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STUDY OF MASS TRANSFER IN THE EXTRACTION OF MOISTURE FROM CAPILLARY-POROUS MATERIALS

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Processes of extraction of water from moist clay minerals by an organic solvent, dioxane, are examined. It is shown that these processes conform to the fundamental laws of mass transfer.

Mass transfer from solids to a liquid flow is comprised of removal of absorbed molecules from the pore walls, diffusion from inside the discrete grains to the grain surface, and outward diffusion through a granular layer to the surrounding medium.

Moist materials consist of a solid skeleton around which water is distributed. It may be free, easily removed from the surface, or be located in micro- and macro-capillaries. The most strongly bound water forms a monolayer. Therefore the process of extraction of moisture from such a substance, like any other mass transfer process, depends on the nature of the bond between the water and the material.

Moisture extraction from solids can be described by the criterial equation

$$E = \frac{c - c_\infty}{c_0 - c_\infty} = A(\mathrm{Re}')^\alpha (\mathrm{Pr}')^\beta (\mathrm{Fo}')^\gamma$$

and by the extraction rate equation

$$dE/d\tau = \varphi(w).$$

We have derived these relations for the case of the extraction of water from moist clay materials by an organic solvent, dioxane, which readily forms a donor-acceptor bond with the water molecule [1]. The small dielectric loss factor of moist dioxane and the unlimited solubility of water in it formed the basis of a capacitive method of studying the moisture content of the extract. Uniform distribution of the water extracted from the moist material in the dioxane was achieved with a special type of moisture-content probe.

The extraction process was investigated on an apparatus consisting of probe-extractor and secondary measuring and recording apparatus. The probe-extractor consisted of a cylindrical brass vessel, the body of which served as the outer electrode of a capacitor transducer. The second electrode, in the form of a grid, was placed coaxially. Weighed amounts of clay materials in the form of separate particles, 1–2 mm in diameter, were placed in a special mesh cup, the axis of which coincided with the axis of the coaxial capacitor transducer. The bottom of the mesh cup was fitted with a small permanent magnet and the cup was rotated by a magnetic stirrer. Because of the special construction of the probe-extractor, the dioxane, after contact with the moist material, almost instantaneously filled the entire volume

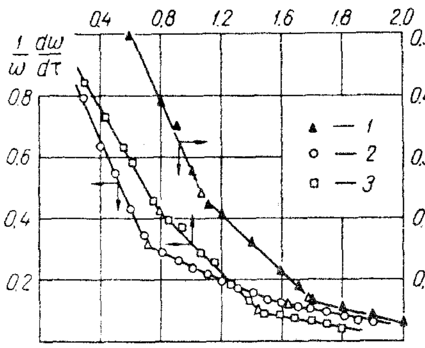

Fig. 1. Dependence of extraction rate of water on the moisture content of the extract (dioxane): 1) Chasov Yar clay; 2) Mukachevo clay; 3) Cherkasskoe bentonite.

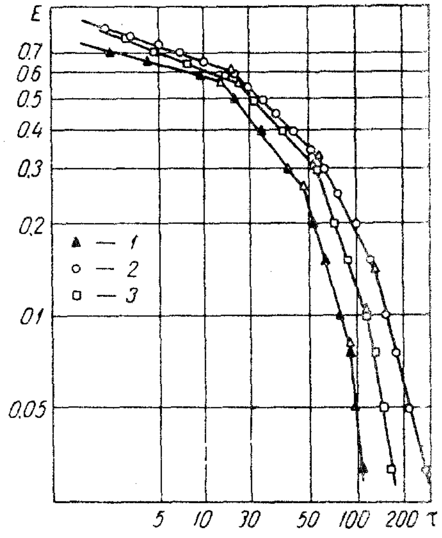

Fig. 2. Dependence of E on extraction time: 1–3) see Fig. 1.

of the condensor-transducer; the measuring instrument recorded the rate of extraction of water. The test samples included Chasov Yar clay, Mukachevo clay, and Charkasskoe bentonite, which have different hydrophilic natures. The quantity of adsorbed water in the samples lay in the range from 7 to 21% [2].

The kinetics of mass transfer, in relation to analysis of the form of the moisture bond in clay materials, were studied by combined analysis of the curves

$$\frac{dE}{d\tau} = \varphi(w) \text{ and } \ln E = \gamma' \ln \mathrm{Fo}' = \gamma \ln \tau.$$

Results of the study are given in Figs. 1 and 2. As follows from the figures, the extraction process is nonuniform. The rate of extraction is a maximum at the beginning of the process, and decreases towards the end. On the extraction rate curves it is easy to distinguish the critical moisture contents $w_{2,1}$ and $w_{2,2}$, which correspond to a sharp change in the nature of extraction. The curve $E = \varphi(\tau)$, $[\ln E = \gamma \ln \tau]$ is represented by four straight lines intersecting in points corresponding to definite moisture contents $w_{1,1}$, $w_{1,2}$, $w_{1,3}$, which are given in the table. These correspond, with sufficient accuracy, with the critical moisture contents on the rate of extraction curve. In order to explain the physical nature of the critical moisture contents, drying thermograms of the materials was taken [2]. The critical points on the thermograms have the following contents: $w_{3,1}$ is the maximum hygroscopic moisture content, $w_{3,2}$ is the adsorption-bound water, and $w_{3,3}$ is the water of monomolecular adsorption. Comparison of the data given in the table shows that the critical moisture contents found by the extraction method compare well with the critical moisture contents found from the drying thermograms. Consequently, the critical moisture contents on the curves correspond to the removal of water bound in the clay materials in different ways.

Values of Critical Moisture Contents

Clay mineral	From curve $E = f(\tau)$			From curve $\frac{dE}{d\tau} = f(w)$		From thermograms		
	$w_{1,1}$	$w_{1,2}$	$w_{1,3}$	$w_{2,1}$	$w_{2,2}$	$w_{3,1}$	$w_{3,2}$	$w_{3,3}$
Chasov Yar clay	16.0	6.4	2.6	16.1	6.6	16.0	6.8	2.5
Mukachevo clay	18.7	9.4	3.9	18.7	9.4	20.0	8.6	3.2
Cherkasskoe bentonite	26.2	14.0	6.4	26.6	14.3	26.9	14.0	6.8

Notation

E—concentration simplex; c—concentration; c_0—initial concentration; c_∞—concentration at end of extraction; A, α, β, γ—constants; w—moisture content (in %); Re', Pr', and F_0'—molecular Reynolds number, Prandtl number, and Fourier number; τ—time.

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