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AN APPROACH TO REDUCE LOAD ON THE ACID LEACHING CIRCUIT OF THE COMMERCIAL URANIUM RECOVERY PLANT AT JADUGUDA, INDIA

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The commercial uranium recovery plant at Jaduguda, Bihar, India, currently treats around 900 tonnes of ore per day from the Jaduguda mine, containing around 0.05% U_3O_8. Subsequent to removal of the sulphide minerals present in the ore by flotation, nearly 95% of the tailings are being treated in the acid leaching circuit to recover the uranium values. Laboratory investigations on the bulk flotation tailings revealed that around 63% of the uranium values are associated with feebly magnetic material of the tailings. The magnetic product obtained on wet high intensity magnetic separator gave rise to a product containing 0.1% U_3O_8. The rest of the uranium values were found to get enriched to 0.15% U_3O_8 in the $-20\,\mu m$ fraction of the non-magnetic material thereby giving scope to retrieve the uranium values by recovering the slimes. Necessary unit operations needed to be introduced in the plant flowsheet to reduce load on the acid leaching circuit of the commercial uranium recovery plant are discussed.

Keywords: Flotation tailings; Acid leaching; Magnetic separation; Uraninite

INTRODUCTION

At Jaduguda, Bihar, India, M/S Uranium Corporation of India Limited **(UCIL)** is operating uranium recovery plant by treating uranium present as uraninite mineral in the ore mainly from Jaduguda mine and also ore from adjoining Bhatin mine. The details about the mineral constituents and the typical assay [1] of the Jaduguda uranium ore is

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given in Tables I and II. The plant designed to treat around 1000 t/day ore, is currently reported to be treating 800–900 t/day, containing 0.046%–0.06% U_3O_8, as per the flowsheet given in Fig. 1. The flowsheet essentially consists of comminution, classification, bulk flotation to recover sulphide minerals, thickening of the bulk flotation tailings, acid leaching, filtration, ion exchange followed by precipitation to recover the uranium as yellow cake. The ore is ground in presence of cresylic acid, light diesel oil, soda ash and classified to produce a classifier overflow containing around 65% passing 75 μm size. This ground classifier overflow is processed in three banks of flotation cells to recover the 1%–2% sulfide minerals present in the ore as bulk concentrate in the by-product recovery plant. The bulk concentrate containing Cu, Ni and Mo is further processed by differential flotation as per flowsheet given in Fig. 2 to recover Cu and Mo as saleable grade concentrates. However, nickel which gets enriched to around 14% Ni

TABLE I Typical mineralogical composition of the Jaduguda ore

Minerals	*Wt%*
Quartz	63.0
Chlorite–Biotite	23.5
Magnetite	3.0
Tourmaline	3.5
Apatite	3.0
**Sulfides	1.5
Ilmenite	1.0
Uranium and other minerals	1.5

**Chalcopyrite (Cu mineral); Pentlandite, Bravoite, Millerite (Ni minerals); Molybdenite (Mo mineral)

TABLE II Typical chemical analysis of the Jaduguda uranium ore

U_3O_8	[0.04–0.06%]
Mo, Ni, Mo	Mo – 0.02–0.045% Cu – 0.06–0.10% Ni – 0.08–0.12%
SiO_2	67.2
FeO	6.4
Fe_2O_3	7.9
Al_2O_3	5.5
CaO	5.4
MgO	2.20
P_2O_5	1.40
S	0.80
TiO_2	0.66

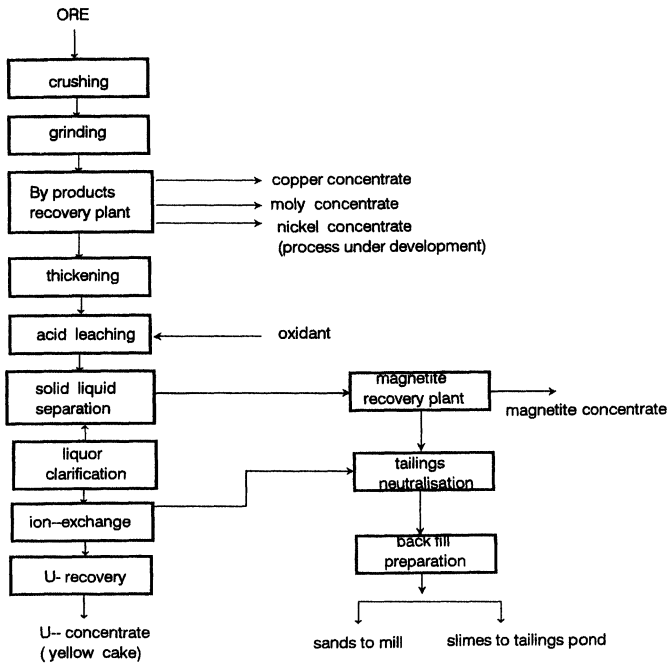

FIGURE 1 Flow sheet of Jaduguda Uranium recovery plant of UCIL.

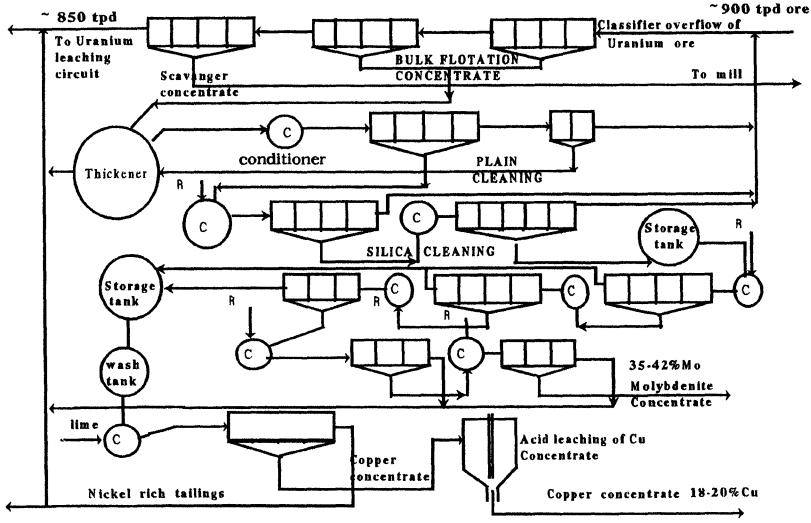

FIGURE 2 Byproduct recovery plant flow sheet at Jaduguda (operated by Uranium Corporation of India Ltd).

after the Cu depletion, is currently not being recovered, due to non-availability of a viable commercial process, and is dumped into the tailings pond.

UCIL has indicated that currently the recoveries of Cu, Ni and Mo in the bulk concentrate are only around 60%, 25% and 55% respectively and sought assistance of the Regional Research Laboratory (RRL), Bhubaneswar to develop a viable flowsheet to recover all three metal values and also to simplify the flowsheet by incorporating the column flotation technology for the molybdenite recovery.

At the instance of UCIL, detailed studies were carried out at RRL on the classifier overflow samples as well as the bulk concentrate collected after the silicate cleaning stage of the flowsheet. During our endeavour to accomplish the desired modification and improvements in the existing flowsheet in the by-product recovery plant, it was also noticed that the magnetic fraction obtained at the magnetic intensity around 18,000 G from the ore as well as the bulk flotation tailings were found to be enriched in U_3O_8 content.

This article describes the detailed laboratory investigations on the classifier overflow sample collected from the operating commercial plant, based on which a modified process could be arrived at to recover uranium from the bulk flotation tailings besides enrichment of the U_3O_8 content from the uranium ore of Jaduguda mine.

SAMPLE AND CHARACTERISATION

The ore from Jaduguda mine was ground in the plant by using the cresylic acid and light diesel oil in the grinding circuit, as per normal plant operating conditions, and the classifier overflow material was collected and sent to RRL as a slurry so that the submerged sample in water is not prone to rapid oxidation. The slurry received in various mild steel barrels was properly sampled and representative samples were drawn for the intended studies. A sub-sample was wet screened into various sieve fractions down to 53 μm and analysed for Cu, Ni, Mo, Fe. The U_3O_8 content was analysed in the bulk sample (Table III). A sub-sample was also subjected to wet high intensity magnetic separation by using BOXMAG Laboratory magnetic separator and the products were analysed for U_3O_8 content (Table IV).

TABLE III Size, Cu, Ni, Fe and Mo distribution in the classifier overflow sample

Size (μm)	*Wt%*	*Assay* (%)					*Cumulative distribution* (%)		
		Cu	*Ni*	*Fe*	*Mo*	U_3O_8	*Cu*	*Ni*	*Fe*
+210	18.9	0.162	0.110	4.88			100	100	100
−210 + 105	26.1	0.087	0.117	5.97	0.009*		78.7	88.1	86.9
−105 + 75	7.70	0.137	0.135	7.33			63.0	70.9	64.9
−75 + 53	8.60	0.170	0.220	7.98			55.7	65.1	56.9
−53	38.7	0.17	0.25	8.60	0.08#		45.6	54.5	47.2
Head (calc)	100	0.144	0.177	7.05	0.048	0.058	100	100	100

* Mo content in the −300 + 75 μm fraction
\# Mo content in the −75 μm fraction

TABLE IV Assay and distribution of U_3O_8 in magnetic products (cof material)

Products	*Wt* (%)	U_3O_8 (%)	*Distribution* (%) U_3O_8
Magnetic	37.3	0.098	63.0
Middling	8.0	0.076	10.5
Non-magnetic	54.7	0.028	26.5
Head (calc)	100	0.05795	100

FLOTATION STUDIES

In order to improve the recoveries of Cu, Ni and Mo in the bulk flotation stage, it was considered essential to introduce the xanthates as collectors in place of cresylic acid. All the flotation experiments were carried out in Denver D-12 sub-aeration flotation cell at 1500 rpm using tap water of pH 5.8. Sodium isopropyl xanthate, potassium amyl xanthate and aero promoter 194 (alkyldithiophosphate) were used as collectors while pine oil and MIBC were used as frothers. The as-received sample was subjected to flotation with various reagents and the details pertaining to these investigations were communicated for publication [2]. The assay of the flotation products and the distribution of Cu, Ni, Mo and U_3O_8 in these products are given in Table V.

CHARACTERISATION OF THE FLOTATION TAILINGS

The bulk flotation tailings obtained during optimisation studies with various collectors were preserved and a sub-sample was subjected to

TABLE V Typical bulk flotation results of the uranium ore

Flotation products	*Wt %*	*Assay, (%)*				*Distribution (%)*			
		Cu	*Ni*	*Mo*	U_3O_8	*Cu*	*Ni*	*Mo*	U_3O_8
Concentrate	6	2.20	1.30	0.585	0.12	95.8	75.3	73.6	12.4
Tailing	94	0.0062	0.0273	0.0134	0.054	4.2	24.7	26.4	87.6
Head (calc)	100	0.1378	0.1036	0.0477	0.058	100	100	100	100

TABLE VI U_3O_8 distribution in various size fractions of the bulk flotation tailings

Size (μm)	*Wt %*	U_3O_8 (%)	*Distribution (%)* U_3O_8
+45	63	0.040	46.5
+20	24.3	0.041	18.4
−20	12.7	0.150	35.1
Head (calc)	100	0.0542	100

wet screening into various size fractions and all the size fractions were analysed for U_3O_8 (Table VI).

Magnetic Separation Studies

The bulk flotation tailings were subjected to wet magnetic separation by using SALA wet low intensity magnetic separator. Around 3% by weight of the magnetic fraction could be obtained which is the magnetite present in the sample. The tailings were classified into +100 μm and −100 μm fractions and each size fraction was treated on BOXMAG wet high intensity magnetic separator at the intensity of 18,000 G. All the magnetic and non-magnetic products were analysed for U_3O_8 (Table VII).

The non-magnetic fraction obtained on the BOXMAG magnetic separator was further wet screened into +20 μm and −20 μm size fractions and both fractions were analysed for U_3O_8. (Table VIII).

DISCUSSION

The general flowsheet of uranium recovery plant (Fig. 1) at Jaduguda treats around 900 t/day ore, assaying 0.06–0.10% Cu, 0.08–0.10% Ni,

TABLE VII Assay and distribution of U_3O_8 in classified magnetic products

Size (μm)	*Wt* %	*Products*	*Wt* %	U_3O_8 (%)	*Distribution* (%) U_3O_8
+100	45	Magnetic	18.36	0.1193	41.37
		Non-magnetic	26.64	0.036	18.11
−100	55	Magnetic	20.24	0.0819	31.31
		Non-magnetic	34.76	0.014	9.19
Head (calc)	100		100	0.05293	100
		Combined magnetics	38.6	0.0996	72.68
		Combined non-magnetics	61.4	0.0235	27.32

TABLE VIII Uranium distribution in the +20 μm and −20 μm fractions of the non-magnetic product of the bulk flotation tailings

Size (μm)	*Wt* %	U_3O_8 (%)	*Distribution* (%) U_3O_8
+20	90	0.0066	28
−20	10	0.150	72
Head (Calc)	100	0.0209	100

0.02–0.045% Mo and 0.045–0.06% U_3O_8, by grinding the ore to a flotation feed size of around 67% passing 75 μm. After recovering the sulphide bearing minerals Cu, Ni and Mo as bulk concentrate as per the flowsheet (Fig. 2) the bulk flotation tailings which are around 95% of the flotation throughput are subjected to thickening followed by acid leaching to recover the uranium values. The leach residue is treated by three permanent rotary magnets to recover magnetite as another by-product which is being supplied to coal washeries. As the sulphide minerals are less than 2% by weight in the ore the bulk flotation tailings are to be more than 95% of the plant throughput as the feed material for the uranium leaching circuit.

The assay of the classifier overflow sample revealed that the Cu, Ni and Mo values are slightly on a higher side than the usual feed assay as can be seen from the Table III. The sample was also found to be coarse in size as it contains around 45% by weight particles coarser than 100 μm size containing around 37% Cu, 30% Ni and 35% Fe values in it.

The flotation studies on this classifier overflow sample, containing 0.13% Cu, 0.14% Ni and 0.045% Mo (Table III) collected from the plant, with various collectors in place of cresylic acid showed that by a combination of amyl xanthate and aero promoter 194 as collector and

MIBC as frother, the overall recoveries of Cu, Ni and Mo could be increased substantially. From Table V it can be seen that the bulk concentrate contains 0.12% U_3O_8 with 12% recovery.

The bulk flotation tailings, which are around 94% by weight, containing the remaining 88% uranium values are the eventual feed to the acid leaching circuit as per the commercial flowsheet (Fig. 1). The size and U_3O_8 analysis of the bulk flotation tailings indicate (Table VI) that nearly 35% of the uranium values are present in the finer (−20 μm) fraction containing 0.15% U_3O_8.

Magnetic separation studies on the classifier overflow sample with SALA wet low intensity drum magnetic separator indicated that around 3 to 4% of the material could be recovered as magnetite. From Table IV it can be seen that nearly 45% of the COF material is magnetic when separated on BOXMAG wet high intensity magnetic separator (at 18,000 G) and contains 73% of the uranium values. Prompted by such indication the magnetic separation studies were carried out on wet high intensity magnetic separator on the bulk flotation tailings after classifying them into + 100 μm and −100 μm fractions. From the results of the magnetic separation studies (Table VII) it is interesting to note that 41% of the uranium values could be recovered from the + 100 μm fraction assaying 0.12% U_3O_8 as compared to 31% uranium recovery from the −100 μm fraction assaying 0.082% U_3O_8. The U_3O_8 content in the combined magnetic fraction, of both the size fractions, was found to contain around 0.10% U_3O_8. This led to conclude that nearly 73% of the uranium values could be recovered from the bulk flotation tailings by resorting to magnetic separation at around 18,000 G besides enriching the uranium content to 0.10% U_3O_8.

Although the majority of the uranium values could be recovered by introducing magnetic separation, the non-magnetic fraction still contains 27% of the uranium values assaying 0.0235% U_3O_8. From Table VIII it is interesting to note that most of the uranium values (72% of the values present) are in the −20 μm size material containing 0.15% U_3O_8 while the fraction coarser than 20 μm contains only 0.0066% U_3O_8. This indicates that by adopting an efficient desliming method the minimum assay of the U_3O_8 in the coarse fraction can be restricted to around 0.0066% U_3O_8 on the sample studied.

As the non-magnetic fraction contains around 10% by weight of fine material (−20 μm) containing 0.15% U_3O_8, the recovery of such fines

by means of hydrocyclone should not be problem although the efficiency of the fines separation depends on the dilution and overall size distribution of the non-magnetic fraction of the bulk flotation tailings. The details about the magnetic separation on the flotation tailings are communicated for filing patent [3]. Taking all the above aspects into consideration, the necessary modifications in the existing flowsheet to recover uranium were suggested with typical material balance in Fig. 3. It is interesting to notice that by adopting the above suggestions in the flowsheet only 42% of the bulk flotation tailings containing around 0.10% U_3O_8 need to be processed as against 95% of the material being handled in the commercial circuit. However, the values projected in the flowsheet 3 should be taken only as indicative as these investigations were carried out on laboratory scale and the sample seems to be relatively coarser in size than the normal plant feed size.

The adoptability of these modifications in the plant are, subject to the reproducibility of achieving the disposable coarse non-magnetic fraction (cyclone underflow) with minimum of the uranium concentration meeting the restrictions imposed.

These modifications in the circuit also reduce substantially the load on the magnetite recovery plant as the magnetite reports to the magnetic fraction.

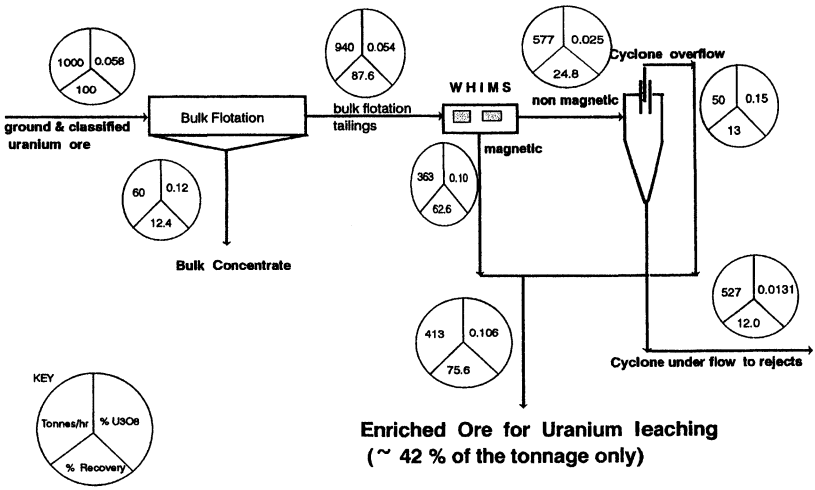

FIGURE 3 Modified flowsheet to recover uranium values with typical material balance.

CONCLUSIONS

The uranium recovery plant at Jaduguda currently treats around 95% of the plant throughput, containing around 0.05% U_3O_8, in the acid leaching circuit to recover the uranium values.

The laboratory investigations reveal that around 63% of the uranium values from the bulk flotation tailings can be recovered into the magnetic fraction, containing 0.1% U_3O_8, by treating on wet high intensity magnetic separator.

The rest of the uranium values present in the non-magnetic fraction were found distributed predominantly in the $-20\,\mu m$ fraction.

As the combined magnetic fraction and the deslimed fines are around 42% of the plant throughput, the eventual feed to magnetite recovery and to uranium leaching circuit are only less than half of the current plant throughput.

The necessary steps to be introduced in the current commercial plant flowsheet are suggested with typical material balance.

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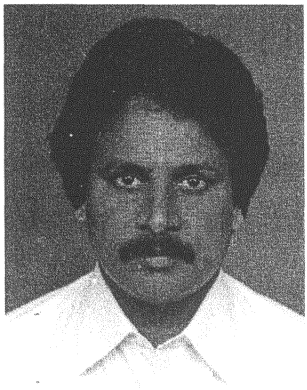

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