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FILTRATION OF SALINE SOLUTIONS IN SOIL ENVIRONMENTS

The regularities of saline solutions concentration influence and their temperature on soil filtration characteristics have been experimentally investigated, substantiated and established. Significant difference between the filtration coefficient of saline solutions, considering their temperature and filtration of pure water was found out. So, at the concentration of saline solutions from 0 to 40…80 g/l the filtration rate increases sharply. With the further increase in the concentration of saline solutions, there is a phenomenon of soil softening, which leads to sharp decrease in their permeability, and, consequently, the coefficient of filtration. Such a pattern can be explained on the basis of physical and chemical processes occurring between mineral particles (solid phase) and saline solutions (liquid phase). In this case, it is got disperse system. Any disperse system tries to reduce its surface energy. In the system of «mineral particles + solution» it can be diminished by both reducing the total surface size and the liquid the surface tension.

***Keywords**: soils, filtration, concentration, saline solutions.*

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ФІЛЬТРАЦІЯ СОЛЬОВИХ РОЗЧИНІВ У ҐРУНТОВИХ СЕРЕДОВИЩАХ

Експериментально досліджено, обґрунтовано та встановлено закономірності впливу концентрації сольових розчинів та їх температури на фільтраційні характеристики ґрунту. Виявлено суттєву відмінність між коефіцієнтом фільтрації сольових розчинів з урахуванням їх температури та фільтрацією чистої води. Установлено, що при концентрації сольових розчинів від 0 до 40…80 г/л коефіцієнт фільтрації різко зростає. З'ясовано, що при подальшому збільшенні концентрації сольових розчинів спостерігається так зване явище осолонцювання ґрунтів, що призводить до різкого зменшення їх водопроникності, а відповідно і коефіцієнта фільтрації. Таку закономірність можна пояснити на основі фізико-хімічних процесів, які відбуваються між мінеральними частинками (твердою фазою) і сольовими розчинами (рідкою фазою) як дисперсної системи. Будь-яка дисперсна система намагається зменшити свою поверхневу енергію. Виявлено, що у системі «мінеральні частинки + розчин» може відбуватися її зменшення як за рахунок зниження величини сумарної поверхні, так і зменшення поверхневого натягу рідини.

***Ключові слова:** ґрунти, фільтрація, концентрація, сольові розчини.*

Introduction. Regularly, oil bases and structures during construction and operation fall into the effects of such an anthropogenic factor as saline solutions. The presence of saline solutions in the soil massif leads to changes in soil filtration, strength and deformation properties. The magnitude and intensity of such properties change may be significant, which leads to the occurrence of unforeseen additional deformations, strength stability disturbance of soil massifs etc. It can be complicated normal operation of buildings and structures, and in some cases leads to accidents in buildings and structures and can bring significant economic damage.

Analysis of recent research papers and publications. Water resistance of the same soils depends to a large extent on the chemical composition and concentration of the filtering fluid. Studies carried out by VS Sharov and BV Deryagin [1] showed that under the filtration of saline solution with a concentration of up to 10% due to montmorillonite clay, the filtration coefficient increased in 2 times compared with the filtration of pure water. Similar studies were carried out by us [2] for homogeneous quartz sand with a grain size of 0.25 mm fractions. The filtering fluid was a NaCl solution with a concentration of 0 to 16%. These studies showed that under the filtration of saline solution at concentration of 5%, the filtration coefficient reached its maximum value in comparison with the filtration rate of pure water. The results of the above experiments were limited only by the concentration of the filtering fluid. The temperature factor of saline solutions was not considered in details.

Among the recent works by foreign scientists devoted to the study of linear and nonlinear processes of groundwater dynamics, heat and mass transfer in homogeneous and heterogeneous soil environments, it is necessary to distinguish works [3 – 6] and other scientists. However, taking into account mathematical models of nonlinear processes that occur under the filtration of saline solutions in ground media requires their further development.

Highlighting of previously unsettled parts of the general problem. As it is known, the process of saline solutions' filtration in soil media is described by a rather complicated mathematical model. The complexity of this mathematical model lies in the fact that the presence of water in one or another of the associated components of salts affects the viscosity of the filtering saline solution, the permeability of the soil, and through them the coefficient of filtration k. Thus, the coefficient of filtration depends on both the properties of the soil medium and the properties of the filtering liquid. The complexity of this physical process has led to the fact that in many cases, for the simplification of the mathematical model which describes the processes of salts mass transfer, small and average concentrations of components contained in the filtration solution are taken. In addition, it is believed that the rate of solution filtration, that is its volumetric quantity, flowing in a unit of time, through a unit area at a given pressure gradient, does not depend on the change in the solution concentration.

However, the following experimental studies on saline NaCl solution filtration in sandy soils yield the fact that the filtration coefficient, and hence the rate of filtration, can vary considerably depending on the concentration of saline solution and its temperature.

Soil is a complex porous medium that is able to pass through itself the liquids, gases and their mixtures that are to be penetrating. The degree of permeability in different soils is different and is determined by their chemical and mineral composition, structural and texture features, the concentration of the filtering liquid, as well as the conditions under which the filtration takes place (the magnitude of the pressure gradient, temperature, etc.). The least studied and the most important these factors are filtered liquid properties.

Task setting. In order to study the parameters of saline solutions filtration in sandy soils and establishment of a quantitative estimation of their impact on the soils permeability, series of experiments determining the filtration coefficient based on the concentration of saline solution and its temperature were performed in the geotechnical laboratory of bases and foundations department of the National University of Water Management and Environment Engineering. In order to reduce the error of the experiment and the influence of various factors, experiments were conducted for homogeneous quartz sands Filtering fluid was a solution of NaCl with the concentration of 0 to 160 g/liter. Determination of the filtration coefficient of saline solution was performed on a standard KF-1 device. Preparation of the device and the studied soil, as well as carrying out the experiment itself, was fulfilled according to the standard procedure in accordance with State Standard of Ukraine [7].

Main material and results. The research results of the filtration coefficient depending on the concentration of the filter solution and its temperature for a single pressure gradient are given in table 1.

Table 1 – The results of filtration coefficient research depending on the concentration of filtrating solution and its temperature

C, g/l	Filtration coefficient *k*, m/day			
	$t = 16$ °C	$t = 25$ °C	$t = 50$ °C	$t = 75$ °C
0	0,20	0,22	0,78	0,80
20	0,30	0,32	0,96	1,00
40	1,20	1,43	1,80	1,88
60	0,40	0,50	3,24	3,50
80	0,38	0,43	2,24	4,90
100	0,40	0,44	1,22	4,00
120	0,39	0,44	0,96	1,80
140	0,39	0,45	0,80	1,60
160	0,40	0.47	0,60	1,60

The mathematical processing of the experiment results is carried out by applying multidirectional radial basis function, which is written in general form

$$k_{(c)} = \sum_{i=1}^{9} a_i \sqrt{1 + (c - c_i)^2} \quad , \tag{1}$$

where a_i – free members which are got in the process of statistical processing;

c – any meaning of saline solution concentration for filtration coefficient determination $k_{(c)}$;

c_i – experimental data of concentration in any research.

The mathematical processing results of experimental data in the most convenient way with the choice of optimal scale are shown on Fig. 1 – 4.

The presence and filtration of saline solutions in soil media, as shown by laboratory experiments, is accompanied by processes of interaction between liquid phases (solutions) and solid phase (mineral particles). These processes lead to changes in the composition and concentration of saline solutions and thus affect the rate of filtration (the coefficient of filtration). So, with increasing concentration of saline solution NaCl from 0 to 4 – 8%, the filtration rate increases sharply.

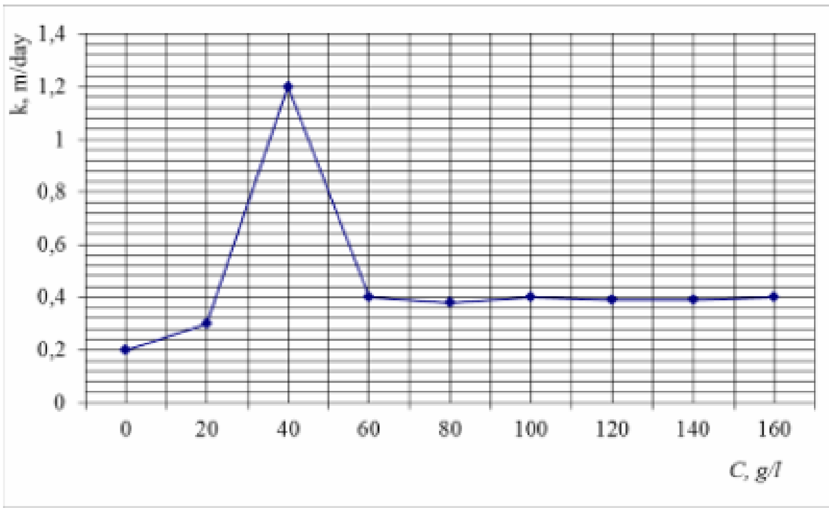

Figure 1 – Graphics of filtration coefficient dependency on the concentration of saline solutions under the temperature of $t=16^0C$

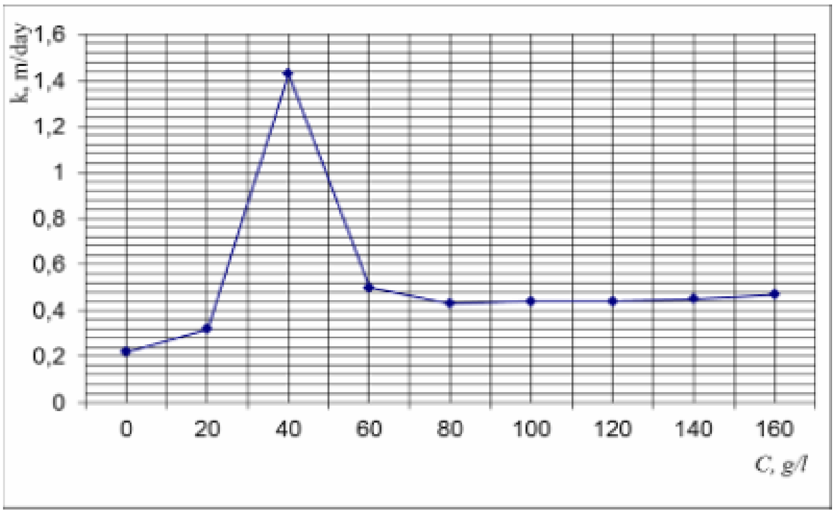

Figure 2 – Graphics of filtration coefficient dependency on the concentration of saline solutions under the temperature of $t=25^0C$

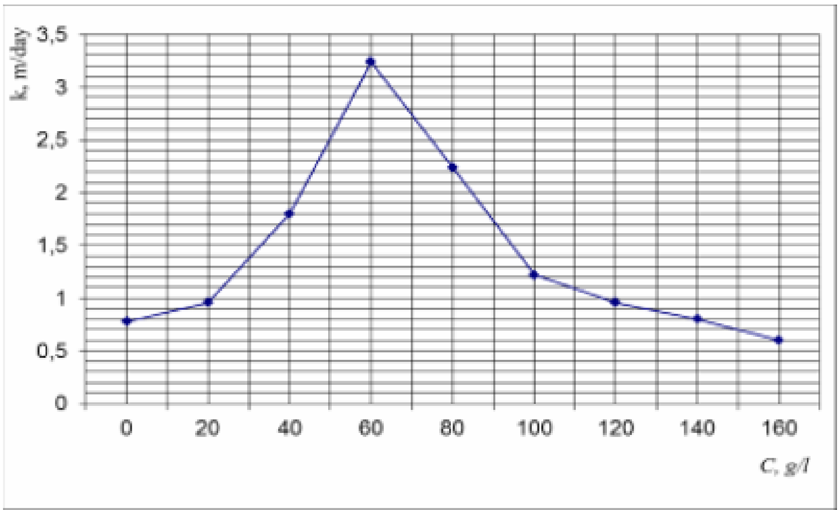

Figure 3 – Graphics of filtration coefficient dependency on the concentration of saline solutions under the temperature of $t=50^0C$

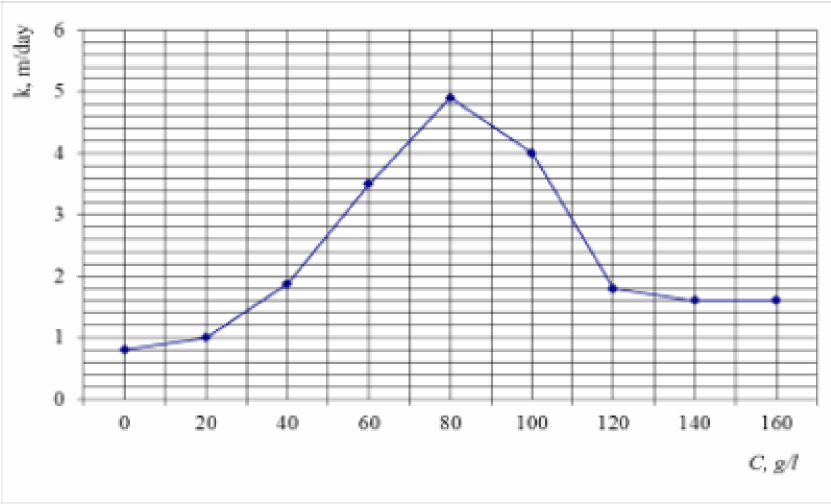

Figure 4 – Graphics of filtration coefficient dependency on the concentration of saline solutions under the temperature of $t=75^0C$

At a given concentration of saline solutions, the maximum value of the filtration coefficient was obtained, which increased by 2 – 4 times compared with the filtration of pure water. With the further increase in the concentration of saline solutions, there is a so-called phenomenon of soils salinization or alkali-affecting, which leads to a sharp decrease in their permeability, and, consequently, the coefficient of filtration. Such a pattern can be explained on the basis of physical and chemical processes occurring between mineral particles (solid phase) and saline solutions (liquid phase). In this case, we have a disperse system. The superficial energy of such a system is measured by the surface tension that occurs at the interface of the disperse phase with the dispersion medium and the magnitude of the total surface of all parts of the disperse phase. Any disperse system tries to reduce its surface energy. In the system of «mineral particles + solution» it can be reduced by both reducing the size of the total surface and reducing the surface tension of the liquid. The latter factor leads to the compression of the liquid diffusion layers, and, consequently, to an additional consolidation of soils and an increase in the coefficient of filtration.

Significant influence on the permeability and compressibility of soils is done by the composition of exchange cations. Thus, soils saturation with sodium ions causes marked decrease in their permeability and compressibility. Sharp decrease in the soil permeability and compressibility from presence of exchange cations is due to its dispersing effect. As a result, pore sizes and formation of a bound water significant amount in soil are reduced, which leads to decrease in the permeability of soils. Furthermore, it should be noted that in presence of saline solutions in disperse systems such as soils, in addition to two components, the solid disperse phase and the liquid disperse medium, there is always the third component, the electrolyte, which is the saline solution. When the salts are dissolved in water, the mineral particles of the soil do not remain passive to the molecules or ions of soluble salts. Dipole molecules of water, orienting in the force field of molecules or ions of soluble salt, form a densified hydration layer around it. Hydrated, or as they say in such cases, solid mineral particles are soaked. So, clay soils are very hydrophilic. Depending on the hydrophilicity degree, the surface retains hydration different amount, or, as it is called, bound water. The content of bound water in clay reaches 25%, which leads to decrease in soils permeability.

Conclusions. Obtained experimental data, as well as their statistical processing, made it possible to evaluate saline solutions filtration process in soil environments depending on filtering liquid properties quantitatively and qualitatively, on its concentration and temperature. Data of experimental researches can be used in assessing the soil bases and structures state by deformation and bearing capacity. Subsequent studies may be an assessment of the stress-strained state of soil bases and structures, considering nonlinear processes that occur during saline solutions filtration of varying temperature.

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