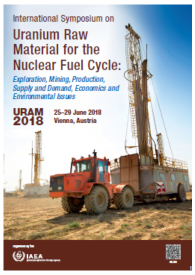

Contribution ID: **197**

Type: **ORAL**

THE RESULTS OF LABORATORY AND FIELD IN SITU LEACHING TESTS AT THE NYOTA URANIUM DEPOSIT (UNITED REPUBLIC OF TANZANIA)

Thursday, 28 June 2018 16:20 (20 minutes)

INTRODUCTION

Uranium deposit Nyota is located in the southern part of the United Republic of Tanzania. The geological setting of the deposit and its hydrogeological properties allow to consider part of the Resources as potentially amenable for mining by in-situ leaching (hereafter referred to as "ISL"). In 2015-2016 Uranium One Group conducted a range of studies for evaluating of the possibility of uranium ISL mining at the deposit. The studies consisted of laboratory core leaching, hydrogeological pumping tests and a field ISL test, carried out without processing of pregnant solutions. The ISL test aimed at determining the main ISL process parameters which are used for calculation of ISL mining parameters. The main ISL parameters are the following: uranium recovery, average uranium content in pregnant solutions, specific lixiviant consumption and liquid-to-solid ratio.

DESCRIPTION

The Nyota uranium deposit is a part of the Mkuju River Project located in Tanzania, some 470 km south-west of Dar es Salaam. The deposit is associated with a series of the Lower Triassic continental sediments of the Karoo Supergroup which are presented by poorly lithified gravelites, sandstones and siltstones. There are three basic mineral forms that represent uranium mineralization: meta-autunite, meta-uranocircite and phosphuranylite. The minerals form a dense interspersed yellowish-green color in the mica-hydrogoethite cement and on the surface of detrital grains. Ore-hosting rocks are of low CO2 content therefore they are considered as non-calcareous.

Ore bodies are outlined with 0.01% uranium grade. Within the bodies ore grade varies from >0.01 to 1.8%. Within the central part of the deposit ore bodies are detected at shallow depths –from the surface to the depth of 60-70 m; within the northern part uranium mineralization detected at the depth of 150-170 m. Groundwater level depths are ranging from 1-2 m within river valleys to 40-50 m at watersheds. So uranium mineralization is partly located above groundwater level and partly below. Ore hosting aquifer is unconfined and has neither overlying nor underlying regional aquitards.

As of 31.12.2016 Proven & Probable reserves of the Nyota deposit were estimated at 25,8 ktonnes of uranium and Measured & Indicated resources were estimated at about 48 ktonnes of uranium [1]. The existing development plan of the deposit provides for conventional open pit mining with hydrometallurgical processing of ore. Due to the recent uranium falling market Uranium One Group is considering another mining opportunities in addition to the open pit mining method. The geological and hydrogeological setting of the deposit gave Russian experts an idea of possibility of uranium mining by in situ leach method. In 2015-2016 Uranium One Group conducted researches to evaluate an amenability of uranium mineralization for ISL mining. The studies consisted of laboratory core leaching tests, hydrogeological tests and ISL field test.

Laboratory tests were conducted on core samples obtained during drilling works in 2015. The boreholes location provided core sampling in the central, the north-eastern and the southern parts of the deposit. Core samples were disintegrated to the size of natural sand grains (0.5-1.5 mm) and averaged.
Laboratory tests were conducted in two modes: static and dynamic leaching. The main objectives of static

leaching were to determine an amenability of uranium to dissolve in leaching solutions; to select an appropriate composition of the leaching solution; and to determine a degree of homogeneity of the samples in terms of leaching. In static tests 10 g subsamples were leached in flasks at a constant liquid-to-solid ratio which was set to 10. Based on the results of preliminary leaching tests, the sufficient test duration was defined as 24 hours. A series of preliminary tests also revealed that sulphuric acid is the most efficient lixiviant. Therefore, further static tests were all carried out using solutions with sulphuric acid concentration 5, 10 and 20 g/l. The overall number of static tests was 222 (71, 73 and 78 respectively). The testing results showed that: a) uranium mineralization is easy to leach, b) all the samples are of the same type in terms of leachability and c) uranium recovery for the entire sample batch is independent of uranium head grade and equals to 100%.

In dynamic tests filtration of leaching solutions through the core material was modelled. For this purpose leaching solutions were pushed upwards through the column loaded with core subsamples (200 g). Pregnant solutions were collected as samples of equal volumes (25 ml) from the overflow and then analyzed for uranium content, acid concentration and pH. Tests duration varied from 3 to 26 hours. The results of the dynamic leaching tests are as follows: uranium recovery 85-99%, average uranium content in pregnant solutions 69-1270 mg/l, sulphuric acid specific consumption 4-60 kg/kgU, liquid-to-solid ratio 1-4. These results are considered as positive.

Hydrogeological studies consisted of single and cluster pumping tests which were conducted in hydrogeological wells drilled in 2015. The pumping tests conducted in line with the ordinary technique –pumping at a constant discharge rate and monitoring of groundwater levels at drawdown stage and recovery stage after pumping was stopped. Considering the possibility of the deposit development by both open pit and in-situ leaching, hydrogeological studies were conducted to evaluate hydrogeological properties of the upper part of uranium hosting aquifer. For that purpose well screens were installed in hydrogeological wells at depth interval 6-83 m. Estimation of hydrogeological properties showed that uranium mineralization is within the aquifer presented by sandstones of nonuniform permeability distribution. Hydraulic conductivity of the sandstones determined in cluster pumping tests is 25-63 m2/day, which means that the aquifer is permeable in general.

The results of hydrogeological and laboratory leaching tests show that uranium mineralization is located in permeable sediments and can be dissolved by sulphuric acid solutions. These results allow execution of an ISL field test.

ISL field testing was executed using the two-spot scheme, invented in Russia [2]. There are only two operating wells –the injection and the recovery ones. The flowrate of the recovery well should be greater than that of the injection well, and the ratio of these flowrates should be maintained constant throughout the test. Such a proportion of the flowrates maintains hydrodynamic isolation of a geological medium involved in ISL test that ensures movement of the solutions from the injection to the recovery well and only within the sampling volume. Planar area of the sampling volume can be calculated using a formula, with the distance between the injection and the recovery wells and the ratio of their flowrates indicated. There is no time variable in the formula so it means that the volume is stable in time. These features of the testing scheme allow reliable estimations of uranium reserves within the sampling volume, and uranium recovery in field tests as well. Maintaining of the stable sampling volume of the geological medium is the main advantage of the two-spot testing scheme.

Pregnant solutions which are moving towards the recovery well are diluted by fresh groundwater when they are pumped off. The degree of dilution of pregnant solutions is controlled by flowrates ratio of the recovery and the injection wells. The pregnant solutions from the recovery well are sampled and then pumped into a discharge well. There is no processing of pregnant solutions and uranium recovery provided. The discharge well is usually located far enough from the test site in order to avoid an influence of the discharge on the test. The main objective of the ISL test is a determination of ISL parameters as follows: uranium recovery, average uranium content in pregnant solutions, specific consumption of a lixiviant and liquid-to-solid ratio. Taken together these parameters are usually used for evaluation of an amenability of deposits or ore bodies for ISL mining in terms of geology and hydrogeology.

Two-spot tests were widely implemented at the deposits of the former USSR, Mongolia and they are currently applied in Russia and China. Duration of ISL tests vary from 2 to 6 months, with the average of 3 months. Thus, two-spot testing is a comparatively cheap and prompt exploration method which allows to evaluate deposits for ISL mining.

Site selection for the ISL field test was based on the results of exploration drilling. Eventually it was decided to conduct the test in the southern part of the deposit, where uranium mineralization occurs below the groundwater table. There are two ore bodies detected within the selected test site. The upper ore body is within the depth of 25-35 m, the lower one is within the depth of 43-50 m. The ore bodies are divided by a layer of 8-10 m thick with uranium grade far below 0.01%. The upper ore body is more sustained in thickness within the test site and has a higher productivity than the lower ore body. For these reasons it was decided to conduct the ISL test only on the upper ore body.

The test site has the following geological and hydrogeological setting (for the upper ore body): 9.6 m average thickness of the ore body, 0.078% average uranium grade, 13.2 kg/m2 average productivity, the aquifer is unconfined, groundwater table depth –18 m, the upper boundary of the ore body is at the depth of 27 m, discharge flowrates of the injection and the recovery wells are about 2 m3/h, the ore body has neither overlying nor underlying aquitards which is typical of the entire deposit.

The following parameters were set out for the test: the distance between the injection and the recovery wells –6 m, screening interval –25-35 m for the whole thickness of the ore body, the recovery and the injection flowrates ratio –5. Concentration of sulpuric acid was initially planned to be 15 g/l, but almost in the beginning of the test it was increased to 30 g/l and maintained at this level throughout the test. The test duration was 10 months.

During the test groundwater level monitoring was conducted both in 5 monitoring wells and 2 operating wells, the injection and discharge flowrates were monitored, leaching and pregnant solutions were sampled. In leaching solutions sulphuric acid concentration and pH were analyzed, in pregnant solutions uranium content, sulphuric acid concentration and pH were analyzed.

RESULTS AND DISCUSSION

On the test completion the actual flowrate ratio of the recovery and the injection wells was 5.1 that is very close to the design value.
Uranium content in pregnant solutions throughout the test was typical for leaching with rapid increase of values in the beginning up to maximum 170 mg/l and the following slowly decreasing values. By the test completion uranium content in pregnant solutions was 125 mg/l.

Average uranium content in pregnant solutions was increasing throughout the test. By the test completion it was 109 mg/l.
Sulphuric acid specific consumption was always decreasing during the test as it normally happens. By the test completion specific consumption was 70 kg/kgU.
Liquid-to-solid ratio varied linearly during the test and was equal to 2.2 when the test was stopped.

According to the requirements of actual guidance documents, ISL two-spot testing should be conducted until leaching process is completed. ISL process completion sets in when uranium content in pregnant solutions decreases to the minimum industrial values (10-15 mg/l). Only completed ISL tests give reliable uranium recovery and other process parameters which can be used for further feasibility analysis. Taking into account that uranium content at the end of the test was still 125 mg/l, the test should be regarded as not carried out up to the end. Its results cannot be used directly for any estimations as they are not supposed to characterize ISL process in full. In this case ISL parameters can be estimated by their extrapolation beyond the test time frame. Extrapolation is available if the ISL parameters'trends clearly appeared during the test. The results available show that these trends appeared, so they were used for the parameters extrapolation.

Liquid-to-solid ratio value which is typical for ISL mining or which is often used in ISL development plans –is 4. So the other test parameters were extrapolated to the above mentioned value of liquid-to-solid ratio. According to uranium leaching dynamics liquid-to-solid ratio of 4 could have been achieved by the 458-th day of the test. By that time uranium recovery could be about 85%. By the end of the test actual sulphuric acid specific consumption achieved the level values which were not expected to change significantly even if we had completed the test. So the final sulphuric acid specific consumption shall be on the same level as it was at the end of the test –70 kg/kgU. Average uranium content in pregnant solutions shall be definitely higher than minimum industrial level of 10-15 mg/l, and it is expected to be about 60-90 mg/l.

ISL tests results are usually assessed by comparison with their criterion quantities. The results are considered positive if all the parameters'values meet their criterion quantities which are as follows: uranium recovery >50%, average uranium content ≥20mg/l, sulphuric acid specific consumption <150-200 kg/kgU and liquid-to-solid ratio < 10. The extrapolated results tally with their criterion quantities. Consequently the studies conducted by Uranium One Group displayed the principal possibility of applying of uranium ISL mining at the Nyota deposit.

The described ISL test at the Nyota deposit is the first one ever carried out in Africa and it yielded encouraging results. On the basis of this, it can be concluded that ISL mining is quite applicable there making mining business more economically efficient and environmentally friendly.

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Country or International Organization

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Session Classification: Uranium Production by the In Situ Leaching (ISL) Process

Track Classification: Track 7. Uranium production by the in situ leaching (ISL) process