calluna*, *Eriophorum* and *Sphagnum* developed. The litter from these species has an intrinsically low rate of decomposition (i.e. low resource quality) and thus contributed to the accumulation of peat to its depth which varies from 0.5 to 4 m. Some peat accumulation probably occurred on the scarp but was unstable because of the slope and has mainly been lost through erosion.

The processes of decomposition and the decomposer populations impact on the developing soil conditions. Analysis of the prevailing state emphasize the processes the interaction of resources quality and physical environment in determining processes and populations within the same general climatic regime. On the blanket bog, primary production is $660 \pm 53 \text{ m}^2 \text{ yr}^{-1}$ from a standing crop of $1500\text{-}2500 \text{ g m}^{-2}$, about half of which is above grounds. The dwarf shrub *Calluna vulgaris* produces about 120 g m^{-2} of green shoots and about $200 \text{ g m}^{-2} \text{ yr}^{-1}$ of woody tissues about half of which is in the form of below ground stems in the 10 cm of the peat. Less than 5% of the shoot production is eaten by grouse and the remainder falls to the bog surface as litter. On death, the stems of *Calluna* remain standing of canopy for the number of years. Tussocks of *Eriophorum vaginatum* produce about $130 \text{ m}^2 \text{ yr}^{-1}$ distributed among leaves, leaf and stem bases, rhizomes and roots, some of which penetrate to 50 cm in the peat. *Sphagnum* production varies from $45 \text{ g m}^{-2} \text{ yr}^{-1}$ on the drier parts of the bog to $300 \text{ g m}^{-2} \text{ yr}^{-1}$ in pool-lawn-hummock complexes. With its characteristic apical growth *Sphagnum* dies its base and the stems and leaves enter the

decomposition subsystem 5-10 cm below the surface of the sward. Production of herbs such as *Narthecium ossifragum* and *Rubus chamemorus* is usually less than $10 \text{ g m}^{-2} \text{ yr}^{-1}$.

The two regulating variables then act in the following ways:

- i) The organic matter for decomposition varies from *Calluna* with low nutrient (0.5% N, 0.04% K) and high holocellulose (50-70%) and lignin (30-50%) concentrations, to leaves of *Rubus* with high concentrations of nutrients (1.3% N, 0.07% P, 0.09% K), low holocellulose (34%) and lignin (6%). The leaves of *Rubus* however have a high concentration of soluble tannins (27%).
- ii) The range of resources is deposited by plants in a variety of microhabitants which, because of shading and wetness, show marked differences in microclimate as indicated by seasonal pattern of maximum and minimum temperatures. Temperatures in the *Eriophorum* litter are often 10°C higher than those in *Calluna* litter but although this associated with higher evaporation. Even in the wet climate the decomposition in the litter is occasionally retarded by low moisture, for example about 20% of *Rubus* leaf samples collected from the field had moisture levels which were suboptimal for respiration.

The rates of weight loss of the main surface litter, measured in litter-bags over 6-10 years, approximate to annual constant fraction losses of between 0.05 for *Calluna* stems and 0.19 for *Rubus chamemorus* leaves. Measurement of litter respiration shows that the rate of catabolism is directly related to weight loss. The rate of respiration however declines as the litter ages as a result of decomposition of the more readily decomposable fraction and an increasing proportion of resistant compounds (Swift et al., 1979).

The older litter is overlain by new litter production and moves down the peat profile, at about 0.5 cm yr^{-1} , entering an increasingly waterlogged environment. The below ground parts of the plants, particularly the roots of *Eriophorum*, are also deposited in waterlogged conditions. The slow rate of oxygen uptake by microbial respiration, results in an increasingly anaerobic environment with depth. The redox potential (E_{h_4}) declines from about -100 mV in the surface litter to a peak of about -400 mV at 10-20 cm, the depth at which the water table frequently occurs. Samples of litter and pure cellulose placed at different depths within the peat profile show a decline in rate of decomposition with depth, relative to the rate at the surface, loss rates declining by 3-5% cm^{-1} (Inisheva, 2009).

The low initial rates of decomposition relate to the low quality of the resource. Even when corrected for a decline in rate with ageing, the loss rates, given current inputs primary production, cannot account for the observed peat accumulation of about 100 kg m⁻². It is only when the retarding of decay rate through waterlogging and the development of the anaerobic conditions at below the water table is simulated that calculations of the current peat profile characteristics approximate to observed values. The overall decay rate in the aerobic zone (0-20 cm) is of the order of 0.02-0.04 g g⁻¹ yr⁻¹ but below the water table it is of the order of 1x10⁻³ to 1x10⁻⁸ g g⁻¹ yr⁻¹.

Feedback mechanism regulating primary production and decomposition processes can be identified in this system; the products of anaerobic decomposition increase acidity and thereby retard decomposition and nutrient mobilization; the increasing accumulation of peat restricts access to mineral soil by plant roots and limits nutrient availability to the component recycled from decomposition or entering the system in rain. As a result the plants tend to conserve nutrients by perennial growth and the concentration of elements in the litter is low. The distribution of the glacial boulder clay initiated the inexorable chain of events in which waterlogging plays a key role in determining the rate of decomposition and thence the pattern of vegetation.

The high loss rate on the peat bog is a result of the higher nutrient concentration and the lower proportion of high molecular organic compounds in the organic matter plus the aerobic soil conditions with pH about 5.0. The difference in resource and soil conditions results not only in greater herbivory and decomposition rate but in greater soil fauna diversity and productivity compared to the bog. Lumbricid populations make a major contribution to the faunal standing crop of about 23 g m⁻² with a production of about 12 g m⁻³ yr⁻¹ compared to a standing crop and production of less than 1 g m⁻² yr⁻¹ on the bog where enchytraeids and tipulid larvae predominate.

REFERENCES

- Bambalov, N., Smychnik, T., Maryganova, V., Strigutsky, V. & Dite, M. 2000. Peculiarities of the chemical composition and the molecular structure of peat humic substances. *Acta Agrophys.* 6. 149-177.
- Borys, M. 2002. Agricultural use of peatland. In Ilnicki, P. (Ed.). *Peat and peatlands.* Publishing House of A. Cieszkowski Agricultural University, Poznań. pp. 263-273 (in Polish).
- Ciavatta, C., Antisari, L.V. & Sequi, P. 1989. Humification parameters of organic materials applied to soil. In Bhattacharji, S., Friedman, M., Neugebauer, H.J. &

- Seelacher A. (Eds). Humic substances in the aquatic and terrestrial environment. Springer-Verlag, Berlin. pp. 177-185.
- Daniel, T.C., Sharpley, A.N., Edwards, D.R., Wedepoh, L.R. & Lenmunyon, J.L. 1994. Minimizing surface water eutrophication from agriculture by phosphorus management. *J. Water Soil Cons.* 49. 30-38.
- Gotkiewicz, J. & Kowalczyk, Z. 1977. Differentiation of biological processes in the soils of the main post-bog habitat types. *Zesz. Probl. Post. Nauk Roln.* 186. 97-117 (in Polish).
- Grootjans, A.P., Schipper, P.C. & van der Windt, H.J. 1985. Influence of drainage on N-mineralization and vegetation response in wet meadows. I. *Calthion palustris* stands. *Acta Oecol. -Oec. Plant.* 6(4). 403-417.
- Grootjans, A.P., Schipper, P.C. & van der Windt, H.J. 1986. Influence of drainage on N-mineralization and vegetation response in wet meadows. II. *Cirsio-Molinietum* stands. *Acta Oecol. -Oec. Plant.* 7(1). 3-14.
- Inisheva, L.I. 2009. Peat and peatland science. Tomsk State University, Tomsk. pp. 210 (in Russian).
- Inisheva, L.I., Zemtsov, A.A. & Novikov, S.M. 2011. Natural conditions, structure and functioning. Tomsk State Pedagogical University. Tomsk. pp. 158.
- Kalbitz, K., Geyer, W. & Geyer, S. 1999. Spectroscopic properties of dissolved humic substances - a reflection of land use history in a fen area. *Biogeochemistry.* 47. 219-238.
- Kondo, R. 1976. Humus composition of peat and plant remains. *Soil Sci. Plant Nutr.* 20. 17-31.
- Kwak, J.C., Ayub, A.L. & Shepard, J.D. 1986. The role of colloid science in peat dewatering: principles and dewatering studies. In Fuchsman, S.H. (Ed.). *Peat and water aspects of water retention and dewatering in peat.* Elsevier Applied Science Publishers, London. pp. 95-118.
- Leinweber, P., Schulten, H.R., Kalbitz, K., Meissen, R. & Jancke, H. 2001. Fulvic acid composition in degraded fenlands. *J. Plant Nutr. Soil Sci.* 164. 371-379.
- Lishtvan, I.I., Bazin, E.T., Gajunow, N.I. & Terentiew, A.A. 1989. Physics and chemistry of peat. Nedra. Moskwa. pp. 304 (in Russian).
- MacCarthy, P., Clapp, C.E., Malcolm, R.L. & Boom P.R. 1990. Humic substances in soil and crop sciences: selected readings. American Society of Agronomy, Madison. pp. 281.
- Maciak, F., Söchtig H. & Flaig, W. 1977. Composition of amino acids in peat-forming plants and in peats. In *Soil Organic Matter Studies. Vol. II. Proceedings of*

- a Symposium Braunschweig, 6-10 September 1976. International Atomic Energy Agency, Vienna. pp. 343-357.
- Marscher, B. & Bredov, A. 2002. Temperature effects on release and ecologically relevant properties of dissolved organic carbon in sterilized and biologically active soil samples. *Soil Biol. Biochem.* 34. 459-466.
- Marscher, B. & Noble, A.D. 1996. Chemical and biological processes leading to the neutralization of acidity in soil incubated with litter materials. *Soil Biol. Biochem.* 32. 805-813.
- Nieder, R., Benbi, D.K. & Isermann, K. 2003. Soil organic matter. In Bendi, D.K. & Nieder, R.R. (Eds). *Handbook of processes and modeling in the soil-plant system.* Food Products Press, The Haworth Reference Press Imprints of the Haworth Press, Inc. New York. pp. 345-408.
- Schnitzer, M. & Khan, S.U. 1978. *Soil organic matter.* Elsevier Scientific Publishing Company, Amsterdam. pp. 261-262.
- Seiter, S. & Horwath, W.R. 2004. Strategies for management soil organic matter to supply plant nutrients. In Magdoff, F. & Weil, R.R. (Eds). *Soil organic matter in sustainable agriculture.* CRC Press. pp. 269-293.
- Skoropanov, S.G., Brezgunov, V.S. & Okulik, N.V. 1987. The extended fertility reproduction of peat soils. Minsk, Nauka and Tekhnika. pp. 248 (in Russian).
- Sławiński, C., Sokołowska, Z. & Walczak, R. 2000. Effects of secondary transformation of peat-moorsh soils on their physical properties. *Acta Agrophys.* 26. 85-93.
- Sokołowska, Z., Szajdak, L. & Matyka-Sarzyńska, D. 2005. Impact of the degree of secondary transformation on acid-base properties of organic compounds in mucks. *Geoderma.* 127. 80-90.
- Swift, M.J., Heal, O.W. & Anderson, J.M. 1979. *Decomposition in terrestrial ecosystems.* Blackwell Scientific Publications. Oxford. pp. 372.
- Szajdak, L. & Sokolov, G. 1997. Impact of different fertilizers on the bound amino acids content in soils. *Int. Peat J.* 7. 29-32.
- Szajdak, L. 2002. Chemical properties of peat. In Ilnicki, P. (Ed.). *Peat and Peatlands.* Wydawnictwo Akademii Rolniczej im. A. Cieszkowskiego, Poznań. pp. 432-450 (in Polish).
- Szajdak, L. 2002. Chemical properties of peat. In Ilnicki, P. (Ed.). *Peat and peatlands.* Publishing House of A. Cieszkowski Agricultural University, Poznań. pp. 432-450 (in Polish).

- Szajdak, L.W., Szatyłowicz, J. & Kõlli, R. 2011. Peat and peatlands, physical properties. In Gliński, J., Horabik, J. & Lipiec, J. (Eds). Encyclopedia of agrophysics. Encyclopedia of earth sciences series. Springer. pp. 551-555.
- Van Dijk, H. 1971. Colloidal chemical properties of humic matter. In McLaren, A.D. & Skujins, J. (Eds). Soil biochemistry. 2nd ed. Marcel Dekker, New York. pp. 21-45.