Uranium Production in Caetité, Brazil

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Abstract: Brazil has nowadays two nuclear power plants in operation which are supplied by the uranium extracted from the only mine now being exploited, located at Caetité – State of Bahia, where mining is carried out on five meters benches open-pit. The ore is crushed in four stages to minus 13 mm, concentrated sulphuric acid is added to agglomerate the fines and the final product is sent to a HDPE lined leaching pad to form piles. Heap leaching is carried out by sulphuric acid solution irrigation over the pile. The pregnant solution is collected in HDPE lined ponds and pumped to the milling plant where uranium is separated by solvent extraction and precipitated as ammonium diuranate - ADU, that is washed and dried. After leaching the drained pile is removed to the mine waste piles. The raffinate from the uranium recovery process plant is treated with milk of lime and sent to HDPE lined tailing ponds from where the clarified liquid phase is recycled to the leaching step. The plant has nominal capacity to process 180,000 ton/year of ore to produce 400 ton/year of U_3O_8 as ADU. From the beginning of commercial production at the end of 2001 until October 2008, some 1,120,000 ton of ore with an average grade of 0.252% U_3O_8 were processed giving some 2,000 ton of U_3O_8 production with an average uranium recovery of 76% and sulphuric acid consumption of 40 kg/ton. An overall environment monitoring program gives data and information that are applied to prevent any damage to the environment.

1. Introduction

Two nuclear power generating plants are currently operating in Brazil. Their average operating demand is some 400 metric tons of uranium as U_3O_8 [1]. To meet this demand, the federal government, through its state company Indústrias Nucleares do Brasil S/A - INB, implanted a uranium concentrate mining and milling facilities in Caetité, aiming the commercial exploration of the Uraniferous Province of Lagoa Real - UPLR, located in the midsouthern region of the State of Bahia, in the Municipalities of Caetité and Lagoa Real. From the economic standpoint uranium is the only local mineral wealth, occurring mainly in the form of oxide, and constituting the mineral uraninite. Its mineral paragenesis, as well as the formation conditions and distribution of uranium mineralization makes the province a single example of economically exploitable uranium occurrence in medium and high-level metamorphic rocks associated with sodium metamorphism.

2. Caetité's uranium facilities - URA

URA is a mining and milling facilities constituted of an open-pit mine and a physical and chemical processing plant, constructed to carry out uranium ore mining and milling activities in UPLR region. URA is owned by INB and is located in the Municipality of Caetité occupying a surface area of 1,200 ha, 45 km from the centre of the Municipality. Mining, milling, waste deposits and support facilities occupy a surface area of some 95 ha. The basic projected processing capacity is 180,000 ton/year of run of mine ore with an estimated average content of 0.29% of U_3O_8 and an average uranium recovery of 70% to produce some 400 ton/year of U_3O_8 as Ammonium Diuranate – ADU.

2.1. Geo-economic aspects

The geological aspect of the region is mostly constituted of migmatites, granites, gneisses, and albitites partially covered by residual soils or poorly transported sediments. It comprises Lagoa Real Granite Complex. Gneisses of medium and high-level metamorphic facies constitute the normal encasements of uranium-mineralized albitites which present a northwest dipping into the southern portion of the area, perpendicular to the center, and an inverse northeast dipping into the northern portion thus characterizing a helicoids structure.

Primary mineralization constituted of uranitite and pitchblende has a litho structural control, and occurs spreadably in albitites carrying sodium, calcium and ferromagnesian minerals, as multi-sized phylolian lenticular bodies. Secondary uranium minerals - uranophane and autunite - are restricted to weathered zones, mostly dependant on fracture systems.

Jazida Cachoeira, located in UPLR, constitutes the first occurrence of uranium in the region which is commercially exploited by INB. It comprises three uraniferous bodies. Bodies 1 and 3 constitute the initial scope of the open pit mining works.

2.2 Mining

Open-pit mining works in Jazida Cachoeira started in December 1999 and until October 2008 some 1,120,000 ton of run of mine ore were mined with a mining waste/ore average ratio of 8.1:1 and an average uranium content of about 0.252% U_3O_8. The five meters benches mining are carried out using conventional techniques and equipments according to the mine planning guidelines. Open-pit mining period in that deposit is estimated in 12 years, and comprises approximately 4,000 tons of U_3O_8. Mining waste is disposed upward to establish modular benches that are promptly rehabilitated. This procedure makes site rehabilitation works easier, and immediately reintegrates the area to the local environment.

2.3. Milling

The general flow sheet of the process is shown in Fig. 1. Ore transported from the mine by 25-ton dump-trucks feeds a primary jaw crusher and then is transferred to a stockpile of up to 3,000 ton by a conveyor belt, at a ore size under 125 mm. Ore is recaptured by a vibratory system located under the stockpile and conveyed to a secondary jaw crusher to reduce the ore size to minus 50 mm, and transferred to a two decks – 19 and 13 mm - vibrating screen. The 19 mm screen oversize is conveyed to a hydrocone-type crusher to reduce ore size to minus 16 mm and the 13 mm deck oversize is conveyed to another hydrocone-type crusher to reduce size to minus 13 mm. Both hydrocone-type crushers undersize product are collected in the same conveyor and conveyed to the belt conveyor that feeds the double-deck vibrating screen. The undersize of the 13 mm screen deck is transferred to an intermediate deposit that feeds continually a conveyor belt where 4% weight of water is added throughout the product transfer to a rotary mixer (6 m long rotary drum with the diameter of 1.2 m). Concentrated sulphuric acid is added to the drum at a rate of 15 kg/ton of ore, to agglomerate the fines and start the leaching process through an initial acid cure [2]. The rotary drum discharges the mixture onto a set of semi-permanent transfer conveyors that feed a 6-m high radial stacker, which in turn unload the agglomerated ore into a pile in a pad lined by a 1.5-mm thick HDPE (high-density polyethylene) membrane and having a 1% slope. The leaching pad admits two piles which, once leached, are removed by hydraulic loaders and trucks to open spaces for new piles. Each pile contains up to 35,000 tons of ore at a height not exceeding 5.5 m, and occupies an approximate surface area of 45 x 80 meters.

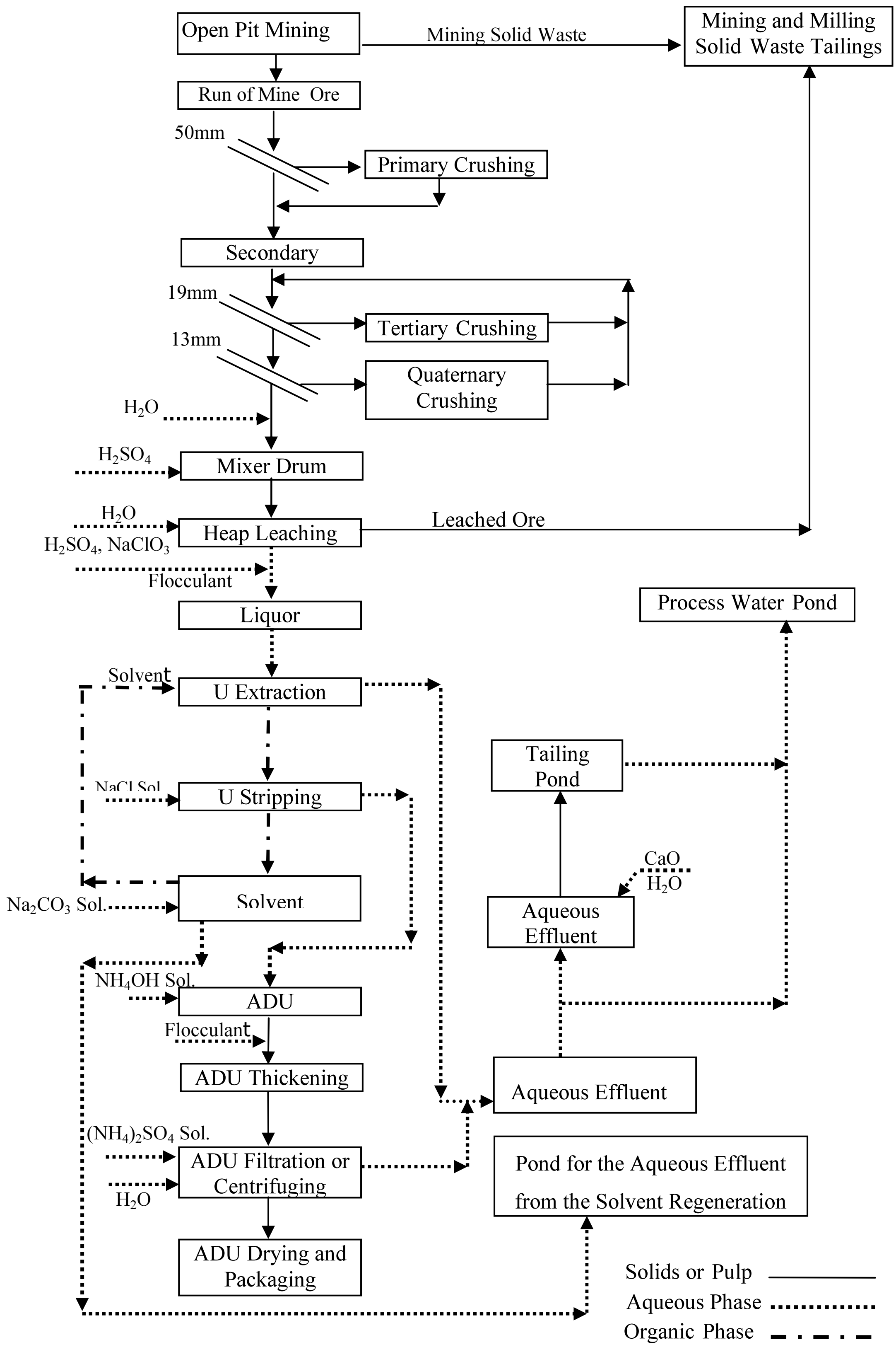

FIG. 1. General Process Flow Sheet

The pile created as above is submitted to three successive washes by dropping systems at a mesh of 45 x 45 cm, which irrigate both the upper and lateral surfaces at a rate of 30 L/h.m^2:

(a) 1st wash or leaching: 25 g/L H_2SO_4 solution at a rate of 0.6 m^3/ton ore;
(b) 2nd wash: 5 g/L H_2SO_4 solution at a rate of 0.3 m^3/ton ore;
(c) 3rd wash: raw water at the rate of 0.3 m^3/ton ore.

After leaching, piles of crushed and leached ore are removed and incorporated to the mine waste in specific areas inside the solid waste deposit.

Liquors are collected in three ponds of adequate size lined by two superposed 1.5-mm thick HDPE membrane, equipped with a liquid detection system between the membranes and between the lower membrane and the 50cm thick compacted clay layer on the pond bottom.

During the transfer to uranium chemical separation plants, liquor passes through a clarification system where it is added a synthetic flocculant, and then filtered by an anthracitous coal bed to reduce the suspended solid content to values lower than 30 ppm to avoid emulsion or crud formation [3].

Uranium is separated from impurities solubilized at leaching by the solvent extraction technique in a continuous system of four mixer/settler cells, using a solvent containing some 7% weight of a tertiary long-chain amine (Alamine 336, Cognis do Brasil Ltda.) in aliphatic kerosene, added of some 3% volume of isotridecyl alcohol to improve phase separation. Uranium is then stripped in another set of four mixer/settler cells by 1.75 mol/L sodium chloride solution with pH adjusted to 1.2 by sulphuric acid, from where is precipitated as ADU by the addition of a solution of ammonium hydroxide in specific reactors, thickened, repulped by a diluted ammonium sulphate solution in an agitated tank, centrifuged and finally dried..

The whole process is thoroughly monitored by a sampling and chemical analysis program to ensure the optimal efficiency for the recovery of uranium contained in the ore and the environment preservation.

Until October 2008 some 2,000 ton of U_3O_8 were produced at the milling facility from the processing of 46 leaching piles. Average recovery of uranium content is about 76%, with an average sulphuric acid consumption of some 40 kg/ton of ore.

The project gave priority to the recycle of all water used in ore processing to prevent its release to the environment and reduce the consumption of new water in a region where this resource is scarce. Liquid effluent is treated by lime suspension to raise pH to about 9. The resulted pulp is transferred to specific ponds lined by 1.0-mm thick HDPE membrane, where the solid phase is retained and the clarified liquid phase is recycled to the process. Bottom drainage systems known as sub-aerial drains have been installed to such ponds, to provide better efficiency of solid phase densification, and consequently the use of useful pond storage volume, in addition to replacing the conventional tailings retention systems with significant environmental advantages.

2.4. Process improvements

From the beginning of the mining and milling activities some improvements were incorporated to the process:

— ore agglomeration and acid cure step by sulphuric acid addition to the crushed ore prior to the pile formation;
— selection and introduction of a new synthetic flocculant to reduce suspended solids concentration in the pregnant liquor before sending it to the solvent extraction step to prevent emulsion generation;
— introducing of a centrifuge as an alternative to the separation and washing of the DUA precipitate before the drying;
— introducing of a new mixer-settler cell to remove chloride ion from the eluted solvent by treating it with sodium carbonate solution prior to its recycle to the extraction step;
— closing of the crushing circuit to give ore size under 13 mm and better uranium recovery efficiency.

Others improvements are being essayed and evaluated to be implanted in the near future:

— conventional ore pulp leaching in agitated tanks to improve the uranium recovery to over 90%;
— direct uranium precipitation with hydrogen peroxide from the pregnant concentrated liquor;
— underground mining of the deeper uranium ore body after the ending of the open-pit mining activities;
— increasing of the uranium production capacity to attend a projected increasing of uranium demand for nuclear power generation

2.5. Water supply

The most remarkable characteristic of streams in the region is their intermittence, which make their use unfeasible. Water demand for human and industrial consumption in URA is met by a supply system mainly constituted of a series of driven wells and a dike to store surface water collected in rainy periods. Annual average precipitation is about 700 mm, and occurs mainly in November-February period.

2.6. Environment and sustainability

Environmental parameter configuration was based on the historical analysis of monitoring results. Where applicable, the current laws for indicator quantification were reviewed. In general, detected variables are in satisfactory levels from the environmental view, and most of them show excellent results as compared to the current legislation [4].

Ongoing environmental monitoring programs mainly targeted at the environment preservation and maintenance of the community's life quality includes:

(1) Erosion and siltation process supervision and monitoring;
(2) Soil structure modification monitoring;
(3) Nutrient and raw material removal monitoring;
(4) Reclamation of degraded areas;
(5) Environmental education;
(6) Management of solid wastes in administrative and support areas;
(7) Groundwater quality monitoring;
(8) Air quality monitoring;
(9) Environmental monitoring of operational stage.

3. Conclusions

Regional uranium reserves in UPLR area and the implantation of URA facilities ensure the annual average fuel supply for Angra 1 & 2 Brazilian nuclear power plant operations.

Although heap leaching, in principle, is a very simple process, URA operation has shown that attention to details is critical for the project success as a whole. Adequate monitoring of the whole production process and the environment, as well as the continuous implementation of changes and new procedures are necessary to supervise the changes occurring in ore characteristics and the chemical composition of solutions, which are particularly important for a system that includes full processing water recycling.

The permanent concern with the environmental preservation, and the reclamation of degraded areas, associated with a regional insertion policy emphasizing the company's participation in the social development have contributed for the project success.

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