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Research paper

Heap leaching. Computer simulation as an alternative technology

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Abstract

The article discusses the possibility of reducing environmental risks and resources by finding ways to optimize technology solutions with a computer program that simulates the heap leaching process. It is shown that the main role in the design and operational control plays simulation and an understanding of the structure and movement of the concentration fronts of substances – leaching participants within the heap. The examples of process control by conventional technological parameters – density of irrigation, fineness crushing or agglomeration bulk and height of the heap – show the attainability a significant reduction in of leaching time and as a result, reducing consumption of energy, water and sodium cyanide. The latter is a major threat to the environment.

Keywords: Heap leaching; Computer simulation; Alternative technology

1. Introduction. Statement of the problem

Heap leaching of precious metals from low-grade ores is highly resource- and energy-intensive process. Lots of heap leaching occupies dozens and sometimes hundreds of hectares of land. In the reverse process at the same time there are hundreds of thousands of cubic meters of toxic sodium cyanide solution. This circumstance represents a significant threat to the environment. Engineering measures taken to protect and prevent possible risks do not eliminate completely the cases of defeat on the surrounding countryside and surface and ground water [1,2].

Reducing the potential risks is achievable with decreasing volumes in circulation solutions that must lead to significant energy savings and reduced consumption of sodium cyanide per unit of output. Searching for opportunities to optimize the heap leaching process by conscious choice of control models can play a significant role in solving the problem of reducing environmental risks and resource.

Heap management is performed in two stages. In the first stage of design as a result of preliminary laboratory and sometimes semiindustrial study of the properties of ore and on the basis of gained experience designers the requirements for the ore fractional composition and the heap geometric parameters are formed. We do not consider here the economic component of the design process, although it also plays a very important role in the choice of a particular technological solution.

After the formation the heap enters a stage of irrigation and metal recovery. The current process control practice of the heap leaching of gold is to regulate the flow of the working solution at the pH and concentration of sodium cyanide and density irrigation. The result is a change of gold concentration in the pregnant solutions arising from the heap. The experience gained by the technologist allows partially to optimize the process for product cost and other economic and technological indicators.

The search for formal criteria to achieve the optimal parameters is an important task of the entire heap leaching technology [3,4].

An optimization problem may be well solved in the presence of a formalized numerical model of the process. Currently, there are different approaches to the creation of numerical models [5–8]. However, the achieved level of formalization of the problem does not allow technologists to obtain fairly complete and comprehensible description of percolation and chemical processes within the heap using existing approaches and software.

The principal drawback of the existing models is a complete lack of information on the state of the heap and current distribution of substances – participants' cyanidation in the inner

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layers of the heap. Experiments on the columns 10–12 m height allow us to obtain the uninformative distribution of substances in the end of the leaching cycle, but do not allow to monitor the situation in real time. For this reason, the information received in such a way has very limited application and may not be practically used for designing or controlling the actual heap. Consequently, in the current literature the question of the internal state and the distribution of chemicals within the heap is not considered due to the lack of approaches to solve the problem. But this very information is necessary for cost-effective and resource-saving solutions search.

The software simulating the heap leaching process considered in this paper may help to overcome such difficulties. This process is similar in the form to the movement of the trailing edge in the frontal chromatography by washing the chromatographic column from the sorbed substance. Such a view makes it possible to understand essentially the process of leaching, although the precise description of the expenditure of sodium cyanide within the heap has some specific features that do not adequately develop this analogy further.

2. Results

2.1. Description of mathematical models and software

Heap is considered as granular medium with a flow passage between the pieces of ore and non-flowing channels inside pieces of rock or agglomerates. Block of hydrodynamic equations is based on the well-known and fairly comprehensive van Genuhten [9] model, which allows to simulate flows in granular media in both saturated and unsaturated mode. This model is supplemented by equations describing the kinetics of the interaction of cyanide solutions with gold and impurity metals absorbing sodium cyanide as it flows through the ore layers and the equations of exchange solutes between flowing and nonflowing channels, carried out mainly by diffusion. Thus, the programme skeleton has more than a dozen of partial differential equations and equations of exchange. With the increasing complexity of the fractional composition of the ore or the number of irrigated tiers or heaps at the same time the number of solved equations has grown significantly, but, nevertheless, it has a little effect on the duration of the simulation. The simplest model of the heap having single fraction in one layer is calculated on a standard PC within minutes. Calculation of more complex multi-tiered and multifractional model may take hours.

The programme menu is made in Russian.

The model of single heap or complex flowsheet is created from separate blocks, allowing designer to collect sophisticated variants site heap leaching like in tinker toys. Each heap may consist of a set of fractions that differ in their kinetic and hydrodynamic parameters, gold content and exchange constant between the flowing and unflowing areas. Heaps can be irrigated in parallel or in series, which allow to carry out simulation of recirculating irrigation regime or multi-tiered pile with consistent showering on the upper tiers as mining lower.

Here the monitor displayes in the real-time distribution curves within the heap of sodium cyanide and leachable gold inside of agglomerates in the solid phase and passed into the solution, and solutions for flow and stagnant zones separately.

There is a continuous calculation of solutions casted on a bunch in terms of volume and sodium cyanide weight and cyanide solution in heap and their output from the heap. Also the balance of gold is estimated and this information is also available in real time.

This information allows to search for a targeted technological solution that reduce the consumption of water, electricity, sodium cyanide and critically reduces the cyanidation time and related environmental risks.

2.2. Physics of the leaching. Movement of concentration fronts

For further analysis, we have modeled the classical dependence of the concentration of gold in the product solution on time – the kinetic curve – with very plausible parameters for clay or silty ores (Fig. 1).

These hereinafter illustrations are arranged from the actual windows as they appear on the screen at a time stop counting.

As an example we take into consideration the element of heap of 1 m area and 6 m high, of single fraction, while the time of diffusion exchange $\mathbf{T}_{\mathbf{diff}} = 100$ hours, the concentration of [NaCN] = 0.2 g/l, density irrigation $\mathbf{j} = 5$ l/m^2 * h.

Here and below, for ease of comparison of the curves, we shall provide the data for the end of the process when it reaches 95% of the production of leachable gold. The obtained results on the consumption of sodium cyanide, solutions (and electricity) can be easily converted to a bunch of any size. In practice, there are heaps, markedly different from the one proposed, but we have chosen this because of its high ductility, i.e. clear and pronounced response in the behavior of the heap to changes parameters characterizing both ore and leaching process.

On the curve there are two expressions area: peak and shoulder. It is natural to expect that the physics of the leaching process is also different for the two parts of the curve.

As stated above, the computer simulation of the leaching process allows us to see what happens with the substances – participants in the thickness of the heap. The Fig. 2 shows the

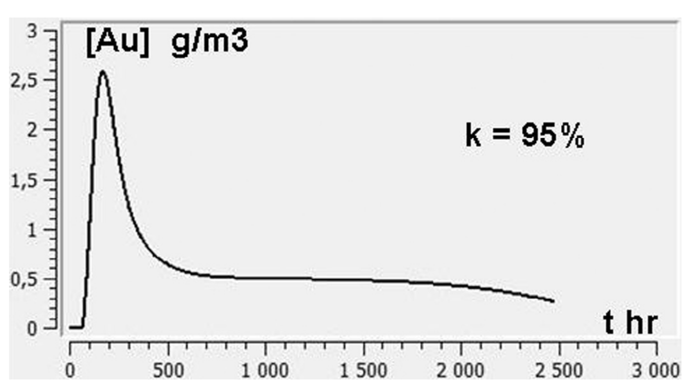

Fig. 1. The kinetic curve of the initial model experiment. The main important parameters: heap height is 6 m, recovered gold coefficient is 0.95, the concentration of gold extracted is 1 g/t, the concentration of [NaCN] is 0.2 g/l, the density of irrigation **j** is 5 l/m^2 * hour, time diffusion transfer $\mathbf{T}_{\mathbf{diff}}$ is 100 hours.