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THE INFLUENCE OF CHOSEN CALCULATION PARAMETERS ON THE TOTAL VOLUME OF THE LNAPL PRODUCT ESTIMATED IN A MATHEMATICAL MODEL***

1. MODEL CHARACTERISTICS

The mathematical model calculations were performed using the MARS (Multiple Areal Remediation Simulator). MARS is a programme taking into account a multi-phase surface flow in the 3-dimensional transport in underground water. The programme performs a simulation of the underground water flow connected with LNAPL, it can also simulate the LNAPL recovery and migration [1]. The input data of the MARS includes a list of parameters, and of the initial and boundary conditions. The data include also the simulated pressures of water and oil phase, the velocity of the water and oil phase movement at every node, the total volume of water and oil in time as well as the value of the recovery of water and oil in the predetermined period of time. The programme also performs the calculations of the volume of the free LNAPL recovery and its spatial concentration in time [4]. The data required for the analysis of the two-phase flow water-oil include the initial values of the air-water table Zaw and air-oil table Zao, the hydrogeologic properties of the ground and boundary conditions. The Van Genuchten model, together with the liquid scaling parameters, is used to calculate the volume of water and oil phase.

2. THE ASSUMPTIONS AND OBJECTIVE OF THE MULTI-PHASE FILTRATION MODEL

The objective of the conducted model investigations is to estimate the effect of the selected parameters defining the ground-water environment and the oil product on the total volume of LNAPL – V_o.

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The developed mathematical model covers the area measuring 400 × 400 m – the surface area of 1600 m^2. The model area was discretized with a quadrangle grid 21 × 21 (441 nodes) with the step of the discretization grid dx = dy of 20 m. The following data were assumed for the simulation: the groundwater level in the piezometers and the thickness of the oil product. The maximum simulation time was predetermined for a period of 350 days. The capillary zone was predetermined at the height of 0.5 m. The aquifer bottom was assumed on the ordinate of app. 70 m a.s.l. The aquifer is made up by medium sands. The ordinates of the groundwater level were from 99 to 100 m a.s.l., respectively. LNAPL was predetermined for the central part of the model, with the thickness of from 0 to 0.4 m.

The distribution of the reduced LNAPL thickness assumed in the mathematical model with the operating dewatering wells is presented below (Fig. 1).

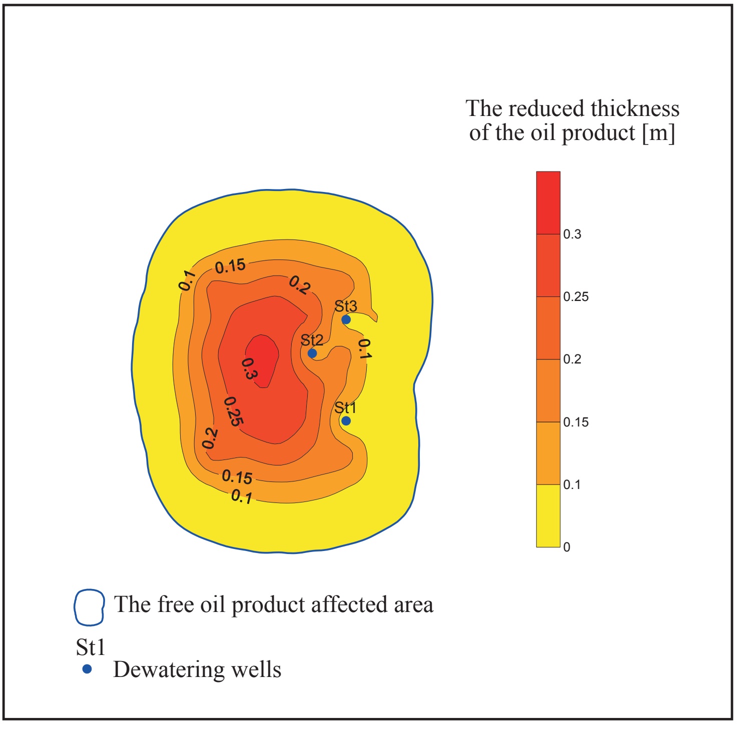

Fig. 1. The thickness distribution of the free oil product

The model was used to perform the analysis of the total volume of the free oil product (LNAPL) with respect to the change in the ground porosity as well as the change in individual parameters characterizing the liquid phase:

ρ_{ro} – ratio of oil to water phase density,
η_{ro} – ratio of oil to water viscosity,
β_{ao} – air-oil phase scaling parameter,
β_{ow} – oil-water phase scaling parameter.

3. ANALYSIS OF PARAMETERS CALCULATED IN COMPUTER SIMULATION

The developed mathematical model was applied to analyze the impact of selected calculation parameters on the total volume of LNAPL – V_o. In the polluted area the operation of three dewatering wells recovering the free LNAPL was simulated. It was assumed that three pumping wells S-1, S-2 and S-3 would be operating simultaneously, each of them having a maximum discharge of up to 10.0 m^3/h. In the same hydrogeological conditions a selected calculation parameter was changed and its effect on the model-calculated total volume of LNAPL V_o was observed. In the first case the porosity was altered. It was assumed that a uniform, isotropic aquifer appears in the model. The porosity within the aquifer was changed within the range of 0.25 to 0.35. The porosity growth was accompanied by a linear growth of the V_o, this value is directly proportional to the ground porosity (Fig. 2). With each porosity increase by 10% the total volume of LNAPL grew by 13%. A graph showing the relationship between the porosity alterations and the total volume of LNAPL is presented below. With the total porosity having changed by 32%, the total volume of LNAPL increased by app. 46%.

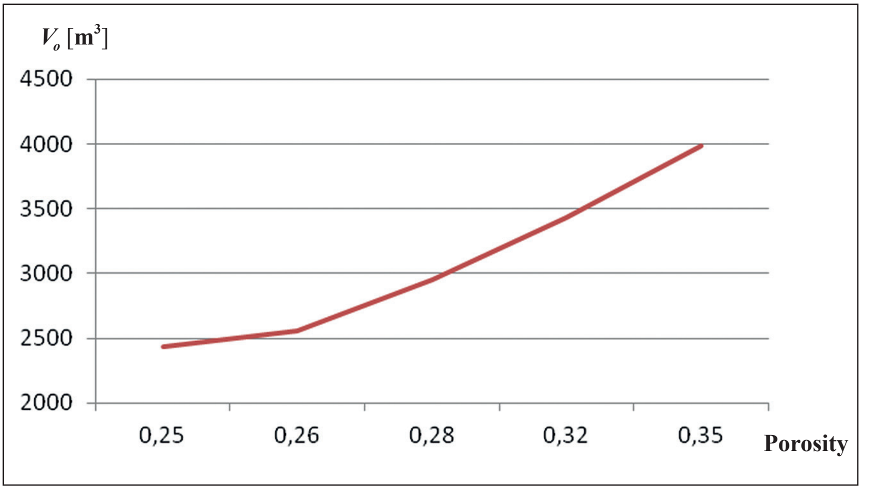

Fig. 2. Relationship between porosity change and the total volume of LNAPL – V_o

The further investigation focussed on determining the relation between the parameters defining the oil product and the total volume of LNAPL. The value of the air-oil phase scaling parameter B_{ao} was changed in the model within the range of 2.2 to 3.5. As the B_{ao} grew, the linear increase of the total volume of LNAPL occurred (Fig. 3). Changing the successive B_{ao} values by 10%, resulted in the mean change of the V_o value by 0.65%. The changes in the B_{ao} parametre do not have a significant effect on the total volume of LNAPL. With the total change of the air-oil phase scaling parameter B_{ao} by 50% , V_o grew by 3.3%.

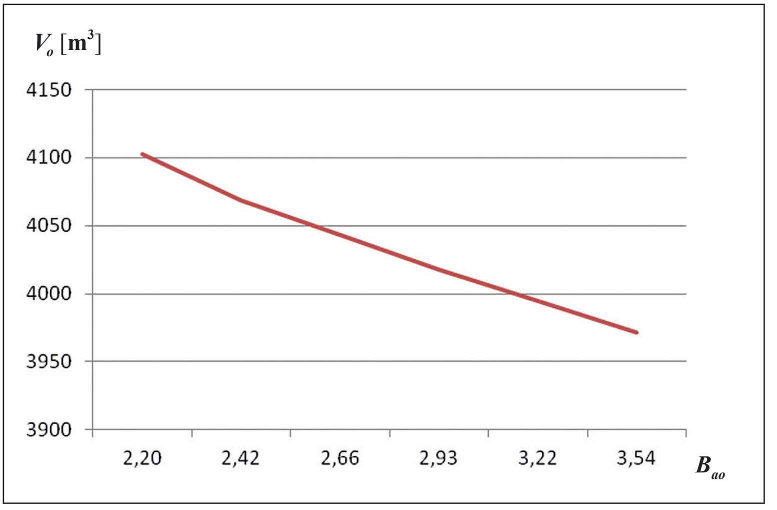

Fig. 3. Relationship between air-oil phase scaling parameter B_{ao} and the total volume of LNAPL – V_o

The increase in the oil-water phase scaling parameter B_{ow} causes the growth in the total volume of LNAPL (Fig. 4). B_{ow} values were changed in the model within the range of 1.4 to 2.05. The total volume of LNAPL increased together with the growing B_{ow}. As the successive B_{ow} values were changed by 10%, V_o increased by 2.76 on average. The changes of the B_{ow} do not cause a significant change of the V_o. With the total change of B_{ow} at the level of 40%, the total volume of LNAPL increased by 11%.

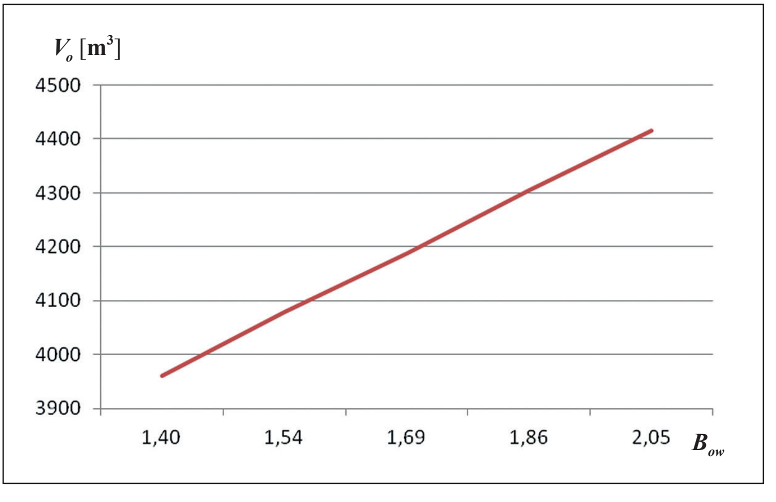

Fig. 4. Relationship between the oil-water phase scaling parameter B_{ow} and total volume of LNAPL – V_o

The ratio of oil to water phase density RHOW parameter was changed within the range of 0.730 to 0.972. Together with the growth of RHOW, the total volume of LNAPL decreases (Fig. 5). RHOW in the model was changed by 10%, as a result of which the total volume of LNAPL decreased by 26% on average. For the range of RHOW of 0.730 to 0.803, V_o decreased by at least 5%, for RHOW of 0.880 to 0.970, V_o decreased by 38%. The changes of the RHOW parameter have a significant impact on the total volume of LNAPL calculated in the model.

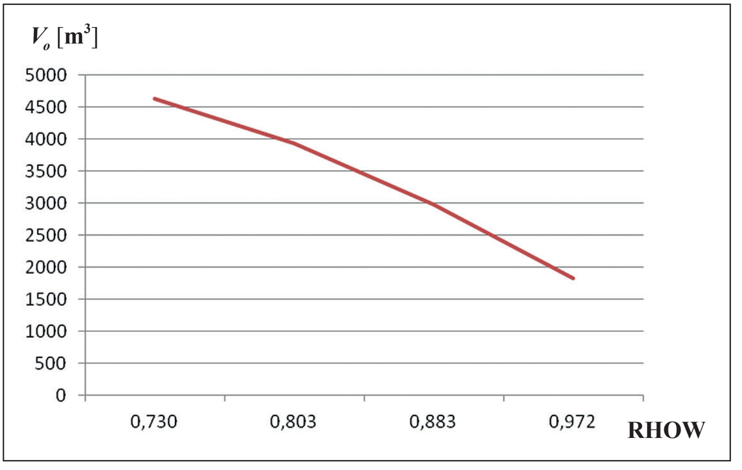

Fig. 5. Relationship between the ratio of oil to water phase density – RHOW and the total volume of LNAPL – V_o

The ratio of oil to water viscosity VISOW parameter was changed for the range of 0.5 to 30. The total volume of LNAPL increased together with the growth of VISOW (Fig. 6).

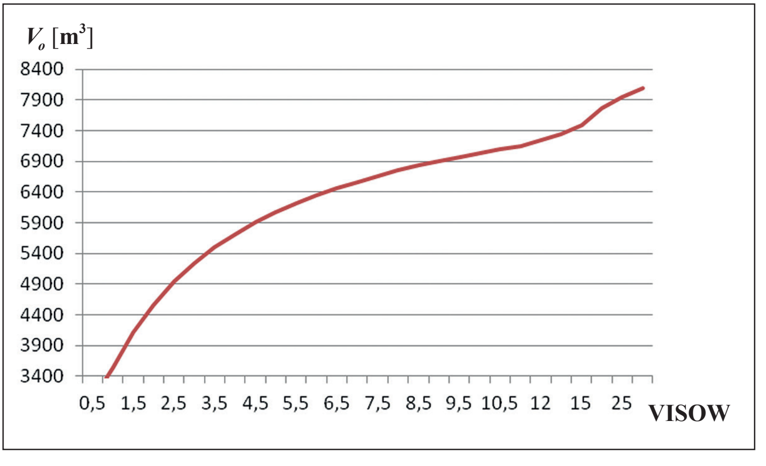

Fig. 6. Relationship between the ratio of oil to water viscosity – RHOW and the total volume of LNAPL – V_o

Changing VISOW for the range of 0.5 to 2.5 with the intervals of 0.5, gave the increase in the total volume of the free product by 14% on average. Changing VISOW for the range of 3 to 30 gave the rise in the total volume of LNAPL by app. 2%. Altogether, the change of VISOW by 480% caused the increase in the total volume of LNAPL by 100%.

4. CONCLUSIONS

1. The simulation calculations conducted by means of the multi-phase filtration model MARS permitted defining the influence of selected parameters related to the ground-water environment and the oil product on the total volume of LNAPL calculated in the mathematical model.
2. The viscosity of LNAPL and the ground porosity have the greatest impact on the Total volume of LNAPL.
3. The greatest increase in the total volume of LNAPL accompanies the change in porosity, where the porosity change by 30% causes the increase in the total volume of LNAPL by app. 45%.
4. The smallest increase in the total volume of LNAPL occurs with the change in Bao – air-oil phase scaling parameter. When Bao is changed by 30%, the total volume of LNAPL is increased by 3.3%.
5. The decrease in the total volume of the LNAPL was recorded with the ratio of oil to water phase density RHOW parameter. With RHOW altered by 30%, the total volume of LNAPL decreased by app. 80%.
6. The knowledge of the effect of the initial data on the final result of the model facilitates the verification and validation of the mathematical model and enhances the reliability of remediation systems modelling.

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