PROBLEMS OF HEAT/MASS TRANSFER AND STRUCTURE FORMATION IN EASILY DEFORMABLE NATURAL DISPERSE SYSTEMS

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The results of studies of the processes of structure formation and moisture transfer in shaped organogenous materials are presented. Principles have been formulated for selecting and using SAS and HMS for desired variation of moisture transfer and migration of ions in natural disperse systems. The results of experimental and theoretical investigations of heat/mass transfer and structure formation in freezing organogenous systems are given.

In present-day colloidal-chemical terms, organogenous easily deformable natural disperse systems (peat, brown coals, sapropels, soils, etc.) are semi-colloidal high-molecular multicomponent polyfractional hydrophilic systems with the features of polyelectrolytes and micromosaic heterogeneity [1, 2]. At different stages, the colloidal-chemical investigations of such systems, including the study of the problems of heat/mass transfer and structure formation, were multiple investigations covering a wide range of research. Their establishment and advance were greatly influenced by the works of A. V. Dumanskii, P. A. Rebinder, A. V. Luikov, F. D. Ovcharenko, M. P. Volarovich, N. V. Churayev, K. S. Akhmedov, S. G. Solopov, S. S. Korchunov, et al. [1, 3]. The studies of the colloidal-chemical properties of peat were conducted on the basis of the classical colloidal chemistry works of A. V. Dumanskii, P. A. Rebinder, B. V. Deryagin, F. D. Ovcharenko, S. M. Lipatov, et al. [4]. An important contribution to the development of the basic notion of peat as a disperse and semi-colloidal high-molecular system was made by the works of M. P. Volarovich, N. V. Churayev, V. Ye. Rakovskii, P. I. Belkevich, F. A. Opeiko, N. I. Gamayunov, et al. [1-4]. The studies of Soviet physicists-chemists on the dispersiveness, hydrophility, rheology, and mechanics of peat as well as investigations of its ion-exchange and electrophysical properties and processes of structure formation and heat and mass transfer under different conditions have become widely known [5, 6-28]. Colloidal-chemical investigations were advanced in the context of the problems of practice and contemplated development of scientific foundations for the present-day technologies of peat production and raw peat processing with the intent of obtaining new products and materials [9, 10, 20, 22, 23, 25-27].

The dispersiveness or fractional composition of peat is the most important characteristic of its colloidal-chemical properties [2, 3, 25]. Practically, any mechanical operation in extraction and shaping of lump peat and in peat milling entails change in the peat dispersiveness when the peat is processed in the presence of surface-active substances (SAS) and electrolytes. Thus, it was shown that the addition of some amounts of SAS facilitates an increase in peat dispersiveness due to adsorption of these materials on the phase interface. When peat is processed in the presence of alkalis, the effect of chemical dispersion shows up in full measure only on the addition of anionic SAM's. Through eased breaking of particles, the specific energy expenditures (referenced to new unit surface) in peat processing can be lowered by 5—70%.

Extensive investigations of the dispersiveness of peat of different botanical compositions made with the aid of an electron microscope show that mechanical processing and dispersion in the presence of up to 1-20 mg-eq/100 g m.w. of alkali metals do not alter the distribution into the fractions of less than <1 μm. Processing in the presence of SAS qualitatively changes the fine fraction, with the predominant accumulation of the fraction <5 μm.

The dispersiveness of peat varies substantially in the plowing horizon of peat bogs. This is associated with

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the processes of mineralization of organic material, wind and water erosion, as well as with effects exerted on the soil in the course of land development.

The entire complex of research into peat dispersiveness allows the conclusion that the structure of peat should be evaluated using the fractional composition, the content of overall fractions, rather than its specific surface, since phase phenomena in peat and other organogenous disperse systems are expressed but slightly [2]. Basic to all kinds of peat and sapropels are structures with interlocked remnants of peat-forming plants, supermolecular complexes of decomposition products and individual species of organic and mineral components being in equilibrium with the aqueous solution of low- and high-molecular substances. In peat, soils, brown coals, and sapropels inorganic compounds are represented by insoluble minerals of various origins, adsorptional formations of minerals with humic degradation matters, inorganic components of the water of peat bogs, and ion-exchange heteropolar organic-mineral derivatives. The basic kinetic unit of such systems is the aggregate-associates of the macromolecules of coexisting components permeable for water molecules and ions. The ordered portions of decomposition products or new phase nuclei along with bitumen aggregates, oriented portions of hardly and easily hydrolyzed substances and insoluble inorganic compounds are relatively impermeable for water molecules and ions [1-3].

In organogenous natural disperse systems one must distinguish between macro- and microstructures. Wood, grass, and moss nondecomposed remains form easily deformable interlocking structures whose degree of development is mainly determined by the level of biochemical decomposition of original plants. The peat microstructures form supermolecular formations of organic and mineral compounds. If these compounds are comprised into associates (aggregates), we can isolate inter- and intro-aggregate structures of various overall sizes. The basic features of such structures depend on the botanical composition of peat, the degree of decomposition and the peat formation conditions, and the chemical composition of the medium.

As shown by electronic-microscopic observations, the associates can involve fibers, scraps of vegetable tissues of different dispersiveness, bitumen systems, decomposition products and mineral inclusions that form a gamut of unstable complexes. Their compact form is determined by the nature of peat, the energy and character of intermolecular forces, basic to which are the interactions between active functional groups through hydrogen bonds, ions and molecules of the medium, as well as through chemical and other bonds. For this reason, the peat systems are governed by the rule of dynamic dispersional equilibrium: compactly aggregated state $\rightleftarrows$ gel $\rightleftarrows$ sol $\rightleftarrows$ true solution.

The present paper considers some findings of investigations recently carried out at the Institute for Problems of Use of Natural Resources and Ecology of the Academy of Sciences of Belarus and at the Laboratory of the Physicochemical Mechanics of Natural Disperse Systems. Taking part in those studies were A. A. Terentiyev, A. M. Abramets, A. M. Lych, N. N. Bityukov, I. V. Kosarevich, I. I. Romanenko, V. I. Tanovitskii, G. P. Brovka, A. A. Murashko, P. N. Davidovskii, I. V. Dedyulya, et al.

First of all, let us consider the results of research into the processes of structure formation and moisture transfer in shaped organogenous materials. In recent years this kind of product has been widely used as communal fuel and raw material in chemical technology, particularly in the technology of the production of wax and combined granular fertilizers. Not all kinds of raw material allow one to obtain finished products that would satisfy the strength standard. This is especially true for valley peat. Due to nonuniform shrinkage, this peat is liable to crumbling while being dried. Optimally correlated, the mechanical dispersion and chemical modification can ensure regulation of the product-quality indices within wide ranges. Usually, when shaped peat is being dried, a continuous process of transition of coagulation- to phase-type contacts takes place. In peat, coagulation-type contacts originate during the interaction of functional groups directly through water molecules and ions of multivalent metals. The main condition for the formation of extremely dense structures is the correspondence of the rate of shrinkage to that of dehydration. However, in real conditions this is rarely realized. Already in the first stages of dehydration the structure becomes so strong that molecular and capillary forces are unable to displace its elements in accordance with the quantity of removed water. And even if deformation (shrinkage) is taking place, the accumulating nonrelaxed stresses may lead to the local break in the material continuity. In this case the strengthening mechanism amounts to the necessity of plasticizing the system, i.e., of increasing its fluidity. This facilitates material shrinkage in a larger range of moisture contents and creates the conditions for the origination of elastic bonds between the structure elements that diminish the dimensions of compact structures. These conditions are partially realized when low-molecular SAS's,

polyelectrolytes, and HMS solutions are employed.

When using ASAS and NSAS, the dependence of the relative strength on the SAS concentration passes through a maximum and has a characteristic form. Three regions can be isolated: partial filling of a monolayer, formation of secondary adsorptional layers, and appearance of SAS in the pore solution.

It was observed that ASAS and NSAS interact only with the surface of a peat particle and do not penetrate into its interior. Therefore, the strengthening is based on the surface (adsorptional) rather than volumetric phenomena. Being adsorbed by the hydrophobic mechanism, SAS equalize the wetting ability of the surface and create a structural-mechanical barrier on it. The aggregation ability diminishes and, as a consequence, plasticity increases, which is prerequisite for creating strong structures. However, this condition will be realized only in the case where the capillary forces responsible for shrinkage do not become smaller. They will become smaller if surface tension-reducing SAS molecules appear in the pore space.

The strengthening efficiency is influenced by the salt composition of the medium, its pH, and the length of the reagent hydrocarbon radical. If peat has a great number of cations, a portion of ASAS molecules interacts with the cations of polyvalent metals. They lose their SAS properties. Partially, ASAS can be sorbed on peat through a polyvalent cation and can block it and make the given portion water repellent. For this reason, the efficiency of ASAS in the valley peat, rich in polyvalent cations, is not high. More promise attaches to NSAS in combination with ASAS. To attain the maximum effect, the hydrocarbon chain should be of a fully defined length. If the chain of the molecules is long, their adsorption may lead to blockage of hydrophilic portions and growth of the micromosaic heterogeneity of peat particles. The optimal length of the hydrocarbon chain is C_{10}-C_{16}. As $C > C_{16}$ grows, the value of KKM becomes smaller and SAS is found in micellar form in the pore space.

The liquid phase transport in natural media, drying and structure formation are very much influenced by the mass transfer properties of such systems, which in turn determine the intensity of moisture transport and the efficiency of a certain scheme of moist raw material processing. On the other hand, the mass transfer characteristics of natural disperse systems vary not only with the type of peat moor, but also within the same moor, allowing one to ensure the required qualitative parameters of the product by using standard extracting and processing equipment in various regions. One of the trends in solving this problem is the use of physicochemical methods of active control of the processes of moisture transfer in natural systems by acting purposely on the surface phenomena.

It was found that the thickness of wetting films and the overall content of the bound moisture depend on the surface charge of the material aggregates. The charge of the structural units of peat is very sensitive to the change in the chemical potential of the medium. As pH rises, the content of the bound moisture in peat systems increases, i.e., as pH in peat varies, the ratio of the bound moisture categories changes, and this influences the moisture mobility in the material. Thus, the water diffusion coefficient (a_m) in peat within the range $2 < pH < 9.5$ varies by about two orders of magnitude. In this case, to low values of pH of the material correspond large values of a_m but smaller values of the thermal mobility of moisture (δ). And conversely, as pH rises, a_m falls, but δ grows.

Generally, the isothermal transfer of moisture in capillary-porous systems chiefly consists in the flow of dispersion medium as capillary and film moisture in the spaces between the material particles and over their surface under the action of the moisture transfer potential gradient (moisture potential). For being able to move in the water molecule volume, the dissolved compounds should overcome the forces of interaction with their "neighbors" and, besides, the molecular forces that act within the layers of bound moisture and impede its motion. Naturally, the diffusional mobility of pore solutions (of dispersion medium) is much smaller within the limits of the action of molecular forces than in the volume. The reduction of the content of bound moisture in peat systems due to the transfer of the surface of the aggregates into an isoelectric state with decrease in the pH of the medium intensifies the diffusional mobility and the transport of ions to the zone of mass sink.

As pH grows, the diffusion of water, moisture conduction and migration of water-soluble compounds in peat systems decrease. However, in this case a certain influence on the transfer of moisture and solved substances is exerted by the changes in the structure and volume capacity of peat, namely, as pH grows, the organic components of peat undergo intense swelling, thus diminishing the active capillary network and the moisture conductivity of the material. As pH falls, the reverse of the process described is observed in peat. Loose humic formations of peat undergo compact coagulation and activate the capillary network and the transfer of moisture in the material. According to the

nature of a_m variation, the peat systems with pH $\leq$ 4 can be related to capillary-porous materials, and those with pH >4 to typical colloidal materials. In the former case this process promotes intensification of the redistribution of ions and in the latter case it causes a decrease in moisture exchange in natural systems. The regulation of pH is a process which can be easily realized in practice by modifying peat systems by means of alkaline or acid reagents.

Ultimately, the investigations have shown that the mobility of the dispersion medium of peat systems depends substantially on the surface character of the phenomena on the interfaces of the aggregates; this finds practical application for regulating mass transfer in hothouse grounds and in drying of lump peat.

As is known, during nonisothermal moisture transfer in the state of equilibrium in disperse material the circulation of the dispersion medium spontaneously develops along a peculiar closed scheme: thermodiffusional vapor flow (TDF) + thermal flow of bound moisture (TFM) + thermocapillary moisture flow (TCF) $\gtrless$ diffusional flow of moisture (DFM) + film flow of moisture under the disjoining pressure gradient (PG). Diffusional processes are most vigorous in a medium less bound by surface forces, where the rate of diffusional processes is maximal, i.e., in the moisture layers closely adjacent to the liquid-gas interfaces. Therefore, in the case of the steady-state regime of moisture exchange (the overall moisture flow in a material unit volume is equal to zero) the thermal flow of moisture in wetting films will be active not over the entire profile, but only in those layers where TFM exceeds DFM. As a result, depending on the thickness of the wetting films on the surface of the structural units the TFM can form in both the layers adjacent to the liquid-gas interface (thin films) and the layers inside of the wetting film (thick films, capillary moisture). In this case, the sweeping of ions by moisture out of the material is higher, the larger the TFM.

The reduction in the content of bound moisture due to the translation of the solid phase surface to the isoelectric state (with a decrease in pH) intensifies the diffusional mobility of the dispersion medium and the transfer of ions and water-soluble compounds by water to the mass sink zone, i.e., to the zone of phase transitions (evaporation) of water in the material.

At low pH's (at a small content of bound water) the contribution of TFM to the thermal flow of moisture in the material falls, but DFM and PG grow. TDF (the moisture flow in the vapor-gas phase) becomes predominant in the thermal moisture exchange in peat. According to the foregoing, this entails intensification of the transfer of ions to the zone of phase changes of water and the change in the direction of the predominant transfer of ions in the material.

Essential components of the pore solutions of natural disperse systems are organic water-soluble compounds which are substances mainly of hydrocarbon and humic nature. During moisture exchange in natural materials, organic compounds migrate only in the direction of DFM and PG and are not transferred by the thermal flow of bound moisture. This is indicative of the fact that water-soluble organic compounds are localized in the dispersion medium not bound by surface forces, i.e., in the pore moisture (moist state) or in wetting films near the liquid-gas interface.

As a result, in nonisothermal moisture transfer in dispersion materials one observes separation of ions by the direction of migration. The transfer of cations by water films coincides with the direction of the bound moisture flow, whereas the migrational flow of anions predominantly occurs in the opposite direction. At the same time, the transfer of ions by water films in nonisothermal moisture exchange in disperse materials is much higher than in the case of isothermal exchange.

For the appropriate regulation of the processes of ion moisture transfer in porous media wide prospects are offered by the application of SAS due to their selective capability to be adsorbed on the phase interface even in the case of their small concentration in the solution. It was found that ASAS's lower water diffusion in organogenous materials, whereas CSAS's raise it. Simultaneously, the modification of the disperse material by ASAS intensifies the thermal mobility of moisture, whereas CSAS (within the range of concentrations not making for the solid phase surface recharging) decreases it. The mechanism underlying such an effect of SAS is quite conceivable since the introduction of ASAS increases the negative charge of unipolarly charged structural solid phase components and, correspondingly, the content of bound water. The adsorption of the CSAS molecules lowers the negative potential of the particles and the content of bound water. Correspondingly, the process of the migration of ions changes: ASAS's lower and CSAS's intensify the redistribution of ions in the material during moisture exchange in it.

Comprehensive studies of the wetting ability of peat are involved with the works on the study of the wetting

heat of peat [21]. It was found that the specific value of the wetting heat of dry peat is 3-4 times higher than the wetting ability threshold, i.e., than the condensation heat of steam on the free water surface. Investigation of the processes of peat wetting is of importance for fighting peat fires and for the problems of reclamated peat soil irrigation. This interest has lately been evoked in connection with the wetting of peat extracted with gasoline. Certain regularities in the impregnation of porous media with the solutions of surfactants were revealed, making it possible to substantiate the generality and specificity of the mechanism involved in the influx of solutions into model water-repelling quartz capillaries, sands, and natural (peat, bituminous coals) capillary-porous systems. The rate of their influx can be raised by two decimal orders as against water. The techniques of using aqueous solutions of anionic (sulfonol) and nonionogenous SAS (oxyethylated higher fatty alcohols) for recovering the water-receptive properties of peat with reduced moisture content have been developed. The high wetting ability of processed peats is preserved after the filtration of water volumes exceeding by 2-3 decimal orders of magnitude the water volume in the material.

During peat extraction and amelioration one often has to regulate the filtrational properties of peat. It has already been established that peat modification in the water-saturated state by cationic and some nonionogenous SAS's leads to the reduction in filtrational moisture transfer. Micellar solutions of cationic SAS's, in particular the 1%-solution of penasolin, cause almost complete termination of the process. Taking into account the ion-exchange mechanism behind the sorption of cationic SAS's on peat we may recommend the cationic SAS's for creating antifiltrational screens when building embankments on the peat base and laying channels. In general, only low-molecular SAS's are capable of increasing the water filtration factor in peat systems.

In recent years, extensive investigations have been carried out in various countries into the thermophysical and structural-mechanical properties of peat at negative temperatures. A multiple investigation along these lines is being conducted in the laboratory. The kinetics of the phase conversions of water into ice and their influence on the process of moisture transfer, the structural-mechanical properties of peat deposits during freezing and thawing, as well as the accompanying processes and phenomena have been investigated.

On the basis of the research done, a procedure has been developed for computer-aided numerical calculation of heat and mass transfer processes in freezing of peat, and formulas are suggested for approximate calculation of the depth of freezing and thawing of peat deposits, and also recommendations for calculating the processes of depositing milled peat in railroad cars. The mechanism responsible for the cryogenic adhesion of peat to different kinds of surfaces has been investigated and the ways for controlling this process have been determined. New principles of combatting the freezing of peat to metallic surfaces by the electropulse method have been recommended.

Using a special apparatus, the cryogenic adhesion of peat was investigated, the magnitude of which lies within the range from 0.2 to 2.0 MPa for different surfaces and which increases with the moisture content and the material consolidation degree and depends on the ambient temperature, the surface nature, and, to a lesser degree, the peat dispersiveness and initial temperature.

Based on the studies of cryogenic adhesion and the kinetics of shear for the material frozen to peat, new methods have been developed for combatting peat freezing to the internal surfaces of transport reservoirs. At the present time the magnetic-pulse method is being implemented. Investigations have shown that the maximum efficiency of the magnetic flux pressure pulse is attained at a plane circular inductor inductance equal to $100\,\mu H$. The pressure developed amounts to 10 MPa and the duration of the forward front increase to 20-40 μsec. Energy expenditures for magnetic-pulse cleaning of cars do not exceed 1.0-1.5 J/kg. Mechanical damping oscillations of a 1.8-2.2-mm-thick steel plate caused by the magnetic field of the inductor propagate, not losing the destructive efficiency within a radius of 1-1.4 m. At the present time, this method is being introduced into practice at the stations of peat discharge, when breaking down the bridging of loose mineral fertilizers in hoppers, and also during transportation of building materials.

In the laboratory, investigations are being carried out into the mechanism of moisture migration in freezing moist disperse materials. According to the Deryagin-Churayev theory, under the conditions of a stationary temperature field the moisture transfer from a melted to a frozen zone during freezing of disperse materials follows the thermocrystallization mechanism. This means that moisture is transferred either over nonfreezing water films on the surfaces of the capillary walls, if the pore is free from ice, or over nonfreezing water interlayers located between the surfaces of ice and substrate when the pore is being filled up with ice under the action of temperature and pressure

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gradients. Moisture transfer over nonfreezing water films in the absence of the hydrodynamic pressure gradient on models of quartz capillaries has been rather well studied in the works of the Institute of Physical Chemistry of the Russian Academy of Sciences. Also given in those works are the estimates of the most important properties (thickness and viscosity) of nonfreezing interlayers. However, in the experiments set at that institute, an ice column in quartz capillaries moved under the action of a pressure gradient. Based on the results of these studies, estimates were made for the thickness and viscosity of nonfreezing water interlayers. But the data on the actual motion of such water interlayers are lacking. To fill this gap, at the Institute for Problems of Use of Natural Resources and Ecology of the Academy of Sciences of Belarus a special technique has been developed. A capillary-porous body was modeled by a bundle of quartz or glass fibers 12 μm in diameter in the quantity of 20–30 thousand pieces enclosed in a glass container. The container was connected with the measuring capillary. The system filled with water was placed in a special chamber in which the required thermodynamic conditions had been created: the presence of melted and frozen zones and of a temperature gradient in the frozen zone. Water moved over films in the frozen zone and froze on the butt ends of the fibers. Its discharge was determined by the measuring capillary.

The results of the experiments proved the existence of liquid flow from the melted to the frozen zone under stationary temperature field conditions. The dependence of the moisture flow density on the temperature gradient in the frozen zone is close to linear, thus proving the validity of the Deryagin–Churayev theory. Based on the results obtained, the thickness of the nonfreezing interlayer was estimated from the magnitude of the migrational flow. However, the estimate was somewhat approximate. This is due to the fact that the interlayer thickness was assumed to be constant over the length of the fibers, although the temperature along the length of the frozen fibers varied from the ice temperature on their butt ends T_{in} to $T_0 = 273$ K. The results of calculations give some mean value for the given experimental conditions. The dependence of the nonfrozen water interlayer thickness on the temperature T_{in} on the end of the bundle of fibers was obtained. The value of the interlayer thickness varied from 95 $\overset{o}{A}$ at $T_{in} = 271.9$ K to 130 $\overset{o}{A}$ at $T = 272.7$ K. This result is close to the results obtained by other methods.

The thermocrystallizational flow attenuates rapidly as the temperature at the place of ice accumulation falls. Thus, already at $T_{in} = 271.5$ K it deteriorated virtually to zero, which is associated with a sharp reduction in the thickness of the interlayers. The flow was also not recorded in the case of the absence of the frozen zone even though the system was at a temperature below 273 K and a temperature gradient was imposed on it. Such experiments were also carried out with specimens of carbonate sapropel. Under the stationary temperature field condition a time-constant liquid flow from the molten to the frozen zone was recorded at the given temperature gradient for a period of five days.

Thus, the results of experiments with the bundles of quartz fibers and the specimens of carbonate sapropel showed the validity of the theory of thermocrystallizing flows for the processes of moisture migration in moisture-saturated dispersed materials under stationary temperature field conditions.

Investigations into the mass/heat transfer and the physicomechanical characteristics of natural disperse materials are first of all attributable to the necessity of predicting the temperature and moisture-content regimes and the strength and strain properties of frozen grounds. In order to be able to give a rather complete prediction of the processes taking place during freezing and thawing of grounds, it is necessary to experimentally obtain a complex of heat and mass transfer characteristics and strain, strength, and structure-texture properties.

At the present time, a number of methods have been developed for investigating heat/mass transfer and physicomechanical characteristics of frozen grounds, and the corresponding characteristics have been obtained. However, the survey of literature shows that many of the studies are of qualitative nature, they analyze the processes determined by a set of characteristics, dimensions of specimens and experimental conditions, and they do not provide quantitative characteristics of materials. Often, when quantitative characteristics are given, no mention is made of the conditions under which they were obtained or the initial characteristics of the materials studied that reflect the natural-henetic, physicochemical, and aqueous-physical properties of grounds. The overwhelming majority of the methods have not been standardized, there are no serially produced instruments for investigating the characteristics of frozen grounds, and therefore the data given in various publications are hardly compatible.

To ensure the comprehensive investigation of heat/mass transfer and physicomechanical properties of frozen grounds special devices and facilities have been designed. Among them are instruments for determining the capillary

potential of moisture and for measuring the start of freezing of moisture in grounds; a vacuum temperature chamber for sorptional analysis and sublimation of ice from frozen grounds; a calorimetric set-up for determining the quantity of nonfrozen water in grounds and of wetting heat; set-ups for determining the thermal conductivity coefficients of grounds, for comprehensive investigation and modeling of the processes of freezing of grounds, and for modeling the processes of heat and mass transfer in grounds; a device for investigating the shift of frozen grounds in order to estimate their strength and rheological characteristics; a set-up for investigating the structure of frozen grounds, etc.

The basic results obtained with the aid of the new methods and the above-listed instruments boil down to the following.

A thermodynamic model of the phase equilibrium of water in natural disperse systems at negative temperatures has been developed.

Theoretical foundations of moisture migration and structure transformation in the course of freezing of natural disperse systems have been developed which take into account the geometry of the pore space, the presence of water-soluble materials, and the effect of the structural cohesion of the material and external loading and gravitational forces.

The thermodynamic parameters of water in sapropel and peat specimens have been investigated as functions of temperature, moisture content, dissolved mineral substances, and external load. An unequivocal correspondence has been found between the thermodynamic parameters of water, determined at positive temperatures, and the quantity of nonfrozen water in organogenous systems.

The thermal conductivity coefficients have been investigated for typical organogenous systems in melted and frozen states, depending on the moisture potentials.

In model capillary-porous bodies and natural disperse systems in the zone of intense phase changes at 273-270 K, flows of moisture over nonfrozen interlayers in stationary and dynamic temperature regimes have been determined and the procedure of determining the moisture transfer coefficients during freezing has been substantiated.

The diffusion coefficients of water in the melted zone and the thermomoisture conductivity of the melted zone have been investigated as functions of the moisture potential and moisture content for typical organogenous systems.

Basic laws governing the formation of the cryogenic structure of organogenous systems have been elucidated. It has been found that the basic mechanisms are the following two: moisture migration from the melted to the frozen zone with subsequent freezing-out in the form of interlayers of segregation ice and the local redistribution of moisture within the freezing and frozen zones in the process of the dehydratation of the organous-mineral frame aggregates with subsequent freezing-out of water.

It was found that the presence of salt or alkali in the pore solution of sapropel with a weight concentration of up to 2% suppresses the process of mass transfer into the frozen zone. In this case, the cryogenic structure of the organogenous system naturally varies. It is characterized by the predominance of vertical schlieren and by the degeneration of the horizontal component, indicating the suppression of the integrational-segregational texture formation. At the same time the presence of HCl in the pore solution does not exert a substantial effect on moisture transfer in freezing.

The mechanism of shear has been investigated with an instrument of a two-plane cut, and it has been found that irrespective of the magnitude of the gap set up in the instrument between the movable and fixed yokes, the shear takes place in a certain space adjacent to this gap. The rate of shear at the same shear strain is proportional to the squared diameter of the specimen. It was found that for a specimen with the standard diameter of 50.2 mm the equivalent shear zone amounts to 20 mm. The discovered trends in the shear make it possible to determine the invariant parameters on the instruments with different diameters of specimens and, in particular, to determine the shear viscosity of ice and frozen grounds.

The strength and rheological characteristics of typical organogenous systems have been investigated, depending on the temperature, moisture potential, and concentration of NaCl in the pore solution. It was found that the presence of salt in the material lowers the shear resistance to the same extent as the temperature rise corresponding to the change in the quantity of nonfrozen water, by the equivalent value.

Based on the full complex of heat and mass transfer characteristics determined for typical organogenous systems, a mathematical simulation has been made for the processes of freezing at different initial moisture contents and temperatures on the cooled surface. It is found that the parameters of the rate of freezing of organogenous systems are virtually independent of the initial moisture content, but are determined by the temperature on the cooled surface. At the same time, the initial moisture content has a strong influence on the increase in the moisture content in the frozen zone and on the swelling coefficient. It is interesting that for all of the studied organogenous systems at moisture contents close to complete moisture saturation and temperature close to 273 K, a sharp increase is observed in the moisture content in the frozen zone up to the formation of the frozen zone of ice alone.

The procedure of predicting the temperature and moisture regime in freezing and melting of organogenous systems has been developed and recommendations on rational freezing-through of sapropel in winter have been suggested.

Comprehensive investigations of the processes of structure formation in the dispersions of sapropels have culminated in the creation and wide experimental verification of the possibility of their use as drilling solutions. The main results of these works are published in [29, 30].

Thus, we may state that the investigations of the colloidal-chemical properties of peat and other natural disperse systems have made it possible to formulate a new scientific trend, viz., the physicochemical mechanics of natural disperse systems, which allows one, on the basis of monitoring the processes of structure formation, to obtain new materials with prescribed properties. This branch of knowledge forms a part of the physicochemical mechanics of dispersed structures developed by the school of Academician P. A. Rebinder [31].

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