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SULFURIC ACID LEACHING OF CENTRAL KYZYLKUM LOW-GRADE PHOSPHORITE

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Abstract. This study investigates the effect of sulfuric acid concentration on uranium recovery from low-grade phosphorite of the Central Kyzylkum region. The initial phosphorite contained 8.69% P_2O_5 and 32.0 g/t uranium. Laboratory experiments were conducted using sulfuric acid solutions with concentrations ranging from 2 to 40 g/L at a solid-to-liquid ratio of 1:10 and a treatment time of 30 min. The chemical composition, pH, uranium distribution, and P_2O_5 content of the resulting solutions and residues were determined. Microscopic and FTIR analyses were also performed to evaluate structural changes in the phosphorite. The results showed that increasing acid concentration promoted uranium transfer into the solution and altered the phosphate mineral structure. The maximum uranium concentration reached approximately 32 g/t. The findings demonstrate the potential of controlled sulfuric acid leaching for preliminary enrichment of low-grade phosphorite and subsequent uranium recovery.

Keywords: Low-grade phosphorite; Uranium recovery; Sulfuric acid leaching; Phosphate ore; FTIR analysis; Hydrometallurgy

INTRODUCTION

Phosphoric acid is mainly produced by the wet-process method, in which phosphate raw materials are treated with sulfuric acid, resulting in the formation of phosphoric acid and phosphogypsum. Because phosphate ores contain various associated components, the produced phosphoric acid may include uranium, rare-earth elements, lanthanides, and other impurities. The large-scale production of phosphate fertilizers makes the recovery of uranium and other valuable components from phosphate materials an important technological and economic issue. In addition, phosphoric acid is widely used in chemical, agricultural, food, and pharmaceutical industries, which increases the importance of controlling undesirable impurities.

Several technologies have been developed for uranium recovery from phosphoric acid and phosphate-processing products. These include ion-exchange, solvent-extraction, sorption, and acid-leaching methods. Ion-exchange resins can selectively retain uranium from phosphoric acid solutions, while solvent extraction using organophosphorus compounds has also demonstrated high uranium recovery. The efficiency of these processes depends on the chemical composition of the feed material, acid concentration, temperature, viscosity, pulp characteristics, and reagent consumption.

Sorption methods have attracted particular attention because of their relative simplicity, low operating cost, and potential environmental advantages. Various natural and synthetic materials, including carbonaceous substances, polymers, zeolites, microorganisms, and modified mineral materials, have been studied as sorbents for uranium and other radioactive elements. At the same time, the use of industrial and agricultural wastes as low-cost sorption materials is considered a promising direction for developing more sustainable recovery technologies.

Phosphate raw materials in Uzbekistan also represent a potential source of uranium. In particular, phosphorite ores can contain uranium in concentrations that become technologically significant when large quantities of ore are processed. Acid treatment promotes the transfer of uranium and associated elements into the solution, while the phosphate component can remain predominantly in the solid phase. However, the presence of iron, aluminum, fluorine, rare-earth elements, and other impurities complicates subsequent uranium separation and requires optimization of the processing conditions.

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Despite the development of various uranium-recovery technologies, efficient treatment of low-grade phosphorites remains an important scientific and technological problem. Therefore, the present study focuses on the enrichment and acid treatment of low-grade phosphorite, with particular attention to uranium dissolution and the behavior of accompanying mineral components. The influence of hydrochloric acid concentration on uranium recovery is investigated, while the possibility of retaining the main phosphate component, expressed as P_2O_5, in the solid phase is also considered.

RESEARCH METHODOLOGY

The experimental study was conducted using low-grade phosphorite samples from the Dzheirau-Sardarinsky deposit. The chemical composition of the initial material was determined prior to leaching in order to evaluate the distribution of the main phosphate component and associated elements. The samples were first crushed, homogenized, and prepared for subsequent laboratory investigations.

The phosphate material was subjected to sulfuric acid leaching under controlled laboratory conditions. For each experiment, 100 g of homogenized phosphorite was placed in a reaction vessel, after which sulfuric acid solution of predetermined concentration was added. The solid-to-liquid ratio was maintained at 1:10, and the mixture was stirred for 30 min at approximately 20 °C. A series of experiments was performed using different acid concentrations to determine their effect on the dissolution of phosphorus and uranium-bearing components.

After completion of the leaching process, the suspension was separated into liquid and solid fractions by filtration. The resulting filtrate was analyzed to determine the concentrations of phosphorus and major dissolved elements, whereas the solid residue was examined to assess changes in its mineral and chemical composition. Phosphorus content in the initial phosphorite, filtrate, and residue was determined by spectrophotometric analysis.

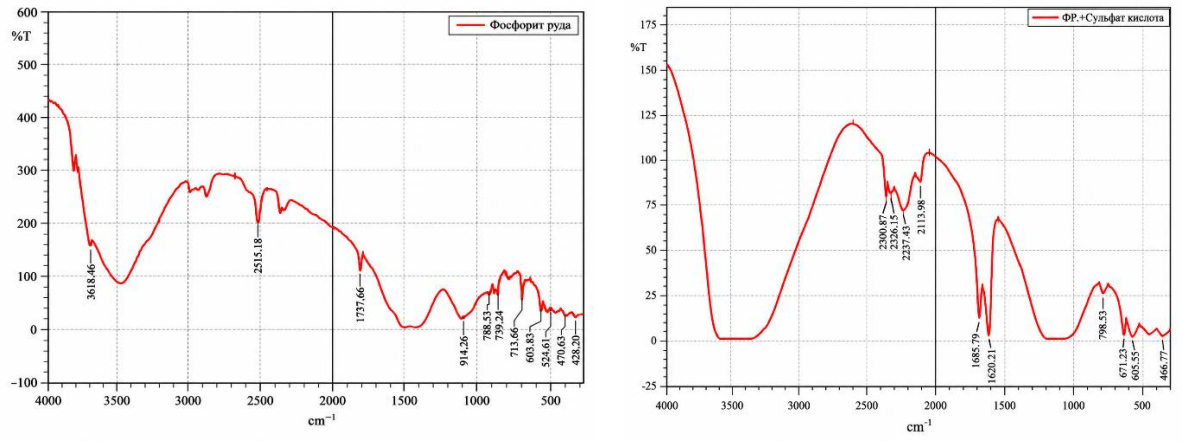
The elemental composition of the obtained products was additionally investigated using inductively coupled plasma mass spectrometry. Infrared spectroscopy was employed to identify changes in the functional and mineral phases of the material after acid treatment. Microscopic examination was carried out to compare the morphology and structural characteristics of the initial phosphorite with those of the leached residue.

The obtained analytical data were compared with the chemical composition of the untreated material. Particular attention was given to the distribution of uranium and phosphate components between the liquid and solid phases. Based on the experimental results, the influence of sulfuric acid concentration on the efficiency of uranium transfer into solution and the preservation of phosphorus in the solid phase was evaluated.

RESULTS AND DISCUSSION

The chemical analysis of the initial low-grade phosphorite showed that it contained approximately 8.69% P_2O_5 and 0.0032% U. The leaching experiments demonstrated that sulfuric acid concentration significantly influenced the dissolution of phosphate and uranium and their distribution between the liquid and solid phases. With increasing H_2SO_4 concentration from 2 to 40 g/L, the pH of the solution decreased, while the transfer of phosphorus and uranium into the liquid phase increased. Under the investigated conditions, the P_2O_5 concentration in the solution reached approximately 7.66 g/L, and the uranium concentration reached about 32 mg/L.

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a b

Fig. 3. FTIR spectra of Central Kyzylkum low-grade phosphorite: (a) untreated phosphorite ore; (b) phosphorite after sulfuric acid treatment.
(Source: Tagayev et al).

The interaction of sulfuric acid with the main calcium phosphate minerals can be represented by the following reaction:

$$Ca_{10}(PO_4)_6F_2 + 10H_2SO_4 \rightarrow 6H_3PO_4 + 10CaSO_4 + 2HF$$

This reaction describes the decomposition of fluorapatite, the principal phosphate mineral, with the formation of phosphoric acid and calcium sulfate. The resulting calcium sulfate can remain in the solid phase, while phosphorus and uranium-containing components are partially transferred into the solution.

Table 2. Effect of sulfuric acid concentration on phosphorite leaching

Experiment	H_2SO_4 concentration (g/L)	pH of leachate	Dry residue mass (g)	P_2O_5 in residue (%)	U in solution (g/t)
1	0	7.99	98.0	8.80	8.8
2	2	8.19	98.1	9.20	16
3	4	8.25	99.1	9.50	32
4	6	8.27	100.9	9.70	32
5	8	8.14	101.9	10.30	32
6	10	6.58	102.8	9.10	28
7	15	6.49	105.9	7.92	17
8	20	7.66	110.2	7.53	32
9	30	6.49	117.3	7.15	6.3
10	40	6.70	123.9	6.94	7.3

Microscopic analysis revealed significant changes in the morphology of phosphorite grains after acid treatment, including partial dissolution and modification of the mineral surface. IR-spectroscopic analysis confirmed changes in phosphate-containing phases and the appearance of sulfate-related structural features, which are consistent with the interaction of sulfuric acid with the phosphorite matrix.

CONCLUSION

The study demonstrated that sulfuric acid leaching is an effective approach for the preliminary treatment of low-grade phosphorite and the transfer of uranium into the aqueous phase. The initial

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phosphorite contained 8.69% P_2O_5 and 32.0 g/t uranium. Increasing the H_2SO_4 concentration significantly affected the pH, solid-phase composition, and uranium dissolution. The maximum uranium concentration in the solution reached approximately 32 g/t, while changes in the P_2O_5 content of the solid residue confirmed the progressive interaction between sulfuric acid and phosphate minerals. Microscopic and IR-spectroscopic analyses further confirmed structural and mineralogical changes in the phosphorite after acid treatment.

The obtained results indicate that controlled sulfuric acid treatment can provide suitable conditions for the preliminary enrichment of low-grade phosphorite and subsequent uranium recovery. The process is based on the decomposition of calcium phosphate minerals and the formation of calcium sulfate, with uranium being partially transferred into the solution. The resulting uranium-bearing solution can be further processed by selective ion-exchange methods, while the phosphate-rich solid phase can be directed to subsequent processing. Thus, the proposed approach has potential for more efficient utilization of low-grade phosphorite and recovery of valuable uranium components.

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