Simulation of the mineral extraction by the underground leaching method

Madina S. Tungatarova, Aidarkhan Kaltayev

Department of Mechanics, al-Farabi Kazakh National University,
39/47 Masanchi str., 050012 Almaty, Kazakhstan

1 Introduction

The underground leaching method (ULM) is used at the low concentrated mineral deposits exploitation. The main idea of this method is in dissolution of mineral by the solver which is injected to the layer (porous media) through networks of pumping wells and then the mineral containing solution is evacuated by extraction wells. This method is very effective in economical and ecological meaning.

According to the existing rules the deposit's extraction is stopped when the average mineral concentration in the productive solution on the extraction well is equal to some critical value. However, the rate of mineral's extraction depends on the type of wells location and the distance between wells at the same average mineral's concentration on extraction well.

The problems dealing with the increasing of mineral's excavation rate and the optimal wells locations arise at minerals extraction by ULM. The mineral's excavation rate depends on the types of wells location, the distribution of minerals in layer, the structure of layers and deposit's exploitation conditions. In this work the influence of wells location on mineral's extraction rate is investigated.

2 Computations

Pumping of water into the salt containing layer, dissolution of salt by water and its evacuation by extraction wells is considered as a model of mineral extraction by ULM. The study of liquid filtration in layer and dissolution of salt are based on the Darcy's law

$$\overline{V} = -K \nabla h$$

and one-step chemistry model of dissolution

$$\frac{\partial \overline{C}}{\partial t} = -\frac{\gamma}{\rho} \overline{C}^{1/2} \left(C_e - C \right) \cdot \quad (1)$$

In addition, the leaching processes in the layer (porous media) is simulated using conservation equations of mass and species:

$$\nabla \left(K \nabla h \right) = -\sum_{l=1}^{M} Q_l \delta \left(x - x_l, y - y_l \right), \quad (2)$$

$$\frac{\partial C}{\partial t} + \frac{\rho_b}{\varepsilon} \frac{\partial \overline{C}}{\partial t} + \vec{V} \cdot \nabla C = \nabla \left(D_{i,j} \nabla C \right). \quad (3)$$

Here $\vec{V}$ – the filtration velocity, K– the filtration coefficient, $h = p/\rho_b g$ – the head pressure, p – the pressure, Q - pumping and extracting wells, x_l, y_l – the coordinates of wells location, $\overline{C}$ – the mineral's mass fraction in the solid layer, C – the mineral's mass concentration in the solution, C_e – the equilibrium mass concentration, γ – the

Correspondence to : m.tungatarova@kazsu.kz

mineral's dissolution velocity, ρ– the density of the liquid, ρ_b – the bulk density of the medium, $D_{i,j}$ – the diffusion coefficient, ε – the porosity. In 2D case $D_{i,j}$ defined as

$$\begin{cases} D_{11} = D_{xx} = \dfrac{\alpha_l u^2}{|V|} + \dfrac{\alpha_t v^2}{|V|} + D^*, \\ D_{22} = D_{yy} = \dfrac{\alpha_l v^2}{|V|} + \dfrac{\alpha_t u^2}{|V|} + D^*, \\ D_{12} = D_{xy} = (\alpha_l - \alpha_t)\dfrac{u\,v}{|V|} + D^*, \end{cases} \quad (4)$$

where α_l , α_t – the longitudinal and transverse dispersion, u, v – the longitudinal and transverse components of velocity, D^* – the molecular diffusion coefficient.

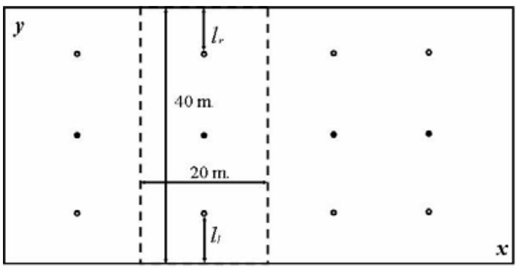
The equation for the hydrodynamic pressure (2) is solved by SOR method. The filtration velocity is obtained from the Darcy's law. Equations of the mineral dissolution and the dissolved components transfer (1), (3) are solved by combination of analytical and Crank-Nicolson numerical methods.

3 Results

Practically two types of wells locations (linear and hexagonal) are widely used at deposit's exploitation by ULM.

At first we are considering the linear type of wells location. Due to the symmetry a part of deposit with *20 m* width and *40 m* length consisting of three wells only is considered (Fig. 1). At initial the salt mass fraction in a layer is $\overline{C}_0$ = 0.23, the mass concentration of salt in solution is $C_0 = 0\ kg/m^3$, the equilibrium concentration is $C_e = 320\ kg/m^3$, the velocity of mineral dissolution is $\gamma = 240\ 1/day$.

a)



b)

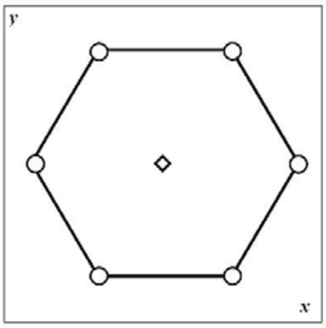


Fig. 1 – The types of wells location
a) linear type of wells location; b) hexagonal type of wells location

Distribution of the pressure, the velocity field (fig. 2), the salt concentration in the solution and in the layer is received for this case. It can be seen that far from wells the filtration of a solution is practically absent, and the so-called stagnant zones that reduce mineral's excavation rate appear. The mineral excavation rate and mineral's concentration on extraction well versus time is shown on the Fig. 3.

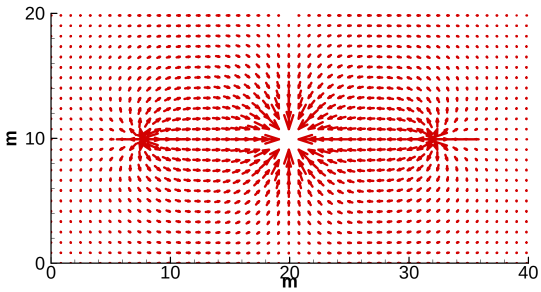


Fig. 2 –The velocity field for the linear type of wells location.

The influences of wells location on deposit's excavation rate and required time are given in Table 1. It is seen that the mineral's extraction completeness depends on the distance between wells and borders. The reduction of this distance results in increasing of the deposit's excavation rate and decreasing the excavation time at the same output concentration on the extraction well. The increasing of output concentration on the extraction well decreases excavation time and almost has no effect to deposit's excavation rate.

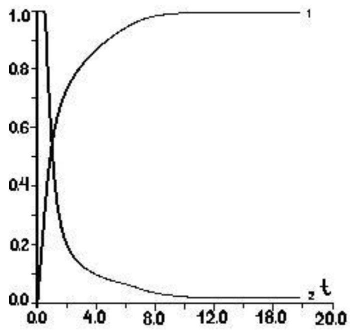


Fig. 3 – The mineral's excavation rate and mineral's concentration on extraction well versus time. Line 1 is the mineral's extraction rate, 2 - relative mineral's concentration on extraction well C_d / C_e.

Table 1 - Calculation of an optimality wells location.

Distance from the well to the left border, l_l, m	Distance from the well to the right border, l_r, m	Relative mineral concentration on the extraction well	Deposit's excavation rate, %	Required time, day
4	4	10	98	110
6	6	10	97	125
8	8	10	96	176
4	4	20	93	83
6	6	20	91	92
8	8	20	87	98
4	4	30	91	70
6	6	30	89	77
8	8	30	77	79

Calculations for one cell set consisting of six reaches, placed in tops of a correct hexagon and one extraction well - in the center of it are carried out. The distribution of the pressure, the velocity field, the distributions of salt concentration in the solution and the layer are received. The mineral's excavation rate and mineral's concentration on extraction well versus time is investigated (Fig. 4).

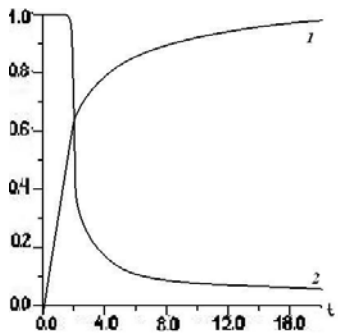


Fig. 4 – The mineral's excavation rate and mineral's concentration on extraction well versus time. Line 1 is the mineral extraction rate, 2 - relative mineral's concentration on extraction well C_d / C_e .

4 Conclusion

The hydrodynamic model of solution filtration and mineral dissolution in porous layer is created in this work. Two types of wells location, which are used widely in practice, are considered: linear and hexagonal wells locations. As a simple case for a linear wells location, the site of a deposit with three wells is considered, for hexagonal wells location - one hexagonal cell.

The results show that the exact value of minerals dissolution velocity does not influence results of such important problems, as an optimum wells location for achievement of the maximal deposit's excavation rate. On the other hand, results of calculations of optimality wells location show that the reduction of distance between wells increase deposit's excavation rate and has no effect on excavation time at the same minimum output concentration on the extraction well. Increasing of minimum output concentration on the extraction well decreases excavation time and almost has no effect on deposit's excavation rate.

In future the elaboration of 3D models of the mineral extraction in the heterogeneous layer with uniform mineral's distribution and the definition of a optimum wells location at the underground leaching method is planning.

5 Acknowledgments

The financial support of INTAS, grant YSF №1000020-5889, is gratefully acknowledged.

References

[1] Chunmiao Zheng, P. Patrick Wang (1999) MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reaction of Contaminants in Groundwater Systems; Documentation and User's Guide, Department of Geological Sciences, University of Alabama, 160 p

[2] Shestakov V.M. (1995) Hydrogeodynamics. Publishing house of the Moscow State University, 368 p. (ISBN 5-211-03067-2)