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Abstract

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STUDY OF THE PROCESS OF WATER FILTRATION IN PEAT BY MEANS OF RADIOACTIVE ISOTOPES

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In developing the methodology of the present work, we first had to decide on the choice of a suitable radioactive "label" for the water whose movement in a peat sample was to be studied. This proved to be rather difficult, since unsuccessful attempts in experiments with soils were known ([1]). After a number of experiments it became clear that the most successful label is radioactive sulfur S^{35} (an aqueous solution of $Na_2S^*O_4$).

The filtration of labeled water through samples of peat with an undisturbed structure was studied. A peat sample cut from the deposit was placed in a glass tube and saturated with distilled water to constant weight. After this, labeled water was poured into the tube above the peat, its level being kept constant. The specific activity of the water used in the experiments, labeled with the isotope S^{35}, was 0.005–0.01 μCu/ml. The filtrate was collected in a burette with a stopcock and periodically drained into test tubes, the time of filtrate accumulation being recorded. The activity of the filtrate samples was measured with an end-window counter using a type B-2 apparatus.

The results of one of the experiments with fuscum peat with a degree of decomposition $R = 10\%$ are shown in Fig. 1 (solid lines). Here the abscissa gives the values of the volume V of the filtered liquid in ml, and the ordinate gives the counting rate N of the filtrate samples. The relative error of the activity measurements, carried out under strictly identical conditions, did not exceed 3%. The same figure gives the dependence of the volume V of the filtered liquid on the filtration time τ in minutes. This dependence is close to linear, which indicates the constancy of the filtration coefficient during the experiment. As can be seen from Fig. 1, the activity of the filtrate samples gradually increases and after a certain time $\tau_k = 39.5$ min reaches, at point C, the value $N_v = 1270$ imp/min, i.e., the activity of the labeled water poured in from above. Analysis of the curve $N(V)$ makes it possible to propose the following filtration scheme.

The labeled water, moving through the pores of the peat, displaces the free (gravitational) water contained in them. At first the free water is displaced from the large pores; then progressively smaller pores enter into operation, and,

Fig. 1

Figure 1: Fig. 1

finally, by the time τ_k the labeled water fills all the water-conducting paths in the peat. After this the activity of the filtrate becomes and remains equal to the activity N_v of the labeled water. If all the pores of the peat had the same dimensions, then, obviously, the graph $N(V)$ would be the broken line $OBAC$ in Fig. 1. The deviation of the actual curve $N(V)$ from this broken line is a measure of the nonuniformity of the pore sizes of the peat under investigation. It should be borne in mind here that only water-conducting pores are meant, i.e., those through which the motion of the filtering liquid occurs. Of course, in reality the mechanism of water filtration in porous bodies is much more complicated, as was noted by N. A. Figurovskii (^{2}), who calculated the pore-size distribution for activated carbon from the kinetics of displa-

displacement of liquid from pores by liquid. The paths of water movement in peat are not rectilinear, and the result obtained by us is only a rough approximation to reality. Nevertheless, it is of interest to estimate, at least approximately, the dimensions of the water-conducting pores in peat.

If it is assumed that the paths of liquid motion in the peat sample do not change during the experiment, then from the curve $N(V)$ it is possible to construct curves of the distribution of the amount of filtering liquid over the velocities of its motion and, using Poiseuille' s law, over the dimensions of the water-conducting pores. The curve of the distribution of the amount of filtering liquid Q over the velocities of water motion for fuscum peat is presented in Fig. 2, a. In this figure, the abscissa axis gives the values of the velocity of motion u, and the ordinate axis gives the values of the distribution function dQ/du. As is seen from the graph, the values of the velocities of motion fluctuate within considerable limits. In Fig. 2, b, for the same peat ($R = 10\%$) the curve of the distribution of the amount of filtering liquid over pore sizes is shown. Here the abscissa axis gives the values of equivalent pore diameters D. Examination of the distribution curve leads to the conclusion that the main mass of the liquid flux passes through pores with dimensions $D = 8$-$12\,\mu$. The distribution of water-conducting pores by size can serve as a characteristic of the structure of peat that determines its filtration properties. The method described above was tested on the simplest disperse system, close to an ideal one, namely on homogeneous fine-grained sand with a grain diameter $< 250\,\mu$. In Fig. 2, b the curve of the distribution of water-conducting pores by size for sand is given. The diameters of the water-conducting pores of sand, as follows from the graph, fluctuate within the range from 30 to $100\,\mu$. The values obtained are in good agreement with the actual pore sizes, comparable with the sizes of the sand grains.

Fig. 1

Fig. 2

Figure 2: Fig. 2

As already noted above, only part of the peat water located in the water-conducting pores participates in motion during filtration. The content of "immobile" (3) water in peat, W, is evidently an important physicochemical characteristic determining the water properties of peat. The amount of "immobile" water can be determined from an experiment with filtration of labeled water. The filtrate that has passed through the peat sample during a time $\tau > \tau_{\mathrm{k}}$ (see Fig. 1), in addition to labeled water, also contains all the free pure water displaced from the peat during filtration.

If the volume of filtrate is equal to V_ϕ and the counting rate of the average filtrate sample is equal to N_ϕ, then the amount of "immobile" water V can be found from the formula

$$V = V - V'_\phi + \frac{V_\phi \cdot N_\phi}{N},$$

where V is the total amount of moisture in the peat sample.

For fuscum peat the relative content of "immobile" water was found to be $W = 41\%$ at a peat moisture content at the moment of filtration $W = 91.1\%$. For a sample of medium peat of the same degree of decomposition, W was 38.5% at a peat moisture content $W = 89.0\%$. The amount of adsorption-bound water, determined by A. V. Dumanskii' s method of centri-

of adsorptive adsorption of sugar (4,5), is estimated for these types of peat as a value of the order $W_c = 15$–20%. Consequently, the share of water in microcapillaries, dead-end and closed pores, in these types of peat amounts to 20–25%.

Thus, the proposed method, in combination with the method of negative adsorption, makes it possible to distinguish more precisely the types of water in peat in accordance with the classification of water in disperse systems according to the form of its binding (after P. A. Rebinder (6)).

As can be seen from the figures given, a considerable amount of peat moisture does not participate in filtration. The porosity of peat n_a, taking immobile water into account, corresponding to the content of water-conducting pores in the peat,

Fig. 2

for sphagnum peat is $n_a = 51.7\%$ (the porosity of the sample without taking "immobile" water into account was $n = 94.3\%$). The actual average velocity of water movement in the pores, calculated from the value of the active porosity n_a, was found to be $u_{\mathrm{avg}} = 0.476$ cm/min, which is close in magnitude to the most probable velocity of motion u on the distribution curve (see Fig. 2, *a*). Experiments to determine the quantity of free water in fine-grained sand showed that there is practically no "immobile" water in it and that, consequently, all pores of the sand are water-conducting. On this basis, the reason becomes clear for the very large difference in the sizes of the water-conducting pores in sand and peat (see Fig. 2, *b* and *c*), although both these systems are coarsely dispersed. The pores of peat are filled with "immobile" water, leaving for the movement of free water only narrow passages of capillary dimensions.

However, the data obtained are valid only in the case when the radioactive tracer is not adsorbed by peat particles. To investigate the adsorption of S^{35} by peat, special observations were carried out. After completion of the experiment with filtration and draining of the labeled water, an experiment was conducted with filtration through the same sample of pure distilled water. Moving through the pores of the peat, the distilled water displaced the labeled water that had filled them during the first experiment. The activity of the filtrate thereby decreased from the activity of the labeled water $I_\mathrm{v} = 1270$ counts/min to zero. The curves $N(V)$ and $\tau(V)$ for this experiment are given in Fig. 1 (dashed lines). In the experiment with filtration of pure water, the amount of "immobile" water in the peat can also be determined. The value obtained in this case, $W_\mathrm{n} = 40.8\%$ for sphagnum peat, differs only slightly from the value W_n calculated earlier, which indicates the absence of noticeable adsorption of the indicator. Negative adsorption of Na_2SO_4 had also been noted earlier ([4,7]).

After filtration was completed, the peat sample was removed from the tube and cut into equal parts along its height. Powders were prepared from the dried peat samples, and their activity was measured with an end-window counter. As the calculations showed, during filtration of water labeled with S^{35}, no more than 3–4% of the indicator is adsorbed by the peat. Similar comparative experiments carried out with radioactive phosphorus P^{32} (an aqueous solution of $Na_2HP^*O_4$) showed that phosphorus is adsorbed even in a thin layer of peat almost completely.

At low rates of liquid motion, a noticeable distortion of the curves $N(V)$, and consequently of the experimental results, may occur because of diffusion of the radioactive tracer in the liquid. Special experiments showed that in our case the diffusion of $Na_2S^*O_4$ could not introduce an error of more than 1%.

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References Cited

1. V. I. Breslav, G. A. Melik-Shakhnazarova, I. M. Taksar, *Izv. AN LatvSSR*, No. 3 (92), 99, 1955.

2. N. A. Figurovsky, *DAN*, 20, No. 6, 453 (1938); *ZhFKh*, 12, No. 5–6, 619 (1938).
3. A. I. Budagovsky, *Absorption of Water into Soil*, Publishing House of the Academy of Sciences of the USSR, 1955.
4. A. V. Dumansky, *Lyophilicity of Disperse Systems*, Voronezh, 1940.
5. N. N. Kulakov, *Introduction to the Physics of Peat*, 1947.
6. S. S. Korchunov, *Investigation of the Physicochemical Properties of Peat*, collection of articles, 1953.
7. A. V. Dumansky, *The Theory of Colloids*, 1948.

Note: Figure translations are in progress. See original paper for figures.