GEOECOLOGY AND LANDSCAPE GEOCHEMISTRY

© LIDIYA I. INISHEVA, LECH W. SZAJDAK
inisheva@mail.ru, szajlech@man.poznan.pl

UDC 631.452

THE CHARACTERISTIC OF FRACTIONAL STRUCTURE OF THE ORGANIC MATTER IN PEATS

SUMMARY. One of perspective organic fertilizer resources is peat, containing many active components. A variety of conditions of bogs existence defines a significant variety of the chemical composition of peat-forming deposits. The purpose of this article is to study the properties of the organic matter (OM) of peats in Western Siberian taiga.

Samples of representative peats (140) were selected on the territory of Tomsk Region and then an analysis of fractional group structure of the organic matter in peats was done. In these samples a specific distribution of organic material fractions was revealed in various types and groups of peats. The research shows that low-lying herbal and wood-herbal groups of peat can be an optimal raw material base for the production of organic fertilizers from peat.

KEY WORDS. Mire plant, peat, decomposition degree, organic matter, fraction composition, hydrolysable matters, humic acids, lipids, fulvic acids.

Nowadays different countries develop alternative agronomy patterns aimed at limiting or rejecting the use of mineral fertilizers in agriculture. In order to maintain and improve soil productivity and get ecologically clean high-quality agricultural produce, it is necessary to use environmentally friendly pollution-free fertilizers which could provide plants with nutrients, growth stimulants and regulate organo-mineral complex status in soils. Peat can be raw material for fertilizers of this type as its qualities meet most of the requirements mentioned above.

A variety of peat qualities allows producing a wide range of peat based organic fertilizers. The composition of each type of fertilizer is improved for each arable crop, i.e. it is plant-specific. Peat, containing a unique complex of biologically active compounds (humic acids, carbohydrates, polyphenols, etc.), is a substantial and, moreover, renewable resource.

The purpose of the study is to examine the properties of the organic matter (OM) of peat bogs in Western Siberia taiga.

Objects and methods. On the territory of six bog areas in Tomsk Region (according to the bog zoning scheme by Yu.A. Lvov [1]) 140 samples of 12 peat types were collected. The samples include low-lying and high-moor peats representative of Tomsk Region. Each peat type (according to its botanical composition) is presented by 6–19 samples collected in peat bogs from different bog areas (Figure 1). Peat samples of various botanical composition are clustered in accordance botanical classification groups presented with 19–35 specimens.

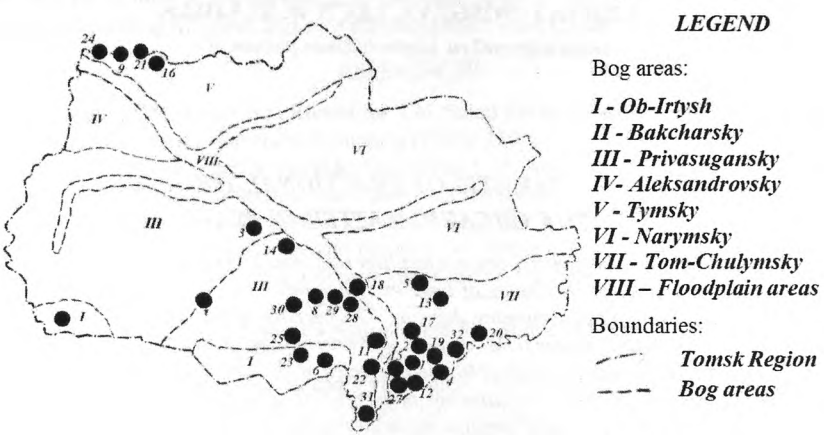

Figure 1: The scheme of peat sampling locations. Peat bogs (p. b.): 1—Pivovarovskoye, 2—Bacherovskoye, 3—Beryozovskoye, 4—Bodazhkovskoye, 5—Bolvan, 6—Vasyuganskoye (zone No. 5) 7—Vasyuganskoye (Yuginskoye zone), 8—Vasyuganskoye (zone No. 22), 9—Vachpugolskoye, 10—Vilkinskoye, 11—Gusevskoye, 12—Kandinskoye, 13—Karakol, 14—Karasyovoye, 15—Karbyshevskoye, 16—Kichanovo, 17—Klyukvennoye, 18—Kolmakhton, 19—Konininskoye, 20—Krasnoyarsk grasslands, 21—Lukashino, 22—Obskoye, 23—Porotnikovskoye, 24—Saim, 25—Sukhovskoye, 26—P. b. in Zarya State Farm, 27—Taganskoye, 28—Tatoshynskoye, 29—Tungusovskoye, 30—Ust–Bakcharskoye, 31—Chiliyskoye, 32—Chumakly.

The following properties of peats were analysed: botanical composition and degree of decomposition (GOST 28245.2-89), ash content (GOST 11306-83), pH of salt extract (GOST 11623-65), fractional group structure of the organic matter (OM) in peats according to the method of V.V. Ponomareva and T.A. Nikolayeva [2].

Results of the study. Traditionally a batch method is applied to analyse OM in peats allowing defining the content of main groups of OM in peat (lipids, carbohydrates, humic substances and lignin). The analysis of fractional group structure of OM, unlike group analysis, also allows identifying separate fractions of substances, whose

properties differ (hemicellulose and cellulose, gray and brown humic acids, separate fractions of fulvic acids (FA)).

Total organic matter potential in peats defines total carbon content (TC), as carbon constitutes the major portion of the organic part of peat—48–65% [3]. In addition, the fractional group structure of carbon should also be taken into account.

In the examined samples of peats, lipids on average make up 8.4%, humic acids—38.1%, hydrolysable substances—16.3% and non-hydrolysable residue—36.7% of TC. Humic acids (HA) and fulvic acids (FA) constitute a substantial proportion of substances.

Total content of humic acids in the analysed peats is 5.2–41.3% of TC (Table 1). Low-lying peat on average contains 24.4% of HA with a range of 5.7–41.3%, high-moor peat—16.5% with a range of 5.2–31.8%. The degree of variation of this property, estimated by coefficients of variation, makes 22–36% for low-lying peats and 28–52% for high-moor peats.

Table 1

Total content of humic acids in peats of different botanical composition, percentage of TC

Botanical composition	No.	$HA_{average}$	HA_{min}	HA_{max}	Cv, %
Low-lying Type					
Wood group	18	24.9	17.8	34.4	21.9
Wood-herbal group	19	26.3	13.0	37.8	27.0
Herbal group	35	26.2	7.0	41.3	25.4
Sedge type	16	23.9	7.0	32.4	28.3
Herbal type	19	28.1	19.1	41.3	21.7
Herbal-moss group	14	19.9	5.7	31.5	36.4
Moss group	14	21.2	9.9	35.6	30.0
High-moor type					
Herbal (*Scheuchzeria*) type	4	21.1	13.3	30.2	34.3
Herbal-moss group	14	17.0	7.4	31.8	49.0
Eriophorum-sphagnum type	12	16.8	7.4	31.8	51.7
Moss group	19	13.9	5.2	32.1	45.2
Fuscum type	6	10.9	5.2	13.9	28.4
Complex type	8	15.4	7.4	22.7	36.9

Note: No.—number of observations, $HA_{average}$, HA_{min}, HA_{max}—average, minimum, maximum content of humic acids in peats, percentage of TC; Cv—coefficient of variation, percentage of average.

The maximum amount of HA is found in wood-herbal and herbal groups of peat, with a medium degree of decomposition up to 26–31%. Types of peat belonging to the low-lying herbal group have a very high average content of HA (see Table 1). Sedge peat violates this trend as along with a high degree of decomposition (27.5%) its average content of HA is much less than the average for the herbal group and it does not exceed 24% of TC. It confirms the important role of the chemical composition of peat-forming plants in the process of humification. It can be supposed that environmental conditions of sedge peat formation contribute to accumulation of non-specific substances resulting in a higher degree of decomposition.

In this regard it is interesting to point out that low-lying wood peat, which has a high degree of decomposition (on average 32.3%), contains less HA than low-lying herbal peat. It may be determined by the original composition of wood residue that consists of 80% carbohydrates [4]. When wood is transformed in the process of peat formation, carbohydrate complex is quickly decomposed by microflora, which leads to a quick plant tissue decay and an increased rate of decomposition. A low content of nitrogen and aromatic fragments in wood does not contribute to HA formation. In addition, it can be influenced by good drainage conditions of wood swamps and an enhanced migration of HA outside peat deposits.

Thus a moderate content of HA along with a high degree of decomposition found in sedge and wood types of peat indicate that decomposition degree does not always reflect the level of peat humification in an adequate way.

It is typical of low-lying herbal-moss and moss groups of peat to have a low content of HA—on average 19.9–21.1%, which is obviously determined by the influence of peat-forming moss.

In view of the above, it can be supposed that the total content of HA in low-lying types of peat is mostly specified by botanical composition rather than the degree of peat decomposition. The total content of HA in low-lying peats increases in the following succession: the herbal-moss group → the moss group → the wood group → the wood-herbal group → the herbal group.

High-moor peat includes much less HA than low-lying peat, and the dependence on the decomposition degree is well-pronounced. Scheuchzeria peat stands out for its average content of HA reaching 21% from total carbon content approaching the figures for low-lying peats. The maximum content of HA in high-moor peats is 30.2% (with a degree of decomposition of 35%). Similar to low-lying peats, the highest average content of HA is found in the herbal group (21.05%), while the lowest average content is found in the high-moor moss group of peats (14%). The herbal-moss group occupies an intermediate position. As for the fractional composition of HA in the examined peats, the first HA fraction (HA1) makes 30%, the second fraction (HA2) — up to 10%, and the third HA fraction (HA3) — 60 %.

The content of HA1 in the examined peats varies from 1.8 to 23.3%. The first HA fraction corresponds to the content of free HA in peat. This fraction is the most oxidized and less polydisperse one, containing a large amount of acid functional groups and mineral elements [5]. Free HA1 in peat is the most active HA fraction.

As a rule, low-lying peat has more HA1 than high-moor peat (except high-moor scheuchzeria type), while the differences in the amount of this fraction depending on the type of peat are less pronounced than the differences in the total content of HA.

On the basis of the research results, we conclude that different types of peat that belong to the same group vary in the content of HA1 less than peats of one type with different botanical composition. Thus both types of herbal peat group have the highest content of free HA, but for moss peat this parameter is lowest. As for herbal peats, low-lying sedge peat has a low content of HA1 which is equivalent to the level of HA1 in moss group peats. Close average values of HA1 in moss peats of high-moor and low-lying types and herbal-moss peats of both types deserve a special consideration. These results demonstrate that accumulation of this fraction of HA is not connected with the trophicity degree of peat-forming environment, but is determined by other reasons, for example, the original composition of plant residue or water conditions of bog plant community depositing this peat.

The second HA fraction (HA2) is linked to calcium and corresponds to the content of "black" or "grey" humic acids. The amount of this fraction is usually low in peats. According to V.N. Pereverzev [6], the content of HA2 in low-lying peats does not exceed 3.8% and in high-moor peats it is equal to zero. A high content of HA2 is found in floodplain peat soils in Ukraine [7] (5–20% from TC) and Western Siberia [8] (5–12%). These data confirm the influence of secondary ash content on the amount of HA2 in peat.

As follows from our research, high-moor peat does not contain more than 2.5% of HA2 from TC. The maximum amount of HA2 in low-lying peat can be up to 10.5%, and it is found in wood and wood-herbal groups of peat which have the highest degree of decomposition and are typical of floodplain peat bogs. The analysis of the obtained average values in peats of different botanical groups has revealed a regular reduction of HA2 content in the sequence of peat types: from the low-lying wood group to the high-moor moss group.

The average ash content changes with the same regularity in the examined peats. However in our researches in almost all groups of peats HA2 is not found, with the exception of low-lying wood and wood-herbal groups typical, as pointed out above, of floodplain peat bogs.

The results have shown that a high content of HA2 in peat can be considered an indication of secondary ash-content influence. HA2 is not characteristic of peats with normal ash content. Apparently, HA2 fraction, whose distribution in general corresponds to ash content distribution, can be assumed to be a parameter of bog biogeocenosis trophicity. Trophicity level in its turn determines a certain plant aggregation structure of a bog biogeocenosis and, subsequently, the chemical composition of the deposited peat. This means that geochemical conditions of peat formation process have some influence on HA2 content in peats.

As it is stated above, in all examined types of peat the predominant HA fraction is the third one, which determines the major regular changes in the total HA content. Along with that, this particular fraction raises a lot of questions. V.N. Pereverzev [6] explains a high content of this fraction in peats by an inadequate analysis procedure leading to artificial formation of HA3, passing into an alkaline extract upon the

application of heat. On the basis of preparative examinations T.T. Efremova [5] describes HA3 as a recovered form of brown humic acids of early-stage humification. Evidently, relying on the idea of the artificial nature of HA3 in peats, some researchers [9-11] view the sum of the first and second fractions of HA as the total HA content in peat soils and do not define the content of HA3.

Low-lying peat contains more HA3 than high-moor peat, and the herbal group contains more HA3 than the moss group. HA3 content in high-moor peat depends on the decomposition degree, while in low-lying peat it depends on its botanical composition.

A substantial amount of humic acids in peat is represented by fulvic acids—31% from TC. The analysis of fractional group structure allows relating all alkali-soluble carbon-bearing substances that remain in filtrate after the deposition of humic acids to fulvic acids (FA). The average content of FA in high-moor peats is 13.7% from TC and in low-lying peats—16.9%. The average content of FA slightly varies in different groups of peat—from 1.6 to 18.9% from TC (see Table 2). In general low-lying groups of peat have a higher FA content.

Table 2

Total content of fulvic acids in peats of different botanical composition, percentage of TC

Botanical composition	No.	$FA_{average}$	FA_{min}	FA_{max}	Cv, %
Low-lying Type					
Wood group	18	18.9	10.4	29.1	23.4
Wood-herbal group	19	17.0	10.7	30.8	30.0
Wood-herbal type	14	16.5	11.9	24.0	25.4
Herbal group	35	17.6	8.3	28.8	28.2
Herbal type	16	17.2	8.3	25.0	26.5
Sedge type	19	18.1	12.3	28.8	30.6
Herbal-moss group	14	14.9	8.3	21.0	29.1
Moss group	14	14.4	7.5	19.7	25.5
High-moor type					
Herbal (*Scheuchzeria*) type	4	14.7	11.0	18.9	22.2
Herbal-moss group	12	11.6	5.9	20.2	31.0
Eriophorum-sphagnum type	14	11.4	8.8	15.4	21.8
Moss group	19	13.5	9.0	26.0	27.8
Fuscum type	6	15.2	13.1	17.5	9.6
Complex type	8	11.6	9.1	13.9	16.5

Note: No.—number of observations, $FA_{average}$, FA_{min}, FA_{max}—average, minimum, maximum content of fulvic acids in peats, percentage of TC; Cv—coefficient of variation, percentage of average.

After the deposition of humic acids in filtrate along with fulvic acids there are other non-specific carbon-bearing substances. Easily hydrolysable substances (EH) identifiable with hemicellulose are found in the examined peats in the range of 0.8—20.9% from TC. The minimum value is revealed in the low-lying wood-herbal group and the maximum value is found in the high-moor moss group. Low-lying peats are characterized by a relatively low content of EH, except moss and herbal-moss groups as well as the high-moor herbal group. Herbal-moss and moss groups of both peat types have twice as high EH content as other groups (Figure 2).

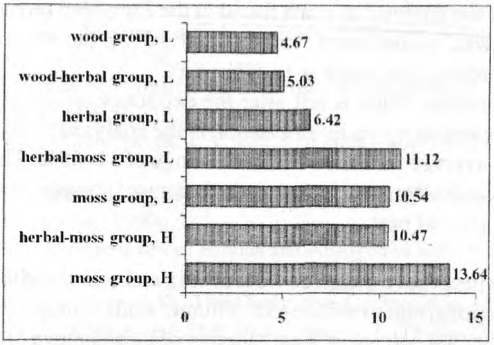

Figure 2: The average content of easily hydrolysable substances in peats, percentage of total carbon. (L—low-lying peat, H—high-moor peat)

It is common knowledge that peat-forming moss plants have a high content of hemicellulose, that is why EH content in peats depends on the quantity of peat-forming moss residues.

The content of difficultly hydrolysable substances (DH) identifiable with cellulose varies in the analysed peats from 0.9 to 47% of TC. Average values in peat groups range from 4.7 to 14.7%. In general low-lying peat is characterized by a low DH content, and high-moor peat has a high DH content (Figure 3).

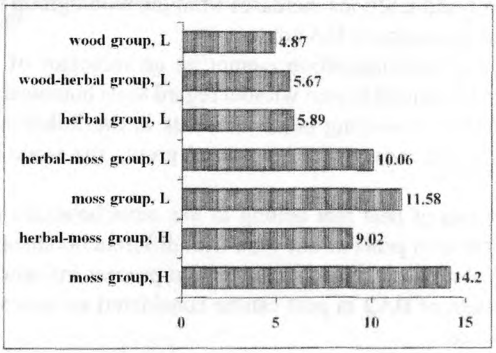

Figure 3: The average content of difficultly hydrolysable substances in peats, percentage of total carbon. (L—low-lying peat, H—high-moor peat).

Other substances that are typically found in peats are lipids (or wax resins following the terminology by V.N. Ponomaryova and T.A. Nikolayeva [2]), including paraffins, waxes, resins, oils and asphaltenes also called bitumens.

Low-lying peats rarely contain over 10% of wax resins. Average values in low-lying peat groups range from 5.7% (wood group) to 7.2% (herbal group). Low-lying moss group is characterized by a low concentration of wax resins, which is typical of wood peat in spite of the difference in the decomposition degree. It confirms the important role of peat-forming plants in enriching peat with wax resins. In comparison with the results of the analysis of peats found in the European territories in which the concentration of wax resins varies from 1 to 18% [12], the examined peats have a higher content of resins: the range is 1–25% of TC.

The organic residue which is left after the extraction of lipids, humic acids and hydrolysable compounds is non-hydrolysable. In the analysed peats non-hydrolysable residue makes on average 36.7% of TC with a range of 11–65%. There have not been found any significant differences based on the botanical composition, ash content and decomposition degree of peat.

Conclusions.

1. High-moor peats have a high content of wax resins and carbohydrates (the sum of hydrolysed fractions) and a low content of humic acids. Compared with peats found in other regions, the OM content of West Siberian peats includes a higher concentration of wax resins. Fraction composition of scheuchzeria peat differs essentially from high-moor peats in a high content of HA, wax resins and a low content of carbohydrates. High-moor moss peat with the lowest degree of decomposition is characterized by the lowest HA content and a high content of carbohydrates with an average content of free HA and a high concentration of wax resins.

2. Low-lying peats tend to have a high HA content and a low content of wax resins, but in general the concentration of wax resins is still higher than in low-lying peats of the European part of Russia.

3. Low-lying peat, unlike high-moor peat, includes fewer hydrolysed fractions. The level of hydrolysed fractions increases from the wood group to the moss group of peat with slight variations of HA content.

4. The degree of decomposition cannot be an indicator of the level of peat humification and HA content in peat without regard to its botanical composition. The total content of HA in low-lying peats increases in the following succession: the herbal-moss group, the moss group, the wood group, the wood-herbal group, the herbal group.

5. Different types of peat that belong to the same botanical group vary in the content of HA1 less than peats of one type with different botanical composition.

6. Geochemical conditions of peat formation process influence HA2 content in peats. A high content of HA2 in peat can be considered an indication of secondary ash-content influence.

7. The concentration of easily hydrolysable substances depends on the quantity of moss residues in peat and is not determined by the degree of decomposition. The

content of fractions of easily and difficultly hydrolysable substances can be an indicator of peat resistance to microbiological degradation.

Thus, the composition of organic matter in peats of different origin should be taken into account when producing peat based organic fertilizers.

REFERENCES

1. Lvov, Yu.A. Learners' Guidelines to Typology and Classification of Tomsk Region Bogs. *Types of Bogs in the USSR and Principles of Their Classification*. Moscow: Nauka (1974): 188–194.

2. Ponomaryova, V.V., Nikolayeva, T.A. Methods of Organic Matter Study in Peat Bog Soils. *Pedology. No. 5*. (1961): 88–95.

3. Lishtvan, I.I., Korol, N.T. Basic Peat Properties and Methods of Their Identification. Minsk: Nauka i Tekhnika (1975): 250.

4. Rakovsky, V.E., Pigulevskaya, L.V. Peat Chemistry and Genesis. Moscow: Nedra (1978): 231.

5. Efremova, T.T. Humus and Structure Formation in Forest Peat Soils of Western Siberia. *Doctoral Thesis*. Novosibirsk (1990): 23.

6. Pereverzev, V.N. Biochemistry of Humus and Nitrogen in Soils of the Kola Peninsula. Leningrad (1987): 256.

7. Olinevich, V.A., Kofman, I.Ya. The Qualitative Composition of Organic Matter in Developed Peat Soils of the Ukrainian SSR. *Pedology. No. 1*. (1977): 73–82.

8. Slavnina, T.P. Pashneva, G.E., Kakhatkina, M.I., et al. Soils of the Middle Ob River Floodplain and Their Reclamation Condition and Agrochemical Characteristic. Tomsk: Tomsk University Publishing (1981): 226.

9. Buhman, V.A. Estimation of Group and Fractional Structure of Organic Matter in Peat Soils of Karelia. *Proceedings of Karelian Department of the USSR Academy of Sciences*. Leningrad (1957): 108–114.

10. Efimov, V.N. Peat Soils. Moscow, Rosselkhozizdat (1980): 254.

11. Shyrokikh, P.S. Organic Matter and Nitrogen Compounds in Lowland Peat Soils with Different Botanical Composition. *Siberian Journal of Agricultural Science. No. 1*. (1981): 16–20.

12. Catalogue of Peat and Sapropel Samples in the Collection of Geoltorfrazvedka Trust. Moscow (1974): 189.