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COMPREHENSIVE EXTRACTION SCHEME FOR MULTIMETAL RECOVERY FROM METASOMATITE–ALBITITE HOSTED LOW GRADE INDIAN URANIUM ORE

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INTRODUCTION

India is making focused efforts to reach human development index (HDI) of 0.9+, a number considered to indicate decent state of living, from its present index value of 0.6 by 2040 [1]. Meeting the projected HDI necessitates amongst others, the strategies for utilization of various energy resources in a sustainable way. The contribution of nuclear energy in the overall mix is very critical in achieving the target HDI primarily due to its low carbon foot-print and local availability of fertile thorium resources [1]. The installed capacity of nuclear power plants of India at the end of 2017 was 6780 MWe [2]. It is planned to increase this to about 35000 MWe by the year 2022, comprising mainly of PHWRs and LWRs with minor contribution from Fast Breeder Reactor (500 MWe) and Advanced Heavy Water Reactor (300 MWe) [3]. It is reported that the identified Conventional uranium resources in India so far are sufficient to support 10-15 GWe installed capacity of PHWRs operating at a lifetime capacity factor of 80% for 40 years [3]. Continuous efforts are being made by different agencies in India to increase the indigenous uranium production for realizing the fuel demand which include exploration for new deposits, establishing of new mills and augmentation of existing mills.

Majority of the Indian uranium occurrences discovered so far fall in low-grade category [4,5]. Maximum utilization of mined ore or comprehensive extraction is an ideal approach for exploitation of lean tenor ores as it addresses the sustainability principles as well as commercial viability terms. Successful cases in this respect which are familiar for uranium ore processing fraternity are the Palabora copper mines (South Africa) [6] and Olympic Dam poly-metallic copper mines (South Australia) [7] and the Jaduguda uranium mines (India) where a Byproduct Recovery Plant (BRP) was in operation for recovering useful metals like Cu, Ni, Mo and magnetite values [8]. With growing interest in rare earth elements for green energy applications many phosphate mine operators are looking into recovery of rare earths in addition to the already established schemes for phosphate and uranium values [9, 10, 11].

Amongst the most promising new uranium findings explored by the Atomic Minerals Directorate for Exploration and Research (AMD), the uranium exploration Agency in India, the Rohil-Ghateswar uranium ore deposit, Sikar district, Rajasthan is prominent one [12]. The Rohil - Ghateswar uranium ore is a metasomatite type deposit hosted by albitised metasediments of Delhi Supergroup in north-west India. The metasomatite uranium occurrences in India are reported to contribute about 3.3% of the total uranium resources and the most important amongst them is the Rohil multi-metal uranium ore which is reported to contain Cu, Mo, Ni and Co values. This paper gives details of the process development studies carried out for multi-metal recovery from the Rohil –Ghateswar low-grade uranium ore.

ORE SAMPLE AND CHARACTERISATION

A composite feed for the experimental studies is prepared by judicious mixing of split core bore-hole ore samples of different locations of Rohil –Ghateswar ore deposit. The XRD and optical microscopic study of the feed indicated uraninite as the chief uranium bearing phase with traces of brannerite and davidite. The other minerals identified are: chalcopyrite, molybdenite, pyrite, pyrrhotite, riebeckite, quartz, traces of albite, biotite, boulangerite, chlorite, covellite and goethite. Chemically the ore sample showed U3O8 ☒0.04%, Cu 0.14%, Mo 0.024%, total S 4.3%, FeO 13%, SiO2 58.9%, CaO + MgO 6.7%, Na2O 4.3%, K2O 1.04% and Loss of Ignition 4.3%. Amongst the sulfides pyrrhotite content is about10% and pyrite 1.1%. Uraninite is mostly liberated however occasionally uraninite of very-fine size is associated with non-pyrrhotite sulphides. The Bond's Work Index of the sample is 21.4 kilo Watt h/metric ton.

PROCESS DEVELOPMENT

The predominant presence of siliceous minerals in the Rohil ore led to the option of choosing sulfuric acid based hydrometallurgical processing scheme for the recovery of uranium values. However, the presence of excessive content of sulfide minerals, particularly the pyrrhotite and pyrite in the ore necessitated a step of physical beneficiation to be integrated with chemical extraction process. Similarly a scheme suitable for recovering copper and molybdenum values in the ore inspite of their low concentration needs to be evaluated due to their vital utility in different futuristic materials. The occurrence of the Rohil-Ghateswar ore body in water-arid region makes design of process scheme for multi-metal recovery a challenging task. Different options have been formulated for achieving the objective of maximum recovery of multi-metals with minimum fresh water requirement. The options include:

Option I: Comminution –physical separation of all the sulfide minerals (magnetic + froth flotation) –hydrometallurgical recovery of uranium values –tailings disposal.
Option II: Comminution –separation of ferro-magnetic pyrrhotite by physical separation (magnetic) –hydrometallurgical recovery of uranium values –tailings disposal.
Option III: Comminution –hydrometallurgical recovery of uranium values –separation of sulfide minerals from leach residue by physical separation (magnetic + flotation) - tailings disposal.
Option IV: Comminution –separation of ferro-magnetic pyrrhotite by physical separation (magnetic) –hydrometallurgical recovery of uranium values –gravity separation of leach residue for non-magnetic heavy sulfide minerals recovery –tailings disposal.

Option I helps in prior removal of sulfides which are detrimental during leaching of uranium values and simultaneously offer exclusive Cu-Mo sulfide minerals pre-concentrate besides yellow cake. Further the negative effects of acid mine drainage (AMD) are also minimized. However, the two disadvantages here are (i) loss of some uranium values in the sulfide float due to their composite nature and (ii) need for larger volume of water during froth flotation and difficulty in effective recycling of flotation reagent water consisting of residual collector reagent and frother. Though treatment of the reagent water post-flotation on biologically activated carbon (BAC) column is reported to remove organics, the process is nevertheless expensive. Option II yields higher uranium recovery, requires relatively less water due to absence of froth flotation but the problem of AMD persists due to left-over sulfides (Cu-Mo and pyrite) in leach residue or solid tailings. Option III too needs higher volume of water but gives sulfide-free tailings and slightly higher or similar uranium recovery like Option II. Though the surface of sulfide minerals may undergo partial chemical modification due to previous chemical leaching (Option II), the availability of specific collector reagents for mixed oxide-sulfide minerals (unlike alkyl xanthates) would minimize Cu-Mo losses. The major advantage of Option IV is maximum uranium and by-products recovery with minimum water inventory due to easy recyclability of water used in both magnetic and gravity separation stages.

The experimental studies were carried out by optimizing various parameters of each unit operation both in physical separation and hydrometallurgical processes. Pyrrhotite values were separated using wet low-intensity magnetic separator (applied magnetic field 4 kilo Gauss), while pyrite, chalcopyrite and molybdenite were pre-concentrated using froth flotation with 'alkly xanthate –pine oil'reagent combination. Gravity separation was conducted on wet shaking table using slimes deck. Uranium values were recovered in the form of uranium peroxide by adopting the following unit operations in sequence namely, conventional agitation leaching with sulfuric acid-pyrolusite reagents –filtration –ion exchange purification –multi-stage precipitation viz. initially the iron-gypsum cake at pH 3 followed by precipitation of uranium peroxide. Separation and purification of uranium from the leach liquor was carried out on a strong base anion exchange resin in sulfate form but eluted with chloride reagent. The overall recovery of uranium for different options was 80 –83%. The U3O8 assay of uranium peroxide product was 73.8%. The mass and water balance computations showed fresh water necessity of about four times more when flotation of sulfides is incorporated in the process flowsheet over the scheme which relies on specific-gravity difference for pre-concentration of Cu-Mo values.

A recovery of about 75% was obtained with respect to Cu & Mo by-products at the pre-concentration stage of the Rohil ore. The sulfide mineral concentrate consists of Cu, Mo, and Fe with traces of Ni and Co. Anand Rao et al have demonstrated sulfation roasting - leaching process for quantitative separation of Cu, Mo, Ni and Co values keeping the Fe oxide phases as insolubles. [13]. Roasting converts sulfides of Cu, Ni and Co to their respective sulfates, and transforms the sulfides of Mo and Fe to their respective oxides by carefully controlling the roasting temperature. The sulfates of Cu, Ni and Co are soluble in mild acidic aqueous medium and MoO in alkaline medium, whereas FeO is insoluble. A forward integration approach helped in treating low-grade concentrates itself for maximizing overall recovery of Cu & Mo.

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Country or International Organization

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