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SIMULATION OF SOIL CONTAMINATION BY PETROLEUM PRODUCTS

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ABSTRACT

The research deals with numerical solution of an applied problem that has substantial ecological sense and great practical importance. Possible contamination of soils by petroleum products is predicted. Mineral fuels, solvents and detergents are classified as Light or Dense Non-Aqueous Phase Liquids (NAPLs) [1]. These liquids are immiscible with gas and water therefore one has to treat multiphase flows in the subsurface. A real object – a service station in Gomel (the Republic of Belarus) – is under consideration. It is a permanent source of diesel oil (LNAPL) infiltrating from the earth surface into the ground under the influence of gravitational and capillary forces until reaching the water table what threatens the drinking water quality. Real data about the soil structure, the typical soil dampness etc. obtained by measuring in the locality are used in computations. The goal of analysis is development of accurate and efficient parallel algorithms and codes for investigating the time-evolution of the contamination domain.

The process of NAPL infiltration is governed by the three-phase flow equations [1, 2]. The model includes conservation of mass and extension of Darcy's Law for water, diesel oil and soil air, two capillary pressure–saturation relations and relationships for relative permeabilities. Relations for capillary pressures and relative permeabilities are strongly non-linear functions of saturations. In the current work the Parker capillary pressure functions [1] and the Stone relative permeability functions [2] based on the two-phase model of Van Genuchten are used.

Before to proceed to the applied problem a number of quasi-1D, 2D and 3D test problems was treated. In the case of two-phase flows the model was transformed to the phase pressure – saturation formulation and implemented by IMPES method [2]. The special algorithm realizing interface conditions on boundaries between different layers of heterogeneous porous media was developed to guarantee physically correct solutions [3]. The 3D problem of DNAPL infiltration into a water saturated reservoir with low permeable lenses was solved on a local network consisting of 14 PC and demonstrated high efficiency of parallelization (about 75 % at the grid size of 10^7 cells).

Results obtained for the Gomel service station (the three-phase flow, the 2D statement over the vertical section) are depicted in Figure 1. As test predictions show that at the domain depth about 10 m (like in the given problem) the air pressure can be considered as constant, there is no need to solve elliptic equation for the pressure [4]. It leads to significant decrease of computational costs retaining the required accuracy.

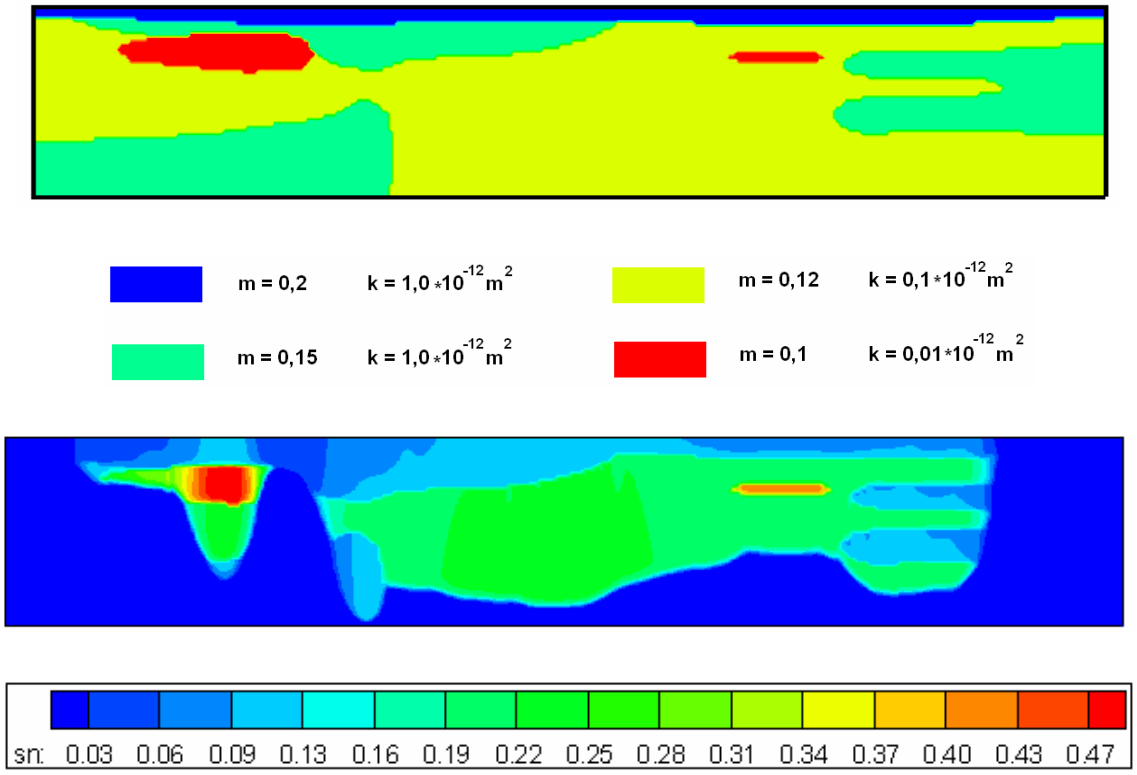

Figure 1: Ground map with porosities (m) and absolute permeabilities (k) and the diesel oil field with saturation values (sn) in 2 years from beginning of infiltration.

The proposed numerical approach satisfies requirements of the engineering practice and can be used for development of steps to environment protection. It is planned in future to turn to the full 3D formulation of applied problems and to implementation on distributed memory multiprocessors.

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