Original Article

Seepage characteristics of the leaching solution during in situ leaching of uranium

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ABSTRACT

Investigating the seepage characteristics of the leaching solution in the ore-bearing layer during the in situ leaching process can be useful for designing the process parameters for the uranium mining well. We prepared leaching solutions of four different viscosities and conducted experiments using a self-developed multifunctional uranium ore seepage test device. The effects of different viscosities of leaching solutions on the seepage characteristics of uranium-bearing sandstones were examined using seepage mechanics, physicochemical seepage theory, and dissolution erosion mechanism. Results indicated that while the seepage characteristics of various viscosities of leaching solutions were the same in rock samples with similar internal pore architectures, there were regular differences between the saturated and the unsaturated stages. In addition, the time required for the specimen to reach saturation varied with the viscosity of the leaching solution. The higher the viscosity of the solution, the slower the seepage flow from the unsaturated stage to the saturated stage. Furthermore, during the saturation stage, the seepage pressure of a leaching solution with a high viscosity was greater than that of a leaching solution with a low viscosity. However, the permeability coefficient of the high viscosity leaching solution was less than that of a low viscosity leaching solution.

1. Introduction

Uranium is a critical energy resource for nuclear power development [1]. Currently, uranium resources are primarily obtained by in situ leaching and mining in China [2,3]. In situ leaching is a uranium mining method that involves injecting the leaching agent directly into the underground ore-bearing rock formation. This allows the chemical reaction between the minerals and the leaching agent to form a uranium-containing leaching solution, from which uranium is then extracted. In situ leaching is essentially a dynamic chemical reaction process with physical effects [4,5]. Physically, the evolution of pore structure in ore-bearing media is a significant factor influencing the physical and chemical seepage patterns, as reflected by the change of permeability coefficient of the ore-bearing layer [6,7]. Chemically, the characteristics of the leaching solution are the most influential factors affecting the physical and chemical seepage laws of the ore-bearing layer medium, which are primarily reflected in the chemical composition of the solution,

solution viscosity and dynamic change of pressure difference during the seepage process [8—10]. In situ leaching of uranium demonstrates the influence of fluid—fluid and fluid—solid physicochemical interactions on seepage [11,12], and is a process of evolution of the flow field environment and medium structural features in which physical and chemical reactions occur [13—15].

Many studies have been conducted on the related issues of physical and chemical seepage in porous media. In recent years, attentions have been paid to the effects of changes in pore structure on different porous media. Xu et al. [16] analyzed the microstructure of remolded loess by scanning electron mycroscopy technique and Image-pro plus software, and discussed the relationship between permeability and micro-parameters of pores. Through the seepage test of oil-water two phase fluid in loose sandstone, Zhou et al. [17] demonstrated the evolution characteristics of sandstone pore structure from microscopic point of view and pointed out that the porosity and permeability of unconsolidated sandstone would decrease with the enhancement of re-compaction. Wang et al. [18] created an accurate model of an actual pumping site and demonstrated that the porosity of the ore layer diminished as a result of precipitates formed as the ion concentration increased

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continuously under acid in situ leaching conditions. Zeng et al. [19] performed acid leaching experiments on uranium-bearing sandstone, investigated the effect of pore structure on leaching efficiency, and found that leaching efficiency could be increased by adjusting the concentration of the leaching agent to alter the degree of pore structure.

During the seepage process, the changes of chemical solution and seepage environment have an impact on the seepage reaction. Yao et al. [20] used aqueous solutions at different pH values for seepage tests and obtained the variation law of the permeability coefficient and seepage pressure. Jiang et al. [21] investigated the uranium leaching experiment of different leaching agents in uranium-bearing sandstone and concluded that adding H_2O_2 oxidant to acidic leaching agent could improve the permeability of the formation. Qu et al. [22] conducted long-term water flooding studies of sandstones with low-permeability and concluded that long-term water flooding decreased the permeability of sandstones while increasing the porosity. Ding et al. [23] performed indoor simulation tests of soil column infiltration, and studied the change of ion concentration and the migration law of solute during the seepage process. Feng et al. [24] created a two-phase flow model in the seepage process by using phase field method, and concluded that the degree of recovery was dependent on displacement velocity, fluid viscosity, and wetting degree. Considering temperature, concentration of leaching agent, oxidant concentration and leaching method, Shen et al. [25] established a thermodynamic model to quantitatively estimate uranium speciation and solubility in aqueous phase.

At present, the influence of the fluid characteristics of the leaching solution during in situ leaching of uranium has not been studied in depth. In the process of in situ leaching and mining, when the uranium concentration in the extraction solution does not reach the uranium-containing concentration required by hydrometallurgy. Then the extraction solution is injected into the injection well again to increase the uranium-containing concentration. The process of in situ leaching for uranium mining is shown in Fig. 1. During this process, the fluid properties and the fluid flow environment change dynamically [26–28]. In order to explore the physical and chemical seepage laws of saturated and unsaturated phases in the seepage process, and the relationship between seepage pressure and permeability coefficient when the viscosity of the solution is used as a variable. In this study, the sandstone of a uranium mine in Aksu, Xinjiang was taken as the research object, and a seepage experimental device built by the authors was used.

To simulate the real situation of in situ leaching of uranium as much as possible, physical and chemical seepage experiments of uranium ore sandstone were conducted by using leaching solutions with different viscosities. Investigating physical and chemical seepage problems during the process of in situ uranium leaching is helpful to adjust the injection parameters in a timely manner during the leaching process, and select the process parameters of the leaching well site suitable for the seepage law of the ore-bearing layer. It can greatly improve the leaching rate of uranium and shorten the leaching period. The work has important guiding significance for the improvement of in situ leaching uranium mining technology.

2. Experimental

2.1. Ore samples

2.1.1. Sample source and composition

The Tarim Basin, which is located in southern Xinjiang, western China, is the largest inland basin in China and is particularly rich in minerals. The uranium-bearing sandstones employed in this experiment were all obtained from a uranium deposit in Aksu City, northwest of the Tarim Basin, as shown in Fig. 2.

The samples of uranium-bearing sandstone were low-permeability ores. The percolation test used uranium-bearing sandstone samples that were all collected from the same drilling hole in the uranium deposit. According to the X-ray diffraction (XRD) analysis, the uranium content of similar-quality uranium-bearing sandstones was equivalent. The specific chemical composition and content of the ore samples are shown in Table 1.

2.1.2. Preparation of cylindrical ore samples

Four groups of cylindrical core samples were obtained from the uranium-bearing sandstone and numbered as R1, R2, R3, and R4, as shown in Fig. 3. R1 had a diameter of 50.2 mm and a length of 100.4 mm; R2 had a diameter of 49.8 mm and a length of 101.2 mm; R3 had a diameter of 49.8 mm and a length of 100.2 mm; and R4 has a diameter of 50.3 mm and a length of 101.1 mm.

2.2. Leaching solutions

After selecting and drying the uneven uranium-bearing sandstone in its natural environment, it was pounded into smaller particles. The ore particle sizes ranged between 0.15 and 0.32 mm after screening. The granular ore was dried dried at constant
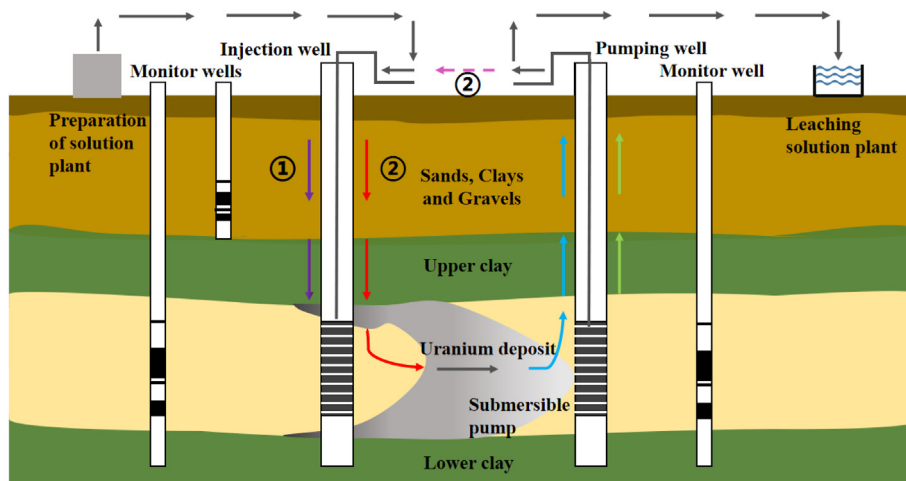

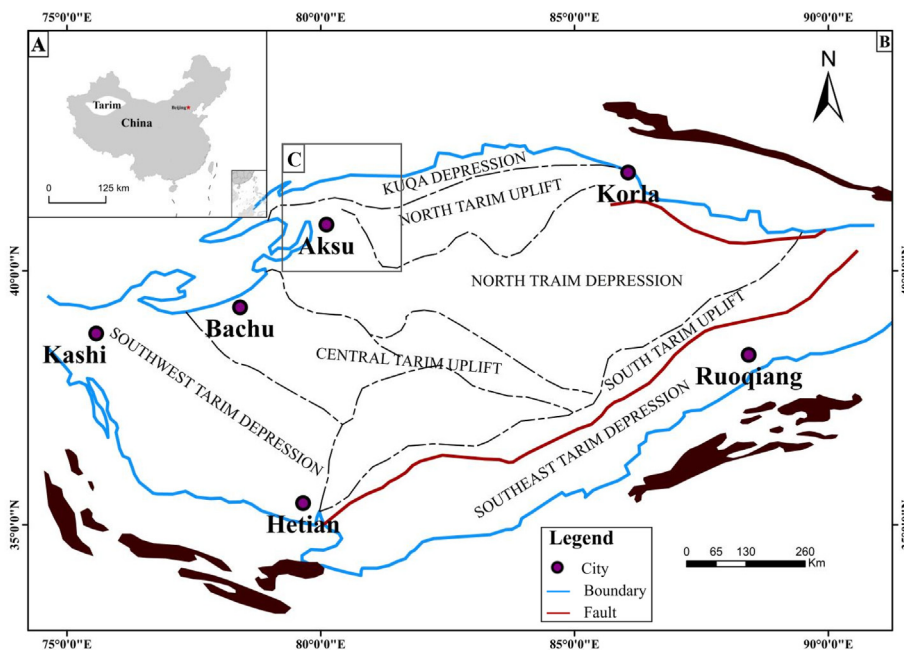**Fig. 1.** In situ leaching of uranium extraction and injection system.

Fig. 2. . (A)Map showing the location of the Tarim Basin in China; (B) Tectonic zoning map of the Tarim Basin; (C) The specific location map of Aksu.

Table 1
Chemical composition content of uranium-bearing sandstone samples.

Chemical composition	Content(%)	Chemical composition	Content(%)
SiO_2	74.726	P_2O_5	0.704
Al_2O_3	15.841	K_2O	0.552
CaO	2.761	Na_2O	0.307
SO_3	2.500	TiO2	0.253
Fe_2O_3	0.943	U(uranium)	0.184
MgO	0.734	others	0.495

Fig. 3. Cylindrical core samples.

temperature (65—75 °C) in a drying oven with a volume of 2 L. Four different leaching solutions of 6 L were prepared for subsequent experiments. A solution of 10 g/L NH_4HCO_3 + 10 g/L H_2O_2 was prepared, which is defined as L1. Alkaline leaching agent has good uranium selectivity, and other metal ions are not easily dissolved under alkaline conditions, so this solution was used as the initial leaching agent to perform static immersion reaction on uranium-bearing sandstone samples [29]. Firstly, the 10 g/L NH_4HCO_3+10 g/L H_2O_2 leaching agent was added to the 1500 g of granular uranium-containing sandstone sample retrieved from the constant temperature drying oven in a conical flask at a liquid—solid ratio of 4:1 [30]. After stirring with a glass rod to fully react the sample particles, the resulting immersion solution is defined as L2. Then, keeping the liquid-solid ratio of 4:1, adding the same mass of granular uranium-containing sandstone samples to the prepared L2 solution to make it fully react, the obtained solution is defined as L3. In order to prepare a higher concentration of leaching solution relative to L3, after repeated leaching tests, the obtained leaching solution is defined as L4. At the end of each reaction, all solid particles and liquids were collected in ten 2500 mL beakers, and the solution was obtained after solid-liquid separation. Finally, the uranium concentration in the leaching solution at each stage is determined by titrating U^{4+} with ammonium vanadate standard solution after reducing U^{6+} to U^{4+} with $TiCl_3$ [31]. The viscosity of the solution was measured using a Pin's capillary viscometer. Under the same temperature and pressure conditions, the viscosity of the solution increased with the increase of its uranium concentration, as shown in Table 2.

2.3. Seepage test of uranium-bearing sandstone

2.3.1. Test equipment

The experimental equipment that was developed by the authors, named "Multifunctional Physical and Chemical Seepage Experiment System Device of Uranium Ore", as shown in Fig. 4. The equipment consists of a stirred vessel, core holding unit (inner diameter 50 × 100 mm), constant-flux pump, pressure system, and computer operating system. The apparatus has a complete array of functions; that is, it can use gases, such as CO_2, or O_2, and liquid, such as an acid solution or an alkaline solution, for the fluid seepage tests separately, or it can utilize gas—liquid mixed fluids for seepage tests. The cylindrical ore sample is fixed on the core holding unit, the solution is added to the stirred vessel, and the system is started after setting the parameters on the computer. After the reaction starts, the real-time inlet pressure, outlet pressure, instantaneous flow rate and time-varying permeability coefficient curves during the seepage process can be clearly observed in the computer system. The operator is required to locate the ore sample and replace

Table 2
Properties of four leaching solutions.

Leaching solution sample number	Uranium concentration (mg/mL)	Viscosity (mm2/s)
L1	0	1.222
L2	0.472	1.567
L3	0.962	1.748
L4	2.258	1.799
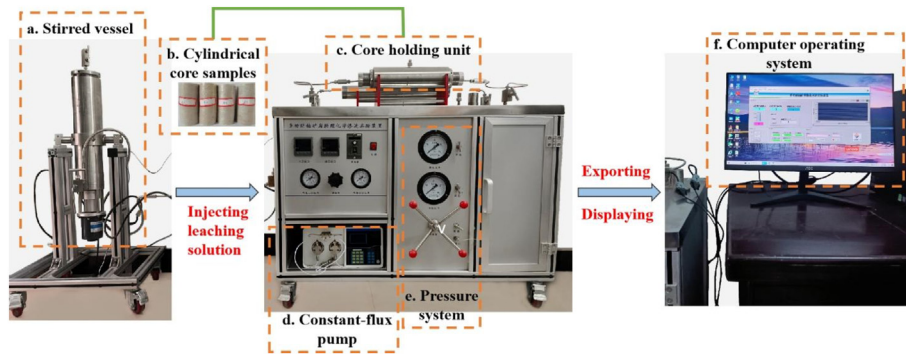
Fig. 4. Multifunctional physical and chemical seepage experiment system device of uranium ore.

the leaching solution according to the time set in the test.

2.3.2. Test model and process

(1) Calculation model of seepage velocity and permeability coefficient

A medium cross-section taken perpendicular to the seepage direction is called a water-passing cross-section. The cross section through which the fluid passes during the experiment is the medium cross section perpendicular to the seepage direction. If the seepage flow rate through the cross-sectional area of water (A) is Q, the seepage velocity across this cross-section is

$$v = \frac{Q}{A},\tag{1}$$

where v is the seepage velocity, cm/s; Q is the quantity of fluid flowing through the sample, cm^3/s; and A is the cross-sectional area of the sample, cm^2. Seepage velocity is the average flow velocity across the flow section. It is merely a speed assumption, not the actual speed of fluid movement, and it is assumed that the mineral medium is completely filled with groundwater with a velocity of v.

A constant flow passed through one end of the uranium-bearing sandstone sample. After a period of time, a pressure difference between the two ends of the sample was produced. According to Darcy's law [20,32], the permeability coefficient (K) of the uranium-bearing sandstone sample can be deduced by equation (2):

$$K = \frac{QL\gamma}{A\Delta P},\tag{2}$$

where K is the permeability coefficient, cm/s; Q is the quantity of fluid flowing through the sample, cm^3/s; L is the length of the sample, cm; γ is the unit weight of the solution, N/cm^3; A is the cross-sectional area of the sample, cm^2; and ΔP is the pressure differential between the two ends of the sample (the seepage pressure),Pa.

(2) Seepage test parameter

Due to the limited permeability of uranium-bearing sandstone, the seepage velocity was extremely low under natural settings, making laboratory testing and research difficult. To expedite the rate of replacement of the water−gas two-phase condition in the ore, an external force must be added to accelerate the process. While conventional procedures frequently employ pressurization to expedite the process, this test employed a novel technique that utilizes a steady flow and changing pressure to increase fluid seepage. In situ leaching of uranium involves injecting a constant flow of solution into the ore-bearing water layer through a liquid injection well. The uranium ore is dissolved in the groundwater, and then the groundwater containing uranium is pumped out through the pumping well. The depth of actual mines for leaching uranium is in the range of 400−500 m, and the injected leaching agent will inevitably generate vertical differential pressure when it reaches the ore-bearing layer. The pressure swing is to inject the leaching agent at a constant flow rate, and the seepage pressure changes continuously during the leaching process as the pore structure evolves. Using this method of steady flow and changing pressure can simulate the actual in situ leaching of uranium process as much as possible. In order to make the solution seepage system reach a certain pressure during the seepage process, the flow rate was set as 0.7 mL/min in the test. Considering the depth of the mine and the pressure in all directions around the ore layer [33,34], and the solution cannot penetrate the upper and lower clay. Therefore, the confining pressure applied in the experiment is slightly larger than the pressure of the seepage system. The confining pressure was set as 6 MPa in the test, and the effect of confining pressure on the pore structure was neglected.

(3) Seepage test steps
1) To cover the cylindrical core, a heat-shrinkable fluorinated ethylene propylene (FEP) tube with a diameter of 55 mm and a length slightly longer than 100 mm was used. A heat gun was used to blow the surface of the heat-shrinkable tube to make it contract tightly around the cylindrical core.
2) The cylindrical core sample was loaded into the core holding unit, the prepared leaching solution was blended

in a blender and then a series of experimental equipment valves were opened to confirm that the fluid path was unobstructed.

3) Through the computer operating system, parameters such as diameter and length of the corresponding rock sample, the density of the solution, the constant flow rate, the confining pressure, and the collection time can be set.

4) Click the "Start" button of the computer operating system to start the device system to start the seepage test. Then click the "Start Saving" button to start the computer operating system. The system will collect data such as seepage pressure, average flow and permeability coefficient in real time at set time intervals.

5) Step 2, 3, and 4 were repeated. In the second step, the rock samples were replaced in turn, and the leaching solution was replaced accordingly.

The corresponding serial number of the test is shown in Table 3. The steps for the preparation of the leaching solutions and the seepage test are shown in Fig. 5.

3. Results and discussion

3.1. The relationship between average seepage velocity versus time

The experimental set flow rate is 0.7 mL/min, and the percolation velocity can be obtained as 6×10^{-2} cm/s. As illustrated in Fig. 6, after 12 h of operation with constant flow and changing pressure, the average seepage velocity reached 6×10^{-2} cm/s. The average seepage velocity increased sharply during the first 0–12 h, and then stabilized at approximately 6×10^{-2} cm/s after 12 h. The test equipment produced a constant flow rate with an accuracy of 0.1 mL/min using a constant flow pump. Because pumping is a pulsed operation, if the flow rate exceeds the set value, the flow rate is automatically lowered, resulting in a seepage velocity that is incapable of reaching the stated value in its entirety and simply fluctuates around the stated value [35].

3.2. Variation characteristics of seepage pressure and permeability coefficient

The seepage characteristics in low-permeability porous media are determined by the pore size, porosity, and connectivity between pores. The in situ leaching process of low-permeability uranium-bearing sandstone is a typical seepage process in porous media [36,37]. The pattern of the curves in Figs. 7 and 8 indicates that the seepage pressure generally increases continuously during the seepage process of low-permeability uranium-bearing sandstones, while the permeability coefficient initially increases and subsequently decreases. Combined with the analysis of seepage mechanics and physicochemical seepage mechanism, there are two reasons for this phenomenon. In the seepage test, seepage pressure is defined as the difference between the intake and output pressures [38], that is, the difference in pressure between the ends of the rock sample during the seepage process.

(1) The leaching solution was injected at a constant flow rate, and the seepage process progressed through the unsaturated and saturated stages. The seepage in the saturated and unsaturated phases is influenced by the interfacial interaction [39,40]. In the unsaturated stage, seepage pressure increased rapidly because the seepage velocity of the rock sample was substantially slower than the injected fluid velocity. A constant flow rate is required to overcome the additional resistance created by the interaction of the leaching solution with the pore surface of the rock sample. For the same rock sample, the greater the flow rate, the greater the additional resistance that needs to be overcome. At this time, the permeability coefficient increased, owing to the fact that the ore pores were in full contact with the leaching fluid and that a significant volume of leaching fluid penetrated into the ore, completing the replacement of the gas–liquid two phase condition in the pore structure and resulting in the increment of seepage pressure, which was smaller than that of the leaching solution. After 12 h of seepage tests, the average flow rate for all tests achieved the predetermined value, indicating that the seepage had attained saturation. Compared with the unsaturated stage, although the growth rate of the seepage pressure in the saturated stage substantially slowed down, it continued to increase and was linearly connected with time variation. At the same time, in the saturation stage of seepage, the permeability coefficient showed a decreasing trend and also had a linear relationship with time.

(2) The physical and chemical reactions of the uranium-bearing sandstone and the leaching solution result in the change of the ore-rock medium structure. Previous research indicates that the permeability coefficient will drop as the porosity of a porous media reaches approximately 20%. The decrease in permeability coefficient is dependent not only on the reduction in overall porosity, but also on the geometry of the pore space and the spatial distribution of precipitates [41,42]. In this study, when the leaching solution came into full contact with the pore surface of the rock sample, the mineral components in the rock sample underwent complex physical and chemical reactions. Not only did the reaction dissolve and leach uranium, but it also reacted with the other mineral components of the rock sample indiscriminately, dissolving the pore medium of the rock sample. The reason for the evolution of pore structure may be that with the continuous reaction, various mineral particles and mineral precipitation produced by dissolution and erosion reaction will be carried away by leaching solution. During this process, small particles will be jammed at the pore throat due to intermolecular attraction and aggregation with precipitates and destroy the original pore structure. The original connected effective pores were transformed into disconnected ineffective pores, so that the channels for the circulation of the solution were reduced. Then the seepage flow of the ore-bearing rock samples passing through would reduce, so that the permeability coefficient of the sandstone medium gradually decreased with the reaction.

Table 3
Test serial number correspondence table.

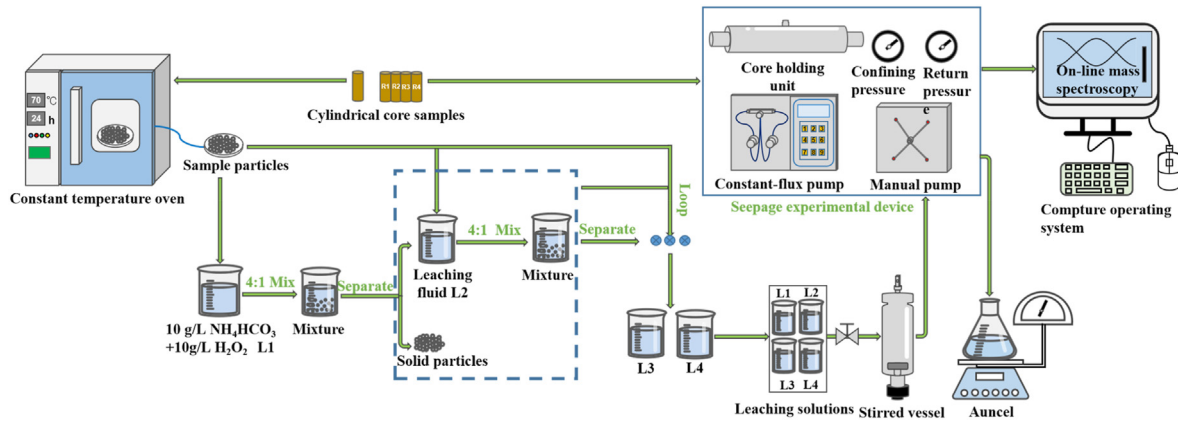| Experiment number	Core sample number	Leaching solution sample number
S1	R1	L1
S2	R2	L2
S3	R3	L3
S4	R4	L4

Fig. 5. Experimental steps of physical and chemical seepage of uranium ore.
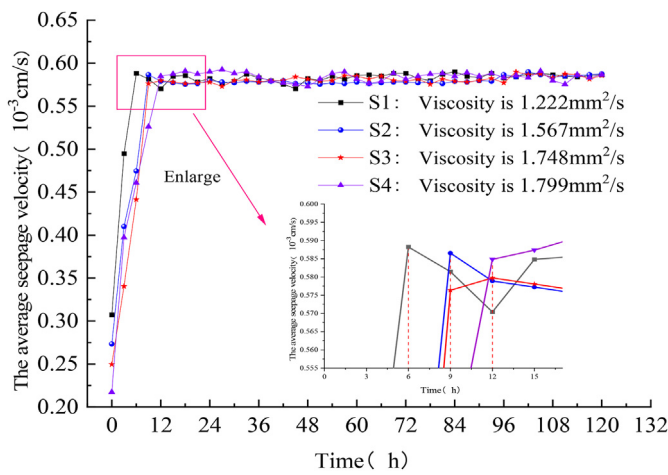

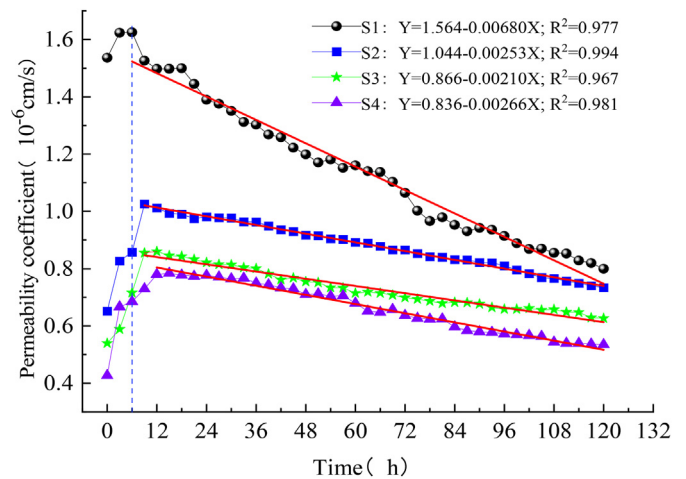**Fig. 6.** The relationship of the average seepage velocity versus time.

Fig. 8. The relationship of permeability coefficient versus time.
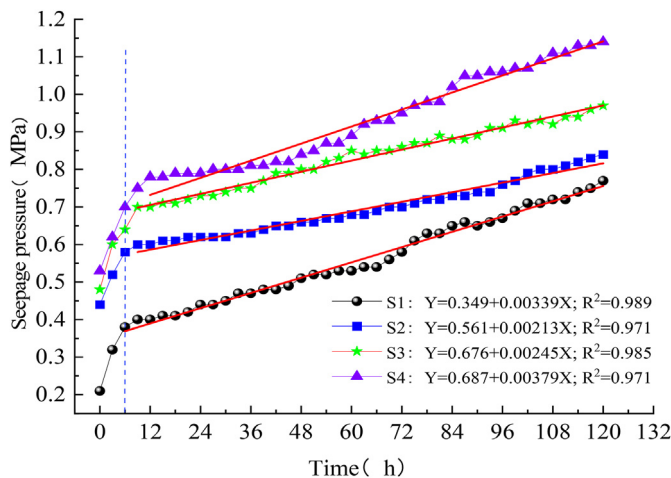

Fig. 7. The relationship of seepage pressure versus time.

To investigate the relationship between the permeability coefficient K of the rock sample and the seepage pressure P, the change curves for the permeability coefficient K and the seepage pressure P were merged and a comparative analysis was performed, as shown in Fig. 9.

The changes in permeability coefficient K and seepage pressure P with time after 6 h were symmetrical at a given time point under the condition of constant flow injection of 0.7 mL/min. The relevant values are shown in Table 4. It can be seen from Figs. 6 and 9 that the average seepage velocity is basically stable after 6 h. And the permeability coefficient has a very significant change compared with the permeability coefficient within 6 h. It began to decrease continuously after a sharp turn, showing a linear negative correlation with the time change. At the same time, the seepage pressure also changed dramatically after 6 h. Compared with the seepage pressure within 6 h, the seepage pressure began to display regular fluctuations, which showed a linear positive association with the time change. Since the seepage pressure and permeability coefficient were closely related to the time change after 6 h, two fairly symmetrical straight lines were generated by linear fitting in the Cartesian coordinate system. Therefore, the fitting findings of the test data indicated that there was a correlation between the permeability coefficient K and the seepage pressure P when the average flow rate of seepage was stable.

Based on the analysis of seepage mechanics and the seepage mechanism of low-permeability medium, the seepage reaction advanced slowly at first, the fluid injection velocity was greater than the seepage velocity of the rock sample. Then increment of the leaching solution gradually accumulated at the inlet, resulting in the inlet pressure and permeability coefficient gradually increased. As seepage progressed, the leaching solution reacted with mineral-bearing substances in rock samples. Minerals were dissolved and
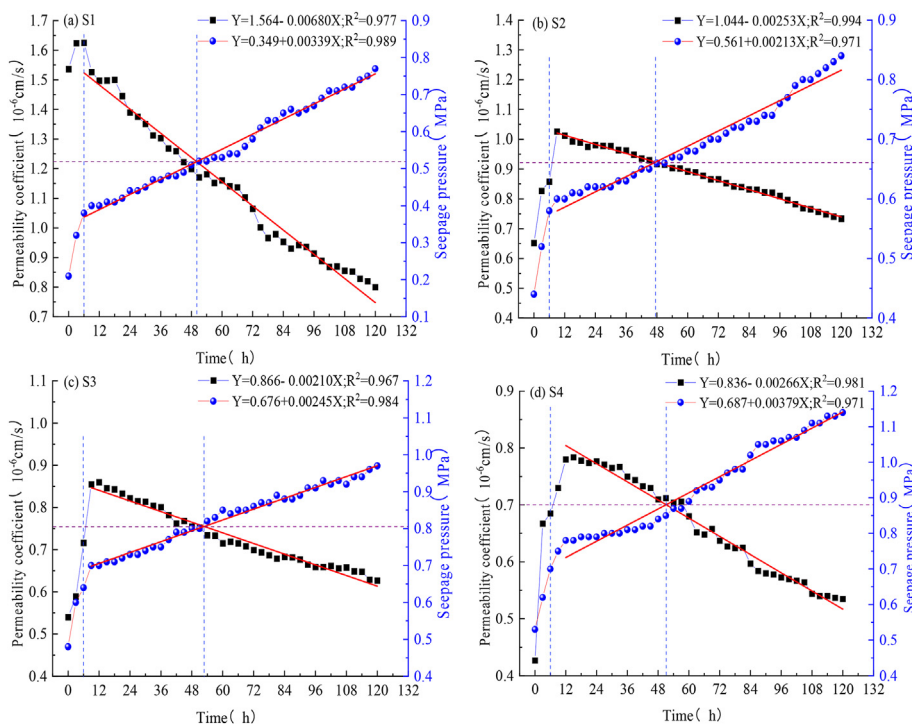
Fig. 9. The relationship between permeability coefficient and seepage pressure versus time.

Table 4
Parameters at symmetric points.

Experiment number	Permeability coefficient (10^{-6}cm/s)	Seepage pressure (MPa)
S1	1.215	0.51
S2	0.924	0.66
S3	0.755	0.80
S4	0.698	0.88

pore structure of rock samples changed. With the continuous injection of leaching solution, mineral particles were released and dissolved in the leaching solution. Some mineral particles moved continuously and some mineral particles blocked the pore channels. At the same time, the sodium ions in the solution were gradually replaced with the cations in the rock sample, causing the expansion of clay minerals and blocking the pores. Therefore, the original effective pores in the sandstone became ineffective pores. The seepage pressure of the liquid in the pore channel was continuously accumulated, and the flow rate of the leaching solution passing through the rock sample per unit area decreased. The permeability coefficient of sandstone was reduced. Therefore, in the process of in situ leaching, permeability coefficient K and seepage pressure P affect each other. They are two important parameters during in situ leaching of uranium, and are of great significance for selecting appropriate injection volume and injection rate.

3.3. Influence of fluid viscosity on seepage characteristics

The seepage characteristics of various fluid mediums to rock samples with identical internal pore structures were the same; however, there were variances in the regularity of the saturated and unsaturated stages. When the seepage flow of the solution reached the average flow rate, the seepage pressure and permeability coefficient were closely related to the time change, showing a linear relationship.

In the seepage process, the time required to reach saturation increased as the viscosity of the fluid medium increased. According to the magnified view in Fig. 6, the test S1 reached saturation after 6 h, the test S2 reached saturation after 9 h, and the tests S3 and S4 reached saturation after 12 h. This was because the viscosity of the leaching solutions varied, as did the permeability of the leaching solution to the rock sample, resulting in a differential in the surface tension of the fluid and the viscous force of the mineral rock medium. As the viscosity coefficient of the leaching solution increased, the time required to reach the saturated state from the unsaturated state increased. Furthermore, the seepage pressure of a medium with a high viscosity coefficient was greater than the seepage pressure of a medium with a low viscosity coefficient, and the permeability coefficient of a medium with a high viscosity coefficient was almost always smaller than the permeability coefficient of a medium with a low viscosity coefficient.

Based on the theoretical analysis of porous media seepage, it can be found that when leaching solution flows at a consistent rate through the mineral rock medium, the large pore radius, strong connectivity, and large fractures in the ore rock medium do not obstruct seepage. When these huge pores and fracture channels are gradually filled with leaching solution, they gradually spread to those with smaller pores and weak connection, as well as to those with smaller fractures. And the leaching solution will produce larger capillary resistance to those channels with small pores and small cracks due to the effect of its own surface tension.

Additionally, these small channels will exert a stronger viscous pull on the leaching solution, preventing it from moving deeper into the narrow channels. As a result of the viscosity variation in the leaching solution, the seepage pressure and permeability coefficient exhibit regular differences, extending the seepage time from the unsaturated to the saturated condition.

4. Conclusions

The impact of variables such as the viscosity of the leaching solution on the seepage properties (seepage pressure and permeability coefficient) of uranium-bearing sandstones were investigated in this study. The following conclusions can be drawn:

(1) During in situ leaching, the saturated and unsaturated seepage of porous media changes continuously with the leaching process. It was not only affected by the dissolution and erosion of the sandstone caused by the leaching solution, but also by the pressure. When different viscosities of leaching solutions penetrate the uranium-bearing sandstone at a constant flow rate, the seepage pressure increased continuously, while the permeability coefficient increased first and subsequently decreased.

(2) Early in the seepage process, the seepage pressure and permeability coefficient increased rapidly at the constant flow rate. This stage was the unsaturated state of seepage. Late in the seepage process, the average flow rate was basically constant, and the seepage of different samples began to enter the stage of saturation. At the stage of saturation, due to the increase of additional resistance and the accumulation of sediments, the growth rate of seepage pressure was slowed down, and the permeability coefficient continued to decrease, and both had a linear relationship with time. At the same time, a correlation existed between the seepage pressure and permeability coefficient.

(3) The seepage characteristics of different viscosities of leaching solutions in rock samples with similar internal pore architectures were identical, but the time required to reach saturation seepage was varied. The increased viscosity of the leaching solution prolonged the time required to reach saturation during seepage. After reaching saturation, the seepage pressure of the high viscosity leaching solution was more than that of the low viscosity leaching solution, whereas the permeability coefficient of the high viscosity leaching solution was usually always less than that of the low viscosity leaching solution.

These findings have important theoretical significance for the development of in situ leaching technology. They are also significant for enhancing uranium recovery and reducing the cost of obtaining uranium. However, the characterization of porous media evolution in ore rocks during alkali leaching seepage is not involved, so it will be the goal of future research.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

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