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STUDY AND ANALYSIS OF THE CURRENT STATE OF URANIUM MINING MANAGEMENT SYSTEM

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Annotation
This paper studies and analyses the current state of the uranium mining management system. The work of leading scientists in the field of uranium mining by in-situ leaching method was analysed. The factors that influence uranium mining are presented. The methods of mathematical modeling of uranium mining by in-situ leaching method are analyzed.

Keywords: Mining, uranium, management, system, modelling.

Introduction

The geotechnological method of mining is the most efficient and is actively used in Uzbekistan. It is characterised by low production costs and, importantly, makes it possible to use a high level of automation and makes it possible to exploit deposits with complex mining and hydrogeological conditions, including significant depths of ore bodies in watered high-pressure horizons and beyond the balance metal content of ores.

The peculiarity of the in-situ leaching (ISL) process is determined by the fluid filtration process in the ground. The permeability of ores and host rocks is one of the most important conditions of leaching solutions (LOS) movement, therefore, the study of filtration properties is one of the main tasks when modelling the LOS processes. However, when using this method, unexploited stagnation zones appear and, therefore, there is a necessity of conducting researches connected with increasing of mineral extraction degree, determination of optimal control systems of electric drives of submersible pumps and operating modes of wells, as well as filtration currents in the reservoir [1].

Methods and materials.

The efficiency of this mining method is largely determined by prompt assessment of the basic parameters of the hydrodynamic state of wells and reservoirs in order to take up-to-date those or other technological methods and management to eliminate technological disturbances.

The existing practice of control systems of geotechnological field (GTP) is characterized by the fact, that the control of technological process of underground leaching consists mainly in maintenance of balance characteristics of flow rates by leaching and productive solutions (PS). The flow rate objectives are based on geotechnological data and the experience and skills of the mine geotechnologist. In this case, the process is conducted under conditions of information uncertainty about the current characteristics of the filtering media, such as the permeability of the ore body, which relate the filtration rate to the head gradient.

Even though the technology of metal mining is fairly well developed, producers are already in need of effective tools to optimise their mining strategy and reduce production costs and, as a result, to make more rational, integrated use of subsoil resources. In this context, the development of effective ISL management systems is essential.

The lack of direct operative control, high inertia of the process, and its length in time make production management a complicated task. And the price of error is high [2, 10].

Possibility of application and efficiency of SP method depend on a wide range of factors determined by geological, hydrogeological and other features of particular deposits.

B. J. Ahrens and A.M. Gaidin proposed to distinguish the decisive, main and secondary factors according to their influence on the IS process. Decisive factors determine the fundamental possibility of using the IS method for field development, major factors determine the economics of the process, and minor factors must be properly considered during design and operation to ensure the maximum effect of development.

All natural factors can be united into five groups which are determined [3,8]:

- geological structure of the deposit, material composition of ores and host rocks;
- hydro-geological features of the deposit;
- engineering and geological features of the deposit;
- morphology, size and parameters of ore bodies;

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- geographic, economic and socio-economic conditions of the deposit area.

The completeness and detailing of the study of these factors makes it possible to assess the industrial significance of hydrogenous deposits for development by the ISL method and to design the corresponding enterprises. At the same time on the basis of studying only natural factors in most cases it is possible to receive only qualitative estimation of the basic geotechnological parameters of the process. Their quantitative estimation, necessary for design calculations, is obtained by carrying out field experiments [4,9].

The efficiency of operation is largely determined by timely of hydrodynamic state parameters of wells and formations, in order to accept technological methods and control for elimination of technological defects in time. For this purpose, a chemical reagent, capable of converting minerals of the mineral into soluble form, is supplied to the ore zone through the holes drilled from the surface. The solution, having passed the way from the injection well to the pumping well, is lifted by technical means to the surface and then transported by pipelines to the plants for processing [5].

By making any control action, the operating engineer will see a system response to this action with a long time delay and very ambiguity. Among the main parameters that can be observed are the flow of produced water from the disposal wells and the concentration of uranium and other elements in it. The operator's toolbox for influencing the process is also quite small. These are the choice of network type, location and number of wells, composition of the reagent solution and its injection and pumping regime [4].

The most common problems are calmotation, in other words clogging of pores and solution flow tubes with uranium changing into hardly soluble compounds. There is also the inverse problem of "scouring" - channels through which the solution reaches the pumping wells without having worked through the correct amount of ore. In both cases, the network must be reconfigured, sometimes by drilling new holes. Added to all this is the traditional mining industry's incomplete and limited geological baseline data. Existing practices and geotechnological field management systems are characterized by the fact that the management of the underground leaching process consists mainly of maintaining the balance flow rates for leaching and productive solutions. The flow rate targets are generated based on geotechnological data and the experience and skills of the mine geotechnologist. In this case, the process is conducted under conditions of information uncertainty of current characteristics of filtering media properties, such as permeability of the ore body, which relates filtration rate to the head gradient [5].

The main area of uranium use today is the production of fuel for nuclear power generation reactors. Geotechnological fields are a geographically distributed network of injection and pumping wells, topologically connected with the allocation of geological blocks and "deposits", equipped with tanks and technological equipment for acidification of leaching solutions, their supply to ore horizons and pumping of productive solutions [5,6].

The objectives of operational and dispatch control of such a complex geotechnological complex of branched structure consist in compiling of the production program and current state control of technological processes and equipment on the basis of hierarchical two-level network of operator (dispatcher) points and the use of technical means of automation. At the lower level (operator), the personnel monitor and record (in the absence of the possibility of automatic registration and data transfer) information about the values of technological variables and the state of equipment [6]. The considerable distance from the central site and the length of the GTF make it difficult to automatically transmit the leaching and production solution flow rates to the upper control levels. In addition, the acidity and uranium content of the solutions are determined by chemical analysis and then transferred and entered manually into a computer. Planning of the production programme is based on predicted uranium reserves by block and current estimates of uranium content in productive solutions. Balance calculations for mining, processing and production are performed.

Although the global resource base for this metal is fairly well developed, producing companies already today need effective tools to optimise their mining strategies, reduce production costs and, as a result, make more rational, integrated use of the subsoil. Mathematical modelling of the dynamics of in-situ leaching is just one of these tools.

Current status of the problem of mathematical modelling of PSV dynamics.

As mentioned above, research into the problems of mathematical modelling of SWP has been carried out since the early 80s of the last century. By now, judging from the published works, two main types of leaching models have been formed: deterministic and probabilistic-statistical. Deterministic models are developed on the basis of the laws of physical and chemical processes. The latter are based on empirically established dependencies between the natural controlled parameters of the process and the results obtained at the output.

Most of the reviewed works are devoted to deterministic modeling approaches. Comparatively few publications are devoted to statistical ones. However, this does not mean that such models are not used in the practice of mining enterprises. On the contrary, statistical models are successfully used to estimate integral process characteristics. For example, to determine the predicted mining life of a particular block, the average value of the required amount of reagent solution that must contact a unit mass of ore (the so-called "liquid-to-solid" or L:T ratio), etc.

Statistical models are well established in the mining industry as a tool for predicting key integral process characteristics. They have been successfully applied to early forecasting tasks, at the design stage of production block systems and, sometimes, as part of CAD and ACS. However, calculating process dynamics, analysing particular cases specific to the presence of filtration heterogeneity zones, zones of possible redeposition of dissolved compounds, and playing out various underground leaching control scenarios are beyond their scope of application.

Deterministic models are better described in the literature. Judging by the publications, intensive work on this subject was carried out in [3,7-10]. Credit should be given to the following researchers who contributed to the formation and development of mathematical modelling of underground leaching: G. N. Glotov, A. V. Kantsel, A. N. Kolchin, V. P. Koptelov, L. A. Linzer, D. P. Lobanov, V. S. Lomovsky, Y. V. Nesterov, V. V. Novoseltsev, S. N. Pykharev, E. A. Tolstov, M. I. Fazlullin, V. J. Farber, and others. In foreign periodicals most often there are works of authors - employees of University of Texas at Austin (P. M. Bommer, R. S. Schechter, L. W. Lake and others [7-8]), US Bureau of Mines, Minneapolis (R. D. Schmidt, S. E. Follin and others [8-10]), and Research Institute of University of Petroleum Minerals, Saudi Arabia.

Most of the papers on deterministic DBH models have some common features. Almost everywhere, the hydrodynamics of the process is described using Darcy's law and the continuity equation. Various assumptions about the homogeneity of formation permeability properties, the dimensionality of the problem and the stationarity of the process are used. The continuity equation is usually solved analytically, assuming reservoir homogeneity. So-called current ribbons (or tubes) are constructed. Then a model of kinetics of chemical interaction and mass transfer of leaching products and reagent is considered. Equations of this model are simplified to one-dimensional and they are solved along solution current belts calculated at the first step. Next, the output uranium concentration is calculated for the pumping wells as a result of mixing the solutions entering that well along all the incoming tapes.

Discussion.

Two approaches are possible to study the efficiency of the in-situ leaching process. The first is the experimental approach and the results obtained from it are empirical. Models based on this approach do not explain the mechanism of the process, but rather accurately reflect changes at the output of the system as a consequence of changes specified at the input. The second approach, theoretical, which consists in applying mathematical modelling methods to the process with analysis of its mechanisms, is considered in this paper.

Initially, the experimental study of the SP regularities was conducted exclusively in laboratory conditions. This was due to the simplicity of the experiment in the necessary range of technological process parameters. However, such results are not always valid and cannot be used for real fields. As a result, the laboratory experiments were replaced by full-scale experiments. In its turn, when carrying out in-situ experiments, there are a number of difficulties associated with significant internal heterogeneity of in-situ DB systems, impossibility to control the process directly in the core, high inertia of such systems, which does not allow to unambiguously link the specified input changes with the output data.

Conclusion

Thus, mathematical simulation of WP process is a demanded tool for design, optimization and control of useful component production. At the design stage of the PV section, simulation modeling allows selecting the optimal configuration of the network of technological wells and determining their operation modes. At the production stage, the mathematical model can be used to monitor and control the IS process.

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