

# Solving Material Transportation Problems In Cracked-Porous Environments

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**Abstract**— The article focuses on several types of balanced and unbalanced adsorption. Hydrodynamic methods for the migration of substances under porous conditions were analysed. General information on the methods of hydrodynamic analysis of the movement of substances in cracked-porous environments is provided. Considering the hydrodynamic dispersion, diffusion effects in the crack and its effect on the migration process in the environment, the problem of material migration in an environment consisting of a single porous block and a single crack of the adsorbed substance is examined.

**Keywords**— Adsorption, diffusion, radioactive (chemical-biological), linear unbalanced adsorption, adsorption coefficient.

## I. INTRODUCTION

Much attention is being paid around the world to the study of the migration of substances in cracked-porous environment, which is associated with environmental problems related to the movement of radionuclide through porous layers. In addition, the problem of assessing the suitability of active, radioactive waste for underground geological storage also requires the study of the migration of substances and radionuclide in cracked-porous environments. Carrying out such research and experiments requires a deep understanding of the diffusion migration processes, the interaction of cracks and matrices [1]. Therefore, in many foreign countries, including the United States, Britain, France, Germany, Japan, China, the Russian Federation and other developed countries, intensification of oil production by pumping liquid-soluble substances in cracked-porous environments and transferring various wastes to underground reservoirs in utilization, great attention is paid to the hydrodynamic modelling of substance migration processes are important[3]. Particular attention is paid to the development of computational algorithms for their study and the creation of modern computational software. There is a growing volume of various industrial wastes in the world, and as a result of the growing trend of environmental degradation, research is being conducted to further improve modern methods and technologies of their disposal and recycling. In this direction, special attention is paid to the development of mathematical modelling, convenient and preferred methods of migration of substances in porous and cracked-porous environments. At the same time, hydrodynamic models are based on fundamental laws of physics and chemistry, and phenomenological approaches to the study of the process must be taken into account[5]. It is also necessary to develop a hydrodynamic model, computational algorithms and programs. The issues of substance transfer modelling

introduced in any country play an important role of technology in solving environmental problems, in particular in the description of the movement of pesticides and active substances in cracked-porous environments, environmental protection, oil and gas extraction. One of the important tasks is to perform these tasks, including the creation of improved mathematical models that represent the processes of migration and flow of substances in cracked-porous environments. Based on the above, it can be said that the study of the processes of migration of substances in cracked-porous cases is relevant, taking into account the phenomena of adsorption, diffusion and radioactive (chemical-biological) decay [2]. Today, a number of existing models of material migration in cracked-porous environments represent the main features of the process, taking into account the adsorption of the substance; chemical-biological (radioactive) decomposition, the problems of migration and the development of algorithm are unexplored[1].

## II. Hydrodynamic dispersion

Considering the hydrodynamic dispersion, diffusion effects in the crack and its effect on the migration process in the environment, the problem of material migration in an environment consists of a single porous block and a single crack of the adsorbed substance. A crack-porous environment element consisting of a single crack and a porous block attached to it is the focus of this study as shown in Figure 1. The crack consists of a semi-infinite area, the distribution of the substance and the flow of the liquid are homogeneous along its cross section. In this case, the second dimension of the crack, the change in its thickness, is not taken into account. The hollow block occupies the first quarter of the plane, that is,  $R_0 x, y_0$  areas are considered.

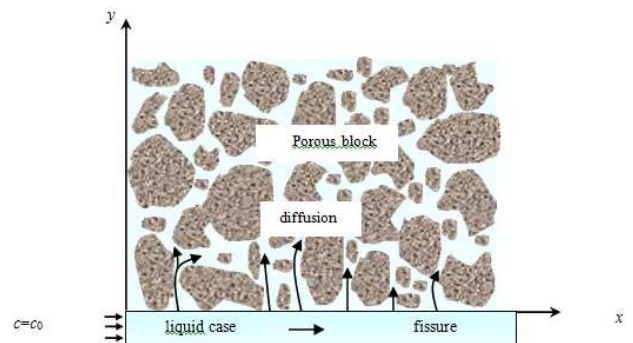


Fig. 1. Schematic representation of the transfer of matter from a crack to a porous block

In a crack, the fluid moves at a constant speed. From point coordinate head  $x_0$  to point constant  $s_0$  concentrated fluid is pumped. The environment in question is filled with clear liquid. In a crack there is

a convective-diffusion transfer of matter, and in a porous Figure 2.

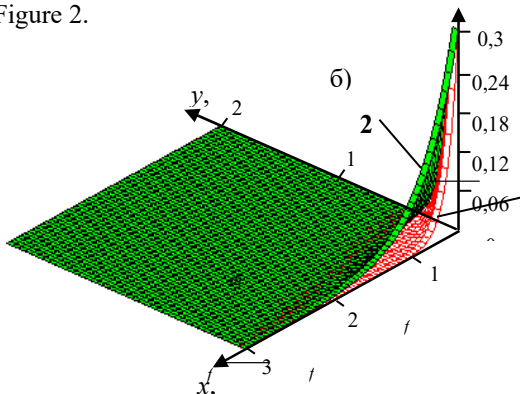


Fig. 2. Relative concentration

Relative concentration  $s_m G s_0$  (a) va  $s_m$  (b) surfaces, in this case  $2 \cdot 10^{-3} M$ ,  $\vartheta = 5 \cdot 10^{-4} M/c$ ,  $t = 10000 c$ ,  $D^* = 0$  (1),  $D^* = 1 \cdot 10^{-5} M^2/c$  (2).

block there is a diffusion transfer. The crack is modelled as a one-dimensional object,

$10^6 s$ ,  $M^3 \text{kg}^{-1}$  therefore its distribution along the longitudinal section is not taken into account. In Figure 2,  $c_m c_0$  is the relative concentration and  $s_m$  is adsorbed concentration area is indicated. It looks like a sack that encloses with a drawstring ( $D^* \neq 0$ ) account of

molecular diffusion in the crack  $c_f$  and  $c_m$  in the porous block (matrix) leads to a wider distribution of the concentration area (Figure 2a). It has also been found that diffusion has a significant effect on the metabolism between the crack and the porous block [4].

### III. Linear unbalanced adsorption

The problem of substance migration in a cracked-porous environment is solved by considering the unbalanced adsorption. Adsorption kinetics are analyzed for linear and nonlinear cases. In equations (1), (2), the change in

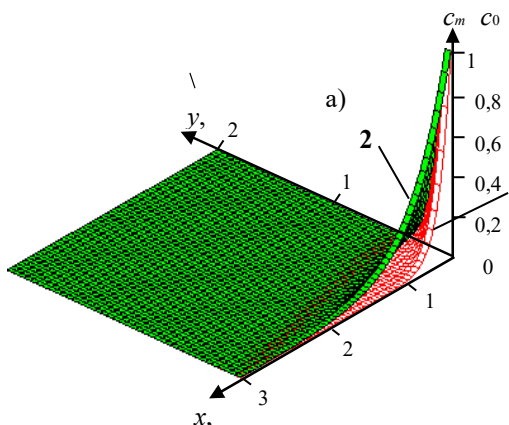


Fig. 3. Linear unbalanced adsorption

adsorption in the R field occurs according to the unbalanced kinetics. The following special cases of unbalanced adsorption are considered: 1. Linear unbalanced adsorption. Here it is assumed that the adsorption of a substance in a cracked-porous environment takes place on the basis of linear unbalanced kinetics.

$$\frac{\partial \sigma_\phi}{\partial \tau} = \alpha_\phi(\kappa) \sigma_\phi, 0 \leq \xi < \infty, \quad (3)$$

$$\frac{\partial \sigma_\mu}{\partial \tau} = \alpha_\mu(\kappa \chi_\mu \sigma_\mu), 0 \leq \psi < \infty, \quad (4)$$

here,  $\sigma_\phi$  the intensity of the adsorption process in the crack and matrix characteristic coefficients,  $s^{-1}$ . (3) and (4) in the equations At t, the following  $s_f k_f s_f$  and d

$s_m k_m s_m$  linear equilibrium adsorption (Henry isotherm). The initial condition for equations (3), (4) is as follows  $\sigma_\phi(0, \xi) = \sigma_\mu(0, \xi, \psi) = 0$ . The system of equations (1), (2) was solved by the method of finite differences, taking into account (3), (4) and the conditions (1) - (2) and (4). Using the results, profiles of concentrations  $c_m$  and  $c_f$  and adsorption fields  $s_m$  and  $s_f$  were constructed. For different values of the adsorption coefficients, the mass flow from the crack to the porous block was determined. According to the analysis of the obtained results, an increase in the adsorption coefficients  $k_f$  and  $k_m$  leads to an increase in relative metabolism. Using these moments, it is possible to estimate the different characteristics of the displacement and adsorption of the substance. These values represent the "average distribution distance" of the concentration of the substance in the crack and the concentration of the adsorbed substance (respectively 2) denote the "average distribution area" of the concentration of the substance in the porous block and the concentration of the adsorbed substance, respectively. The time-varying dynamics of  $\xi \phi \chi, \xi \phi \sigma, \Omega \mu \chi, \Omega \mu \sigma$  were compared for linear equilibrium and linear unbalanced kinetic adsorption. It was found that the unbalanced kinetic adsorption relative to the equilibrium adsorption leads to a reduction in the adsorption area, which in turn leads to a wider distribution of the concentration profile. An analysis of the migration of matter in an element of a porous environment consisting of two cracks and porous blocks between them is given. Putting the problem in this way is not a simple geometric generalization of the issues discussed earlier. In this case, the liquid can move through the two cracks at different speeds, so that the intensity of the transfer of the substance varies [5].

### IV. Substance transfer in cracked-porous environment

Taking into account the unbalanced adsorption, the problem of substance transfer in a cracked-porous environment consisting of two cracks is solved. Here, the environment is assumed to consist of a semi-infinitely porous block between two cracks (Fig. 4).

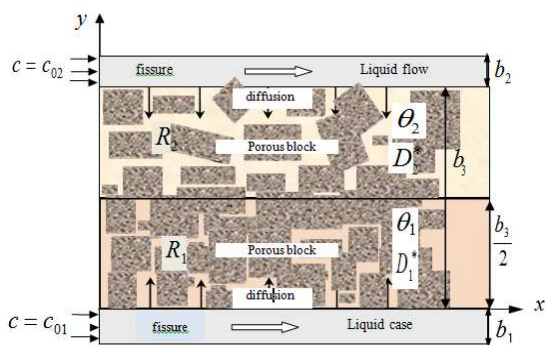


Fig. 4. Schematic representation of the movement of matter in an element of a cracked-porous environment.

At the initial moment of time, the area under consideration is assumed to be filled with clear liquid. From time  $T_0$  on wards, liquids of various  $s_{01}$  and  $s_{02}$  concentrations are generally injected into the cracks. We assume that the concentration area did not reach  $x_2$  area in the considered time range. Concentrations of matter at the boundary of  $y_0$  porous block continuity is ensured. It has been shown that transverse diffusion leads to an increase in the displacement of matter between the cracked and the porous environments, while an increase in the longitudinal diffusion coefficient leads to a further increase in mass transfer [6].

## V.CONCLUSION

The following main conclusions are drawn from the research conducted on the topic "Methods for solving the problem of substance migration in cracked-porous environments":

1. Data on the hydrodynamic analysis of the displacement of matter in a cracked-porous environment are given. Given the effects of convective diffusion and hydrodynamic dispersion, a brief description of the displacement of the adsorbed substance in cracked environment is given.
2. The problem of displacement of the adsorbed substance is solved taking into account the equilibrium adsorption

(Henry isotherm) in the element of a cracked-porous environment consisting of a single crack and a porous block attached to it. Based on the numerical results, the concentration of the substance and the adsorption area and the relative flow of the substance at the boundary of the environments were determined. Taking into account the diffusion effect, a 5-fold increase in the molecular diffusion coefficient in the crack allowed to increase the total flow of matter from the crack to the porous block by 12-13%.

3. The question of whether the substance has chemical-biological or radiation activity was considered. It has been shown that the decomposition of the substance leads to a dispersion of the concentration and a reduction in the adsorption area. It has been shown that this process results in the formation of high concentration gradients at the boundary between the crack and the porous block, which in turn has a significant effect on the relative metabolism at the boundary of the environments.

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