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THE FUNDAMENTAL RESEARCH AND INDUSTRIAL APPLICATION OF THE CO2 AND O2 IN SITU LEACHING PROCESS IN CHINA

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Due to the advantages of less chemical reagent consumption and groundwater pollution, CO2 and O2 in-situ leaching(ISL) process became to be one of the important research field in uranium mining.China was the second country where CO2 and O2 ISL process has been put into production in the world.It is shown that the development and characteristics of CO2 and O2 ISL process in China,including main principle, technological process, wellfield design and production well construction,uranium processing, and so on.In the last, the industrial application status and development potential of CO2 and O2 ISL process in China are summarized.

1 DISCOVERED URANIUM RESOURCES STATUS AND DISTRIBUTION

There are 21 uranium orefield distributied in 13 provinces,including Inner Mongolia, Xinjiang, Jiangxi, Guangdong,etc. Since 1994, the targets of exploration was changed from conventional mining deposits in southern China to in-situ leaching deposit in north of China.A plenty of medium-large scale sandstone uranium deposits have been discovered.As a result, the U resources/reserves increased rapidly since 2000.

The identified resources(Reasonably assured resource and inferred resource)totally amounted to 370,900tU in China, while more than 2 million tU is predicted with a big potential. Uranium resource and share of different type uranium resources in 2016 were listed as follow:sandstone(56.9%,210,000tU),granite(23.6%,87,000tU)volcanicrock(11.1%,41,000tU),carl siliceous-pelitic(7.5%,28,000tU),others(0.9%,3,500tU).The increased sandstone uranium resources mainly comes from six basins: Yili basin,Turpan-Hami basin, Ordos basin, Erlian basin, Songliao basin and Bayin Gobi basin, which all distributed in northern China. Yili basin and Songliao basin are the key and potential area in future.

Most of sandstone uranium deposit in China are complex and about 70% of which are some adverse factors such as high carbonate content(>2.0%,CO2), low permeability(<0.17m/d), low grade t(~0.03%,with delineation of ore bodies 0.01%), ,high salinity groundwater(TDS,5~10g/L) and so on.

2 THE BRIEF DEVELOPMENT HISTORY OF CO2+O2 ISL

CO2+O2 In-situ leaching process of uranium has been developed since 2000 in China. Some CO2+O2 leaching experiment have been carried out to simulate CO2+O2 leaching characteristics and some technical parameters were obtained.

Since 2006, a field test and industrial test has been implemented in Qianjiadian uranium deposit, Songliao basin,Inner mongolia .The buried depth of ore body is 251.8~298.31m with a thickness of 6.46~15.75m, a mean grade of 0.025% and a mean uranium content of square meters of 3.95kg/m2. The modes of occurrence of uranium in Qianjiadian deposit are absorbed uranium, uranium minerals and uranium bearing minerals. The ratio of U(VI)/U(IV) is 0.266~1.116 and the average value is 0.761.

The permeability coefficient of the ore-bearing aquifer is 0.025~0.223m/d and the depth of confined water is 5.29~7.06m. The type of water quality is a combination of HCO3-Na and HCO3-Cl-Na with range of the salinity of 3.10~5.7g/L, the pH of 7.2~8.4, the Eh of 100~200mV .

A industrial-scale well field had been established ,including 10 production wells and 32 injection wells.Depengding on ore body geometry and surface topography, 7-sopt well patterns and 35m well spacing were used. For

injection wells, the average flow rate is 2.8m3/h, the equivalent flow rates for recovery wells are 8.1m3/h, respectively.

3 CO2+O2 LEACHING PROCESS

Both gasous oxygen and carbon dioxide are added to groundwater to produce lixiviant.Oxygen is typically added to maintain the strongly oxidizing conditions required to oxidize tetravalent uranium in ore minerals to hexavalent stage.The oxygen concentration will be changed from 150mg/L to 500mg/L with diffierent leaching stage, depending on uranium concentration and dissloved oxygen of lixiviant.Carbon dioxide is added for pH control and increasing bicarbonate concentration increasing. Carbon dioxide concentration will be changed from 100mg/L to 300mg/L.

After 2a of operation, uranium recovery had been up to 53.1% with L/S ratio 2.64 ,while average uranium concentration was about 32mg/L. Specific consumption of CO2 was 10.8t/tU and specific consumption of O2 was 12.0t/tU.The flow rate of recovery well and injection well remained stable which was shown that Calcium carbonate scaling was not generated to play a
adverse impact on field test.

Uranium mobilization and processing excess water that must be properly managed.The production wells exctract slightly water than is re-injected into host aquifer.The production bleed is more than 0.3-1.0 percent of the circulation rate.The main purpose is to maintain the negative balance helps to minimize the potential movement of lixiviant.

Some technical parameters:
Well pattern:5-spot and 7-spot;
Well-spacing:30-35m;
Drilling hole structure:gravel filling type;
Depth:240-320m;
Lixiviant:100˜300mg/LCO2+150˜500mg/LO2;
Recovery rate: more than 75%;
Uranium extraction: ion-exchange process with fixed bed column;
Water waste treatment:RO (reverse osmosis)and evaporation pond.

4 URANIUM PROCESSING

The common ion-exchange resin is D261 widely used in ISL project in China and the ion-exchange circuit is accomplished in two fixed bed columns in series. Based on average uranium concentrations(about 32mg/L), greater than 97 percent of the uranium ia extracted during the ion-exchage process.The lixiviant exiting the lixiviant columns normally contains less than 0.1 mg/L. Before entering the ion-exchange columns,CO2 was added into the prengnant solution with the concentration from 100 to 300mg/L.The purpose is to contorl the pH from 6.8 to 7.2 and increased the saturated resin load.

The elution process is accomplished in a columns in series, by contacting the resin with a mixed solution of sodium chloride and sodium bicarbonate, thus obtaining an pregnant eluant solution with about 35-50g/L.Typical operational condition are 80-120g/L sodium chloride and 10-20g/L sodium bicarbonate.The is normally than 99.9%.After enough pregnant eluant solution is obtained, it is moved to the precipitation circuit.

In the precipitation circuit, the pregnant eluant is typically acidified using hydrochloric to destroy the uranyl peroxide.The pH of pregnant eluant decreased to about 3.0-4.0 and is required to maintain in 4 hours accompanied by stirring. Caustic soda is then added to precipitate the uranium as sodium diuranate at pH 6.0-7.0.At last, the resulting slurry is sent to a plate-and-frame filter press where it is filtered and washed.Acorrding to the netural uranium product quality standard, the content of U is required to be equal or greater than 60% in solid material, the content of water is required to be equal or less than 30%。

During the process, some liquid waste were generated which may contain elevated concentration of radioactive and chemical constituents.Reverse osmisis was common used to segregated from it. Through reverse osmosis process,two fluids were yielded:Clean water (about 70 percent, Cl-<350mg/L)that can be reinjected into the aquifer ,and brine(about 30 percent) that can be transported into evaporation pond.

5 ISL MINES PRODUCTION STATUS AND POTENTIAL APPLICATION

Due to the advantages of low operating cost, short loading period and less environment pollution, the proportion of uranium produced by in-situ leaching mines increased rapidly.In China, in-situ leaching production dominated uranium production accounting for 65.6% of word production in 2016, which was more than heap leaching(21.1%) and conventional mining(18.5%), the second and the third extracting process of uranium respectively.

2006-2009,the first CO2+O2 ISL project came to commerical operation at Qianjiadian uranium deposit in Inner Monglia.Because of the constantly discovery of ISL sandstone uranium resources, two CO2+O2 ISL mines have been put into operation respectively in Songliao and Yili basins now. Other two mines are being under pilot-scale test in Erdos and Erlian basins.They will be put into production soon.

CNNC(China national nuclear corporation) shut down some high-cost underground and open-pit uranium mines in Southern China, focusing on the development of ISL sandstone uranium resources in Northern China,and plan to build three 1000t/a ISL uranium mines by 2020.

6 CONCLUSION

Because of successful application results and strict environmental requirements, CO2+O2 ISL has become a priority option and the only option for sandstone type uranium deposit with high carbonate content and high salinity groundwater. According to the development plan,about 90% netural uranium production will be provided by ISL ,especially by CO2+O2.Some large-scale and green mines is under planning and implementation.

Country or International Organization

China

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