Acta Agrophysica, 2000, 26, 95-107

PHYSICOCHEMICAL PREREQUISITIES OF PEAT SOILS DEGRADATION

I.I. Lishtvan, A.M. Abramets, V.M. Kraiko, L.S. Skoropanowa, G.S. Monich, S.V. Kokonova

Institute for Problems of Natural Resources Use and Ecology, National Academy of Sciences of Belarus, Staroborisovsky tract 10, 220114, Minsk, Belarus

Abstract. The results of investigation on peat soils with different degree of mineralisation are presented. Regularity in changes in water-physical properties of peat soils due to agricultural trends in utilisation are discussed. It is shown that humic substances provide a significant impact upon hydrophylic properties of the peat soils.

Keywords: peat soils, soil structure, water-physical properties, humic acids, hydrophylic properties.

INTRODUCTION

According to modern ideas, peat soil moisture capacity is defined by structure peculiarities, hydrophylity, matter rheology, contents of various water categories in it. Peat is referred to restricted swelling systems, where moisture adsorption is accompanied by its cellular and osmotic penetration inside structural elements. Thus, organic structure components undergo deformation variations, i.e., swelling. The process continues till the structures existing in the spatial net of the swelling coagulation and inter-binding tension can no longer balance the pressure of material swelling [2].

When used for farming, peat soil undergoes systematic drying- humidification. When peat soil or peat dries, moisture is removed in strictly relation to the energy of its link with matter solid phase [4,6]. First, free moisture is removed, i.e., cell and pore moisture. Further, due to cellular forces, the immobilised moisture is removed (in-cell, structure-captured, osmotic). The immobilised peat moisture, as a rule, is in direct proportion to the hydrophylic colloid contents in it. The higher the contents of gel-like structures, the more immobilised moisture is found in it. At the moisture of about 100-150%, more energetically linked moisture is removed out of

Table 1. Classification of water bound forms in peat systems [3,4]

Moisture category	Energy bond $A.10^3$, J mol^{-1}	Average moisture contents, %
Chemically bound water	40-400	2-5
Physically-chemically bound	20-60	40-50
Water of monosorption	till 60	10-15
Osmotic (entropically-bound) water	2	60-80
Water from mechanical retention		600-900
including:		
cellular retention	0.8	500-600
in-cell retention	-	100-150
immobilized	-	80-110
structure-captured	-	40-50

peat. At the dewatering stage, the solid matter phase undergoes irreversible structure deformation due to contact formation between material particles. As a result, the capacity of peat systems to accumulate water reduces.

When physically-chemically bound moisture is removed from peat soil, its structural and mechanical properties change much more significantly and irreversibly. Dewatering process is accompanied not only by the structural change, but results in an irreversible content decrease of physically-chemically bound moisture. The average moisture content in peat is given in Table 1.

Maximum water contents retained by the material due to various forces of nature (cellular, molecular, osmotic, etc.) is related to dry matter mass and defines its complete moisture capacity [3]. This parameter characterizes balanced material state. Water absorption is a process, characterizing the ability of a material to immobilize (accumulate) moisture. In the process of moisture adsorption by peat, three stages can be singled out tentatively. The initial one (sorption-cellular), when cellular water adsorption is preceded by the sorptional hydration of the solid phase active centers of dry matter by water steam (Fig. 1). This phenomenon is accompanied by heat, relaxation of interaction of material structure elements in relation to one another, i.e., moving apart under pressure impact. At the next stage (transition) porous space of peat systems

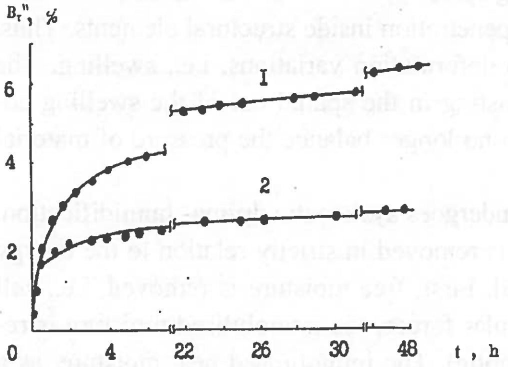

Fig. 1. Reed peat swelling kinetics under water sorption depending on its initial moisture. 1-w_i=59.2 %; 2-w_i=63.1 %.

is completely filled with water. The material absorbs 70-90% of its maximum moisture capacity volume.

The second stage (transitional) is characterised by the diffusion water immobilisation mechanism and its introduction into microporous compact structures, and also into hard-to-reach for moisture material zones.

At the last stage (final) absorption of moisture by the material is due to the entropic and osmotic effects. This process runs slowly, for the material structural elements is accomplished, and its volume deformation refers to the swelling of over-molecular structures of humic peat compounds and under composed residues of peat-forming plants. In relation to the starting moisture content in peat soil, the amount of absorbed water varies in it (Fig. 1). The lower the initial soil humidity is, the more clearly the first stage is shown in the water absorption curves, and vice versa, with an increase in the material moisture, the share of sorption phenomena into the water immobilisation process reduces, or does not reveal at all (Fig. 2)[5,8].

Periodic wetting-drying is the reason for the decrease in peat system moisture absorption ability (Fig. 2). Water properties of peat systems that were firstly dried till air-dry are subjected to especially significant changes. This is due to the processes of irreversible structure change running in colloid peat fragments when dewatered. Mechanical impact upon peat organic matter, peat soils, accompanied by their dispersion increase, enhances degradation efficiency of peat water absorption ability even more.

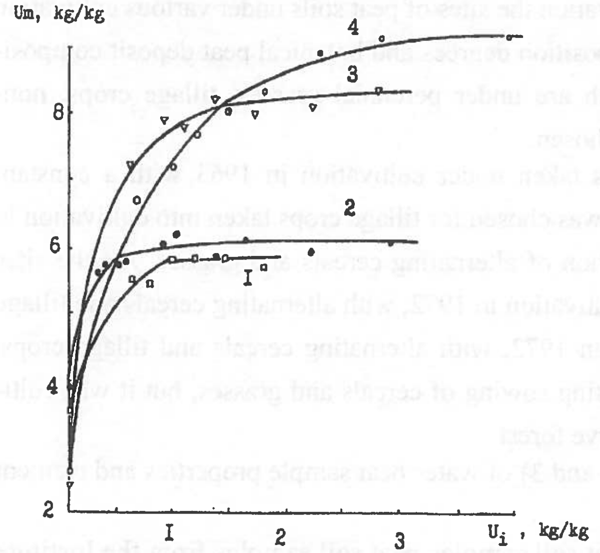

Fig. 2. Maximum water content (u_m) value variation of sedge peat depending on the initial contents of moisture (V_i) in it. The tillage crops site since 1971. 1-h=0.00-0.10 m, 2-4=0.10-0.30 m, 3-h=0.30-0.40 m, 4-h=0.40-0.65 m.

MATERIAL AND METHODS

The study of the regularities of peat soil water-physical property changes due to drying and trends in agricultural utilization was carried out in the period 1974-1996. The research objects were peat soils of the Polessye Test-Ameliorative Station (PTAS), located at the "Khol'che" deposit in the central part of the Polessye lowland. The PTAS

Table 2. Acidity and values of balanced moisture capacity of the water steam sorption for PTAS peat soil samples

Sample No.	Sample selection depth, m	pH		u, kg kg^{-1} ($\varphi=0.9; T=293$ K)
		KCl	H_2O	
1a	0-0.15	5.50	6.31	0.30
	0.15-0.30	4.70	5.71	0.22
1b	0-0.15	4.01	4.63	0.14
	0.15-0.30	4.07	4.60	0.10
3	0-0.15	5.33	5.99	0.33
	0.15-0.30	5.78	6.37	0.13
4	0-0.15	4.95	5.76	0.33
	0.15-0.30	5.05	5.82	0.34
7	0-0.15	6.43	6.91	0.32
	0.15-0.30	6.34	6.96	0.36
8	0-0.15	4.70	5.20	0.40
	0.15-0.30	5.02	5.46	0.40

occupies a territory of 4700 ha, of which 1500 ha is non-drained deposit. Drainage was carried out on 800 ha in 1960-1962. In 1972-1974 drainage was done on 2500 ha. 400 ha were drained by pottering and 400 vertically. The rest of the area was drained by an open channel net. Water catchment is a controlled river bed of the Bobrik. In the territory of the station the sites of peat soils under various cultivation methods with different decomposition degrees and botanical peat deposit composition, farming utilisation, which are under perennial grasses, tillage crops, non-drained virgin land, etc. were chosen.

Point 1 “a” (Table 2) was taken under cultivation in 1963 with a constant monocrop grasses. Point 1 “b” was chosen for tillage crops taken into cultivation in 1963. Point 3 includes cultivation of alternating cereals and grasses. All the sites listed above were taken into cultivation in 1972, with alternating cereals and tillage crops. Point 4 was cultivated in 1972, with alternating cereals and tillage crops. Point 7 is on the site with rotating sowing of cereals and grasses, but it was cultivated in 1972. Point 8 is a reserve forest.

Basic parameters (Tables 2 and 3) of water peat sample properties and element composition were determined.

Besides the Belarusian peat soil samples peat soil samples from the Institute of Land Reclamation and Grassland Farming (IMUZ), Lublin, Poland were used. Physical and chemical characteristics of the Polish peat soils are given in Tables 4 and 5.

The value of maximum water content (w_t) characterises the maximum water content, which the soil can retain. Maximum water content is defined by calculating initial water content (u_n) and maximum water absorption of samples (B_t^W)[7].

$$w_t = u_n + B_t^W(1+u_n) \qquad \text{kg kg}^{-1} \tag{1}$$

$$u_n = \frac{w}{100-w} \qquad \text{kg kg}^{-1} \tag{2}$$

$$B_t^W = \frac{m_t - m_n}{m_n} \qquad \text{kg kg}^{-1} \tag{3}$$

where: m_t - soil weight after wetting in t; m_n - soil starting weight, kg; w initial moisture %.

RESULTS AND DISCUSSION

Figure 3 shows data (1982) on the kinetics of water absorption of the samples from tillage peat soil horizon, formed on the sedge peat deposit of 20-30% decomposition degree. The results obtained show that the greatest moisture amount is absorbed by peat soil of the sites with drained and non-drained virgin land - 278 and 261% correspondingly (curves 1 and 2). Then, in order of reduction, soil of the site occupied with grasses (18 years of cultivation) - 175% (curve 3), soil of the site with cereal cultivation (8 years of cultivation) - 146% (curve 4), soil under tillage crops (18 years of cultivation) - 130% (curve 5).

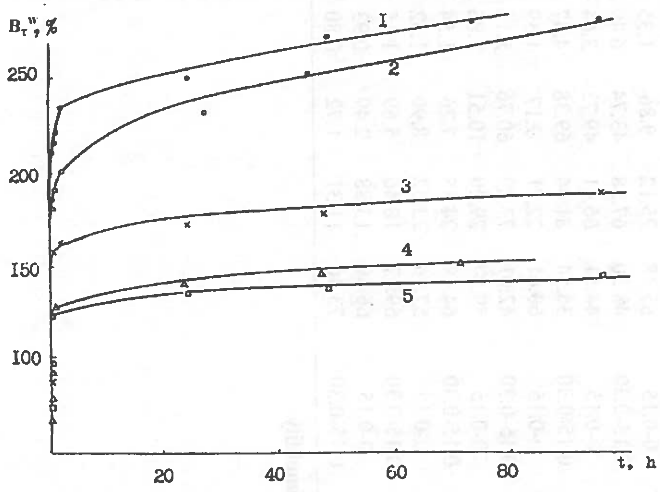

Fig. 3. Kinetics of sedge peat samples and peat water sorption w_i = 60 %. 1. non-drained virgin land; 2. preliminary drainage site; 3. grasses sowing site; 4. cereal crops sowing site; 5. tillage crops sowing site.

Table 6 reflects the maximum water capacity of peat soil in 1982 within the limits of 4.7 - 8.4 kg kg^{-1}. In 1996 on the same areas it was 1.3 - 4.7 kg kg^{-1}; the reason for it is both in the way of farmin and area exploitation.

T a b l e 3. Elemental composition of PTAS peat soil samples (1996)

Sample No.	Sample selection depth m	W*	Ash	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	P_2O_5	S	MgO	Na_2O	K_2O	CaO
		% per dry matter weight												
1a	0-0.15	65.48	25.12	9.86	1.35	3.71	0.07	0.034	1.08	0.54	0.24	0.26	0.77	3.60
	0.15-0.30	48.30	67.58	43.74	6.49	6.12	0.22	0.033	0.60	0.40	0.80	1.03	0.94	3.61
1b	0-0.15	44.51	66.41	49.73	3.64	3.31	0.19	0.029	0.68	0.52	0.41	1.03	1.12	3.25
	0.15-0.30	35.54	81.44	69.38	4.47	1.33	0.24	0.016	0.33	0.25	10.33	1.30	0.92	1.80
3	0-0.15	60.61	22.71	9.17	1.39	2.68	0.07	0.048	0.67	0.47	0.89	0.14	0.44	3.69
	0.15-0.30	42.01	77.89	60.76	5.15	1.70	0.26	0.016	0.47	0.28	0.30	1.20	0.95	3.96
4	0-0.15	59.87	29.29	10.51	1.86	2.09	0.09	0.032	0.70	0.57	1.21	0.05	0.66	6.29
	0.15-0.30	64.79	24.35	7.26	1.54	2.04	0.07	0.029	0.49	0.57	1.02	0.15	0.53	5.61
7	0-0.15	57.76	23.52	8.90	1.52	2.56	0.07	0.026	0.47	0.57	0.40	0.05	0.37	4.72
	0.15-0.30	69.17	18.46	5.69	1.15	2.16	0.05	0.019	0.34	0.52	0.57	0.07	0.29	3.95
8	0-0.15	66.49	13.88	2.49	0.93	1.99	0.04	0.025	0.23	0.38	0.45	0.06	0.09	3.90
	0.15-0.30	73.46	11.31	1.72	0.80	1.58	0.03	0.016	0.17	0.35	0.36	0.03	0.07	3.16

*W - soil humidity

Table 3. continuation

Sample No.	Sample selection depth m	V	Co	Cr	Ni	Cu	Zn	Sn	Pb	As	Sr	Zr	Mo	Cd	Sb
		1.10^{-4} % per dry matter weight													
1a	0-0.15	20.12	<0.75	14.62	2.03	3.01	33.18	<2.51	14.52	1.56	94.20	18.99	<1.26	<1.26	<2.51
	0.15-0.30	157.73	7.91	61.84	6.01	12.64	18.38	<6.76	43.86	<3.38	59.06	88.66	<3.38	4.87	<6.76
1b	0-0.15	27.89	<1.99	23.77	3.92	<6.64	27.69	<6.64	8.04	6.11	71.19	77.77	4.18	<3.32	<6.64
	0.15-0.30	36.16	<2.44	19.06	4.32	<8.14	15.96	<8.14	6.76	<4.07	66.86	92.92	<4.07	<4.07	<8.14
3	0-0.15	22.73	<0.68	14.22	4.79	9.90	21.82	<2.27	15.83	2.75	63.15	21.35	<1.14	2.57	<2.27
	0.15-0.30	28.51	7.94	40.42	5.45	11.06	7.79	<7.79	7.48	<3.89	41.28	88.56	<3.89	<3.89	<7.79
4	0-0.15	9.84	<0.87	15.17	4.51	6.74	15.88	<2.93	13.56	<1.46	51.61	20.24	<1.46	<1.46	<2.93
	0.15-0.30	17.61	0.90	13.42	5.84	<2.44	11.57	<2.44	2.36	1.49	45.92	16.24	<1.22	<1.22	<2.44
7	0-0.15	11.83	<0.71	13.50	4.07	4.37	15.59	<2.35	6.37	1.69	28.88	12.42	<1.18	<1.18	<2.35
	0.15-0.30	12.94	<0.55	8.79	3.45	2.71	6.33	<1.85	1.18	1.07	28.23	8.81	<0.92	<0.92	<1.39
8	0-0.15	8.59	<0.42	6.36	3.71	2.10	3.76	<1.39	3.66	1.68	17.06	3.78	<0.69	<0.69	<1.39
	0.15-0.30	8.05	<0.34	8.62	3.82	2.16	1.88	<1.13	5.04	13.55	4.31	4.31	<0.57	<0.57	<1.13

T a b l e 4. Elemental composition of peat soil samples (IMUZ, Lublin)

Sample No.	W*	Ash	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	P_2O_5	S	MgO	Na_2O	K_2O	CaO
		% per dry matter weight											
1	78.1	18.1	4.63	1.34	1.22	0.05	0.040	0.29	0.52	0.35	0.060	0.23	5.30
2	62.8	18.3	4.19	1.29	2.68	0.05	0.020	0.21	0.64	0.44	0.130	0.14	4.79
3	59.5	39.4	22.39	4.44	3.23	0.16	0.010	0.17	0.48	0.30	0.460	0.45	4.64
4	68.0	18.8	2.27	0.61	2.42	0.02	0.010	0.28	0.56	0.53	0.130	0.12	6.53
5	57.7	23.9	5.11	1.46	2.83	0.07	0.025	0.34	0.83	0.33	0.105	0.16	7.29
6	66.6	22.8	4.65	1.36	2.78	0.07	0.270	0.42	0.79	0.64	0.130	0.14	6.66
7	76.6	16.0	3.64	0.92	2.17	0.06	0.150	0.30	0.60	0.47	0.140	0.17	3.83
8	68.8	24.6	5.27	9\0.75	1.50	0.06	0.020	0.32	0.88	0.96	0.079	0.16	8.27
9	72.5	19.7	4.94	0.98	3.47	0.02	0.020	0.32	0.58	0.28	0.050	0.13	4.97
10	63.2	24.4	8.50	1.58	3.13	0.10	0.030	0.35	0.69	0.32	0.080	0.21	5.63
11	74.6	20.6	9.30	1.68	2.53	0.12	0.020	0.36	0.44	0.09	0.270	0.22	3.31
12	81.5	23.7	12.11	2.14	2.34	0.14	0.020	0.031	0.53	0.57	0.250	0.27	3.06
13	73.2	15.5	1.59	0.47	0.24	0.02	0.001	0.24	0.71	0.37	0.060	0.05	6.04
14	70.1	22.7	6.29	1.13	0.91	0.06	0.090	0.38	0.92	0.37	0.230	0.15	7.26

*Soil humidity.

T a b l e 4. continuation

Sample No.	W	Ash	V	Co	Cr	Ni	Cu	Zn	Sn	Pb	As	Sr	Zr	Mo	Cd	Sb
			$1\ 10^{-4}$ % per dry matter weight													
1	78.1	18.1	5.7	1.3	7.1	2.6	7.9	31.5	2.3	9.40	7.0	31.1	21.2	2.1	<1.0	<2
2	62.8	18.3	15.7	<0.5	9.7	5.2	6.3	8.5	<2.0	5.30	9.0	28.3	17.0	<1.0	<1.0	<2
3	59.5	39.4	48.5	1.9	36.8	10.2	14.9	16.5	<4.0	15.13	9.9	47.0	83.2	<2.0	<2.0	<4
4	68.0	18.8	5.1	<1.0	4.9	1.3	2.3	6.8	<2.0	13.60	2.9	52.8	8.8	<1.0	<1.0	<2
5	57.7	23.9	23.7	<1.0	9.5	3.1	10.5	13.1	<2.0	8.80	2.8	59.9	18.4	<1.0	<1.0	<2
6	66.6	22.8	6.3	1.7	7.5	3.4	7.9	12.3	<2.0	24.60	9.2	46.7	14.5	<1.0	<1.0	<2
7	76.6	16.0	6.8	1.3	4.6	1.9	3.0	17.1	<2.0	14.10	11.3	23.5	14.3	1.4	<1.0	<2
8	68.8	24.6	5.0	2.2	6.1	3.0	5.7	15.2	<2.0	12.20	3.8	68.9	26.1	<1.0	3.0	<2
9	72.5	19.7	7.5	<0.6	6.7	5.7	3.2	3.6	<2.0	6.90	5.9	46.4	17.0	<1.0	<1.0	<2
10	63.2	24.4	9.1	<0.6	11.6	9.4	9.0	11.3	<2.0	17.50	6.4	54.0	40.6	3.5	<1.0	<2
11	74.6	20.6	17.3	3.1	15.1	4.5	9.7	19.0	2.9	22.60	7.1	56.3	34.6	1.4	<1.0	<2
12	81.5	23.7	15.1	<1.0	12.3	4.7	15.0	71.8	<5.0	31.90	9.2	45.8	49.0	<1.0	<1.0	<2
13	73.2	15.5	4.8	1.4	2.1	1.7	3.7	11.5	<2.0	2.90	2.9	115.5	10.1	1.6	<0.8	<2
14	71	22.7	12.1	3.0	7.7	4.7	9.1	5.3	<2.0	13.70	4.7	157.4	31.3	3.6	<1	<2

Table 5. Composition of functional groups of organic matter from IMUZ, Lublin

Sample No.	C_{org} in soil % (to dry matter weight)	Content, % (to C_{org})								
		bitum	HM	HA (tot)	HA (1 fr.)	HA (2 fr.)	FA	EHM	HHM	NHR
1	38.52	2.96	23.72	15.62	5.71	9.92	8.09	14.81	4.83	53.68
2	43.23	2.22	40.29	33.63	20.03	13.60	6.66	7.82	3.32	46.35
3	32.10	4.42	38.03	30.94	20.55	10.39	7.09	7.06	3.76	46.72
4	38.33	2.50	42.06	29.31	10.90	18.41	12.75	11.36	4.12	39.95
5	39.78	3.57	37.87	29.94	20.17	9.77	7.93	7.94	4.08	46.55
6	40.35	2.08	35.22	27.16	19.93	7.24	8.06	7.84	3.32	51.53
7	42.42	2.36	42.13	32.75	16.50	16.25	9.38	11.10	4.10	40.30
8	37.13	2.10	36.22	24.55	10.70	13.85	11.67	11.65	4.87	45.15
9	39.81	4.19	36.45	26.84	13.70	13.14	9.60	9.53	3.52	46.29
10	37.81	3.70	42.16	31.98	10.90	21.08	10.18	9.90	4.36	39.88
11	36.03	5.24	39.83	31.12	12.62	18.50	8.71	11.96	5.02	37.95
12	34.77	5.58	38.66	29.82	8.62	21.21	8.84	12.45	5.19	38.11
13	39.37	1.83	25.89	14.40	5.97	8.43	11.49	11.60	4.49	56.18
14	37.17	1.32	34.29	21.95	8.55	13.40	12.33	12.55	4.52	47.32

Descriptions: HM - humic matter; HA - humic acids; FA - fulvic acids; EHM - easily hydrolysable matter; HHM - heavy hydrolysable residue; NHR - nonhydrolysable residue.

Note: assessment of peat HM wetting with water was done by the analysis of the kinetics of absorption of a distilled waterdrops by the pressed material plate.

Table 6. The value of maximal water content and water content for PTAS peat soil

Sample No.	u_n	W_t	B_t^W	U_n	W_t	B_t^W	Reduction of water accumulation
	kg kg^{-1}						
	1982			1996			
8	1.5	278	8.4	2.0	89.7	4.7	-
3	1.5	178	5.9	1.9	55.9	3.5	0.17
7	1.4	146	5.0	1.5	57.3	2.9	0.15
1á	1.5	131	4.7	0.8	26.9	1.3	0.24

The maximum w_t value is noted in the soil samples, from non drained depo-sits, and the minimum under tillage crops. The rate at which reduces water accumulation (kg kg^{-1} a year) under cereals and grasses is the level of 0.15-0.17 and is enhanced distinctly on the soils under tillage crops (0.24), where soil water degradation abilities are 1.5 higher than under grasses. Peat soil under tillage crops annually lose their ability to keep about 240 g of water per kg of soil dry matter. Besides, this index does not mean soil organic matter losses due to mineralisation. Taking this parameter into consideration reduction of the total moisture accumulating tillage soil horizon under tillage crops is considered more valuable. Moisture immobilisation by porous peat soil structure depends mainly on the solid phase hydrophylity. Soil wetting with water predetermines the intensity of cellular phenomena in the material, as well as the rate of infiltration and cellular moisture transfer in the soil. Peat soils are polycomponent systems that contain mineral and organic compounds. The nature of their surface (or hydrophylity) varies. Hydrophylic properties of mineral soil particles during the dry-wet process are subjected to no changes practically. Non-decomposed peat that form plant residues represent cellulose formations with no hydrophylic property transformations when dried. Humic peat matters, in turn, change their properties under hydratation quite substantially [1]. Thus, humic acids salts deep their hydrophylity even under many times of drying (Table 7). Humic acids in H-form at 10% moisture represent a material, which practically does not wet with water. The rate of water sorption into the plates of pressed powder is quite different for humic acids (HA) in H-form and in the form of salts (Table 7). This phenomenon requires a more detailed study of its nature. Nevertheless, this experimental fact proves that functional groups determined in the molecular structure of humic matter predermines their hydrophylic properties.

When drying the soil of selected sites under tillage crops, its hydrophylic and water properties vary significantly (Tables 2 and 6). Its sorbate moisture reduces, as wetting worsens. Irreversible humic compounds coagulation results in the reduction of swelling and immobilisation of moisture by the soil.

Regularities are analogous also for peat soils of Poland (Table 5, Figs 4-7). The more humic acids in their composition, the worse is their water wetting at air dry moisture. And, vice versa, the more Ca in the composition of the exchange complex of the same soil samples is, the more hydrophylic they are (Table 5, Figs 4

Table 7. Impact of moisture and peat humic matters form upon absorption rate of water in them

Peat humic matters	Moisture %	Time of water absorption into the pressed powder plate of a material s
Humic acids (H-form)	35.4	19.7
	20.7	310
	15.4	7400
	10.1	>86400
Ca - HA (Humic acids salts)	16.6	4.4
	7.2	3.1
Na - HA (Humic acids salts)	19.2	2.4
	7.2	2.1

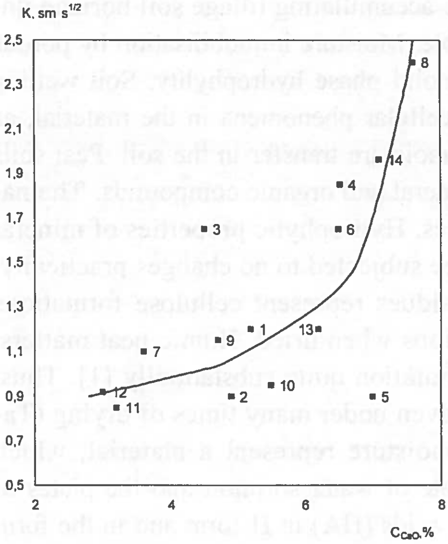

Fig. 4. Influence of the Ca ions contents in the samples of peat soils of Poland on their wetting at dry weight.

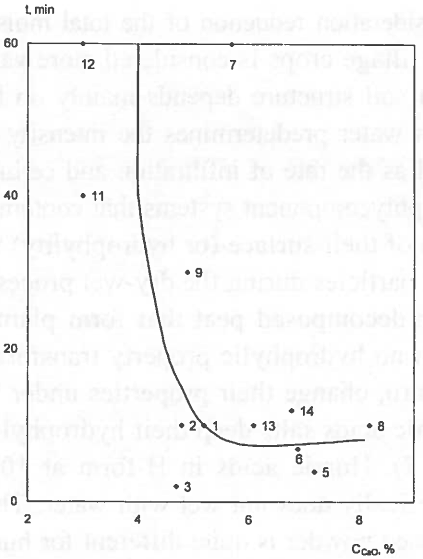

Fig. 5. Influence of the Ca ions contents in the samples of peat soils of Poland on their wetting at air dry moisture (sedimentation method).

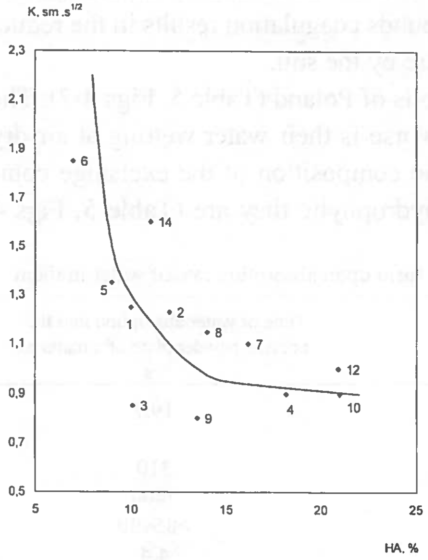

Fig. 6. Influence of the first HA fraction contents in the samples of peat soils of Poland on their wetting at dry weight.

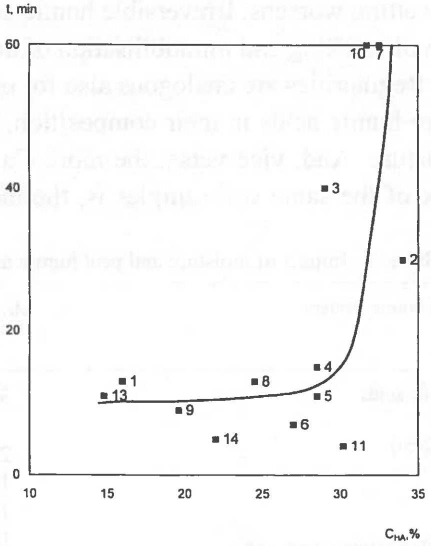

Fig. 7. Influence of humic acids contents in the samples of peat soils of Poland on their wetting at air dry moisture (sedimentation method).

and 5). Moreover, the results in Table 5 and Figs 6 and 7 show, that the most substantial impact on peat soil water features exerted the first HA fraction, i.e., HA fraction, in which molecular structure preserves aromatic fragments. The higher the content of a given HA fraction, the worse water properties of the soil. The mechanism of action of these HA fractions calls for independent experimental analysis.

CONCLUSION

Analysis of the presented results proves that the main impact upon water peat soil properties is exerted by the way it is cultivated, i.e., the way of farming. Peat soil is subjected to maximum degradation of water properties where tillage crops are cultivated. Change of water properties of peat soil systems, in general, is a result of transformation processes of their organic matter. Their intensity rate depends, certainly, also on such factors as: water and heat deposit regime, its type, peat acidity, mineral fertiliser doses etc. But, the research carried out enabled to reveal interrelation between transformation processes of the humic complex of peat soils and changes in their water properties.

REFERENCES

1. **Abramets A.M., Lishtvan I.I., Churaev N.V.:** Mass transfer in natural dispersed systems. Minsk: Nauka i Tekhnika, 288, 1992.
2. **Amaryan L.S., Bazin E.T., Lishtvan I.I.:** Study of the mechanism of swelling of weakly decomposed (fibrous) peats. In: Problems of physical-chemical mechanics of fibrous and porous dispersed structures and materials. Riga, 407-411, 1967.
3. **Bazin E.T., Gamaunov N.I., Lishtvan I.I.:** Peat water properties. In: Peat physical-chemical properties (water properties, heat-mass transfer). Kalinin, 4-26, 1975.
4. **Churaev N.V:** Impact of peat drying on its water and structure-mechanical properties. In: Tr. Kalininskogo Peat Institute, M.-L., 2963, pub. 13, 29-38, 1963.
5. **Lishtvan I.I., Bazin E.T., Kosov V.I.:** Peat water properties. In: Peat physical-chemical properties (water properties, heat-mass transfer). Kalinin, 4-26, 1975.
6. **Lishtvan I.I., Korol N.T.:** Basic peat properties and their identification techniques. Minsk: Nauka i Tekhnika, 320, 1985.
7. **Lishtvan I.I., Terentyev A.A., Bazin E.T., Golovach A.A.:** Physical-chemical bases of peat industry technology. Minsk: Nauka i tekhnik, 232, 1983.
8. **Sorokin A.I.:** Change of water-physical peat properties under agricultural use of peat deposits. Avtoref. diss. kand. nauk. - Minsk, 1986.