(74) Dup. (74)

Amenability of Low-grade Uranium towards Column Bioleaching by *Acidithiobacillus Ferrooxidans*

Abhilash, K.D. Mehta*, V. Kumar*, B.D. Pandey*[1] and P.K. Tamrakar***

*MEF Division, NML, Jamshedpur-831007, India **CR&D Dept., UCIL Jaduguda, Jharkhand, India

[1]E-mail: bdpandey@nmlindia.org

ABSTRACT: R & D studies were carried out at NML using *Acidithiobacillus ferrooxidans (Ac.Tf)* in column for the bio-recovery of uranium from the low-grade uranium ore containing 0.024% U_3O_8 of Turamdih Mines, Singhbhum. A recovery of 55.48% uranium was obtained in bio-leaching as against ~ 44.0% in sterile control in 30 days at 1.7pH in a column containing 2.5kg ore of particle size mainly in the ra[illegible] 5-1mm. In the large scale column, leaching with 80kg ore of particle size ~0.5cm, uranium bio-recovery was found to be 69.8% in comparison to a recovery of 55% in control set at 1.7 pH in 50 days. The uranium recoveries followed indirect leaching mechanism.

1. INTRODUCTION

As the high-grade ore deposits are becoming rare, the importance of processing low-grade ore is increasingly being recognized. Metal-solubilization processes were believed to be chemical reactions mediated by water and oxygen until 1947, when bacterial catalysis of iron oxidation and sulphuric acid formation in mine waters was demonstrated [Colmer et al., 1947]. Today bioleaching is an actual economic alternative for treating specific mineral resources uranium as a result of rapid growth of the nuclear power industry. Presently the world's power reactors with combined capacity of nearly 370 GW, require about 68,000 T/yr of uranium. Due to higher burn-up of fuel, demand is steadily increasing and so is the need for bio-leaching of low-grade uranium ores.

In bio-hydrometallurgy of uranium [Guay et al., 1977; Tuovinen,et al.,1984; Mathur et al., 2000; Abhilash et al., 2006], the insoluble uranium (IV) is oxidised to the water soluble uranium (VI) by bio-oxidation of pyrite of ore with the generation of ferric ions as:

$$UO_2 + Fe_2(SO_4)_3 \rightarrow UO_2SO_4 + 2FeSO_4 \ldots (1)$$

Leaching in column simulates the flow of a liquid percolating through a mass of material by gravity. The lixiviant also penetrates into microfissures and micropores of the ore reducing the need for energy consuming crushing and grinding steps [Lizama et al., 1989; Muiioz et al., 1995]. This paper discusses the results on bioleaching of Indian low grade uranium ore by *A. ferrooxidans* in a laboratory and a large scale column.

2. MATERIALS AND METHODS

Low grade uranium ore (0.024% - 0.03% U_3O_8) was collected from Turamdih mines, Jharkhand, India. A representative sample was prepared by coning and quartering for chemical analysis by Fluorimeter (UCIL) and AAS (Model: GBC 908BT) for other metals (NML). The chemical composition of the ore for large scale experiments was 0.0278% U_3O_8, 10.64% Fe, 0.093% Cu, 0.048% Ni, 0.056% Co, 47.4% SiO_2, 1.085% CaO, 0.383% TiO_2, 0.168% S and 15.5% Al_2O_3. For laboratory column, the ore contained 0.024% U_3O_8, 11.05% Fe, 0.090% Cu, 0.049% Ni, 0.058% Co, 47.6% SiO_2, 1.092% CaO, 0.412% TiO_2, 0.172% S and 15.5% Al_2O_3. XRD analysis of the ore showed silica, alumina and magnetite as the major phases while aluminium silicate, ferro-silicate and hematite being minor phases. Uranium was present as uranitite (UO_2). The ore with proper sizes was packed in 2.5 kg laboratory column [-1mm to 60mesh: 200g, -5mm to 1mm: 2.0kg and 5mm to 4mm: 300g]. For large scale experiments (80kg) only two fractions such as 0.5cm (70kg) and 2.5cm (10kg) were used. Bacteria used in this work were isolated from the mine water of Turamdih mines. The isolated *Ac.Tf* was microbiologically and was grown in $9K^-$ medium and sub-cultured at 1.7pH and 35°C (Silverman,1959). For column leaching, 10% (v/v) culture was adapted on 5% (w/v) ore at 1.7pH. In case of chemical leaching, addition of mercuric chloride acted as bactericide.

Fig. 1 shows the schematic diagram of the lab scale column set-up for 2.5kg ore leaching. The laboratory column was fabricated from 0.2cm thick Plexiglass, 75cm high and 6.5cm I.D. A high density support rubber cork with a hole was placed in the bottom of the column. The column was sprayed with the bacterial solution (10L) using a metering pump at the rate of 3L/h, while re-circulating the leach solution. The leachant had 10% inoculum (cell count of 6.4 × 10^7 cells/mL). In large scale, the column (rubber lined MS) had 80kg ore while spraying 360L leachant at the flow rate of 55L/h containing 10%inoculum (cell density of 6.9 × 10^5 cells/mL).

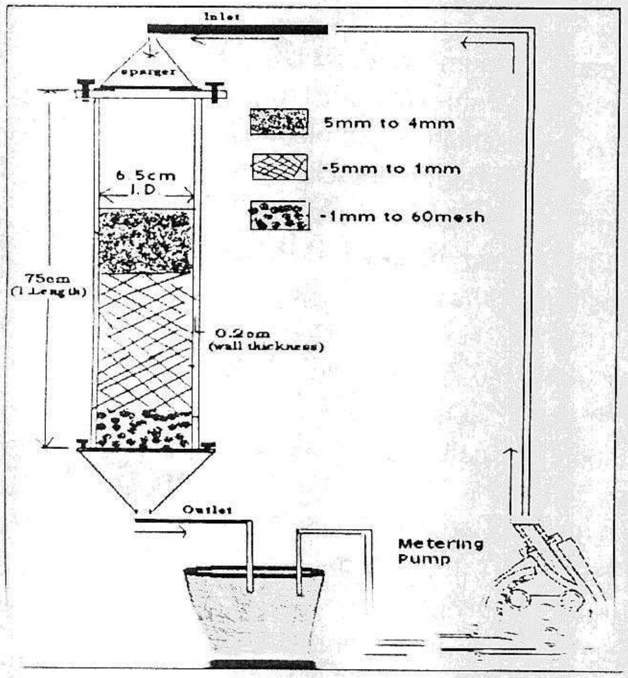

Fig. 1: Schematic of 2.5 kg Scale Column reactor

Feed and leach liquor were sampled and analyzed to estimate the extent of metal dissolution. Cell count was determined in a Petroff-Hauser counter with Leica biological microscope. Fe^{2+} was analysed by titration against $K_2Cr_2O_7$. The pH of the leach solution was maintained on alternate days. Redox potential (Eh) was measured against SCE.

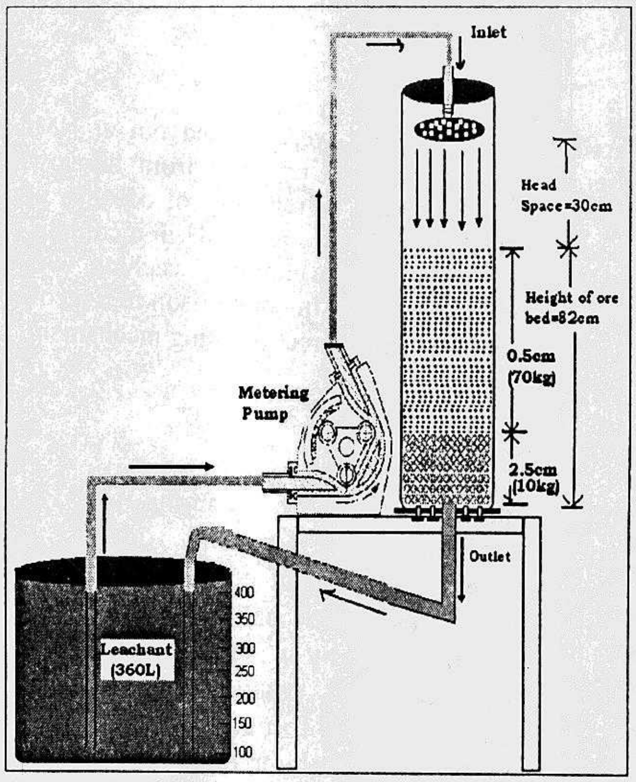

Fig. 2: Schematic of 80 kg Scale Column Reactor

3. RESULTS AND DISCUSSION

3.1 Column Leaching at 2.5 kg Scale

The effect of pH on uranium recovery was evaluated with equal load of ore. The uranium leach recovery showed increasing trend with time which may be correlated to increase in bacterial cell count from 6.5 × 10^7 to 1.3 × 10^9 cells/mL at pH 1.7. Thus uranium bio-recovery was found to be 58.91% as against 56.82% at pH 1.9 in 40days [illegible]. The dissolution of uranium in [illegible] leaching [illegible] days at 1.7 and [illegible] pH (Fig. [illegible]).

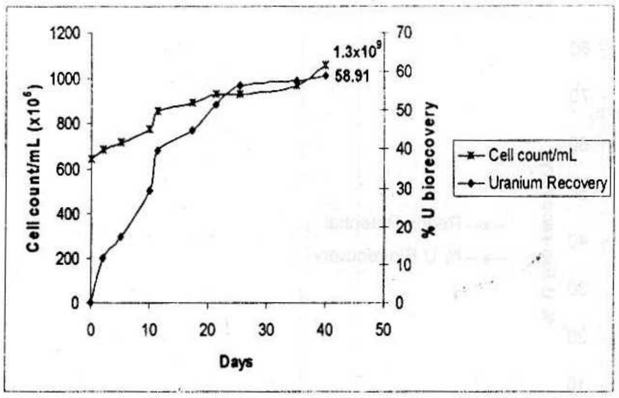

Fig. 3: Change in uranium biorecovery with cell count at pH1.7 using 2.5 kg ore

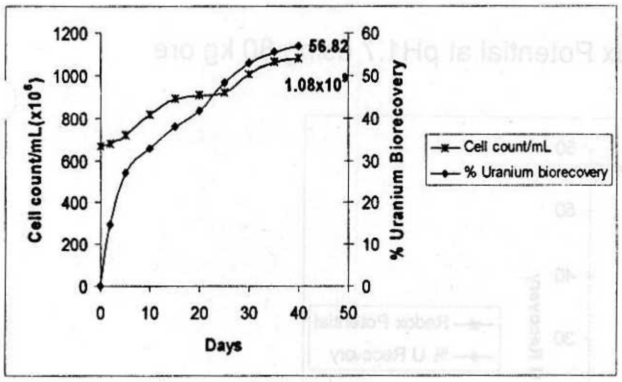

Fig. 4: Change in uranium biorecovery with cell count at pH1.9 using 2.5 kg ore

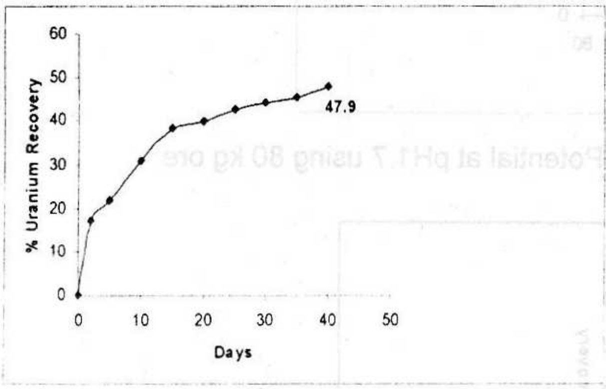

Fig. 5: Uranium recovery in control leaching at pH1.7 using 2.5 kg ore

The extraction rate increased particularly rapidly at the lower pH of 1.7 where formation of jarosite precipitate was very light. The jarosite formation appears to limit the rate of uranium solubilisation by hindering the permeation of soluble reactants through this layer.

Variation of Eh (mV) and change in Fe(II) levels in bioleaching columns at 1.7 pH is shown in *Fig.6*. The Eh increased from 530 to 635mV with corresponding decrease in Fe (II) to 0.12g/L in 40days time, showing consumption of Fe(III) in leaching. In case of control leaching, change in Eh was found to be in the range 350 to 564mV in 40days which was almost constant from 20th day onwards as against a steep rise in Eh beyond 32days during bio-leaching at 1.7pH. At pH 1.9, Eh varied from 540 to 623mV.

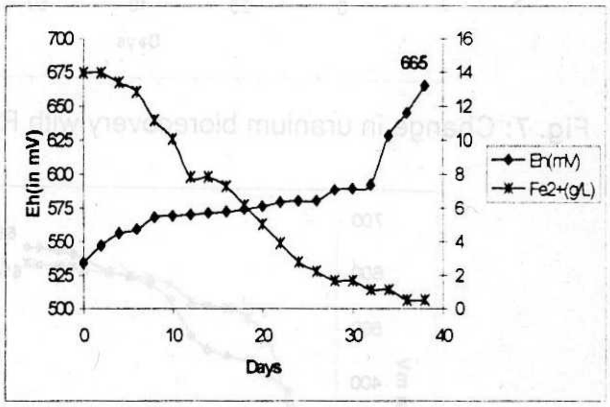

Fig. 6: Variation of Eh (mV) and change in Fe^{2+} concentration in column bioleaching at 1.7pH

3.2 Column Leaching at 80 kg Scale

Column bioleaching on large scale was carried out in two columns, one for bioleaching and other for control leaching with a flow of lixiviant at ~9 h/day basis for 50days. The results reported in *Fig. 7-8* showed an appreciable bio-recovery of 69.8% at 1.7pH against a control recovery of 55% in 50 days with a respective rise in E_h from 325 to 638mV and 332 to 614 mV.Indirect leaching mechanism is thus responsible for uranium bio-recovery. The cell count of *Tf* increased from 6.3×10^7 to 2.66×10^{10} cells/mL in 50 days, which may be responsible for the rise in redox potential due to the oxidation of Fe (II) and corresponding increase in bio-recovery of uranium *(Fig. 9)*. Thus, uranium bio-recovery in large column was higher than those in laboratory column.

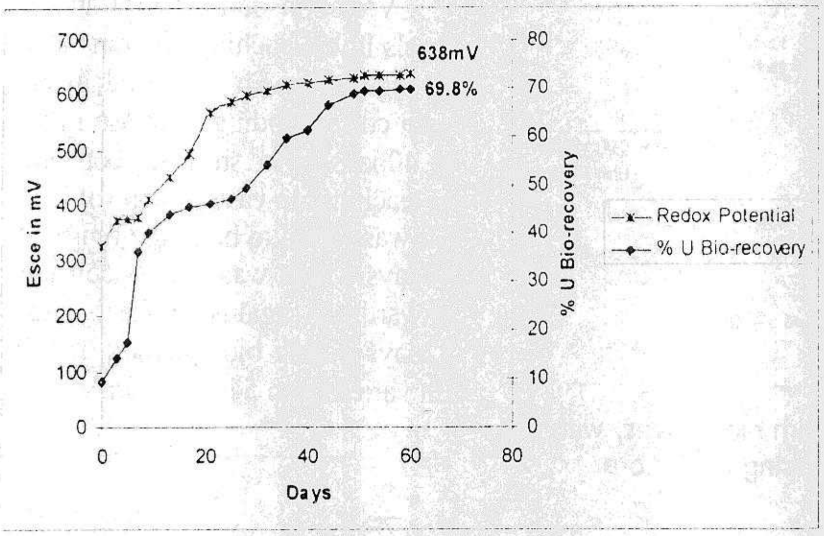

Fig. 7: Change in uranium biorecovery with Redox Potential at pH1.7 using 80 kg ore

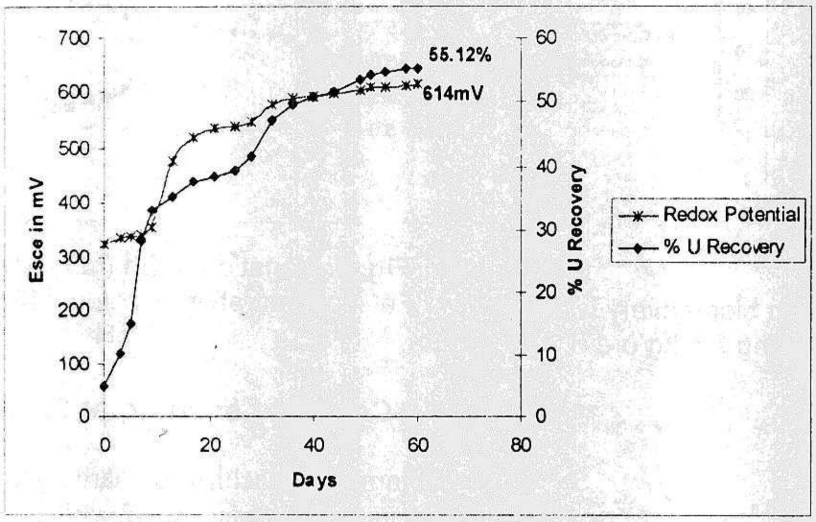

Fig. 8: Change in uranium recovery with Redox Potential at pH1.7 using 80 kg ore

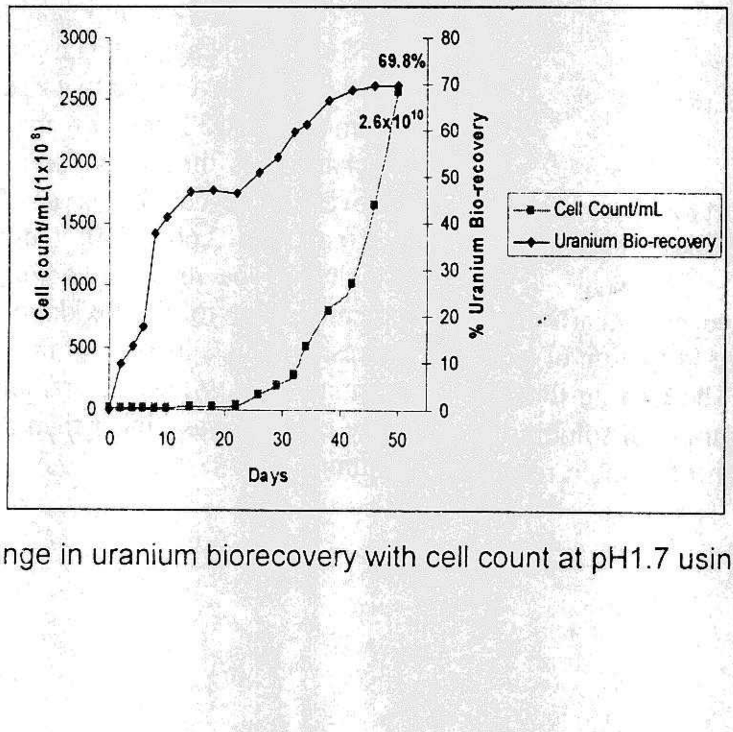

Fig. 9: Change in uranium biorecovery with cell count at pH1.7 using 80 kg ore

4. CONCLUSIONS

The low grade uranitite ore of Turamdih mines was found to be amenable to bio-leaching in column by the native *A. ferrooxidans*. In 2.5 kg laboratory column, 58.91% uranium bio-recovery is recorded in 40days at 1.7pH as against-56.82% at 1.9pHn with respective maximum Eh of 635mV and 623mV. Control experiments yielded a lower recovery of 47.91% in 40days at 1.7pH.

On large scale (80kg), bio-recovery of 69.80% at 1.7pH against a control recovery of 55.12% in 50 days is achieved with rise in E_h from 325 to 638mV and 332 to 614mV. The cell nts increases from $6.3x10^7$ to 2.66×10^{10} cells/mL in 50 days, which aids the oxidation of iron (II) and increasing the uranium recovery by indirect mechanism.

REFERENCES

Abhilash, Singh, S., Mehta, K.D., Kumar, V., Pandey, B.D. and Pandey, V.M., Microbially catalysed process for uranium dissolution from its ore, Int. Sem. Min. Proc. Tech. (MPT-2006), Chennai,2, 717-724 (2006).

Colmer A.R. and Hinkle M.E., The role of microorganisms in acid mine drainage: a preliminary report. Science 106,253-256 (1947).

Guay, R., Silver, M. and Troma, A.E., Ferrous iron oxidation and uranium extraction by Thiobacillus ferrooxidans, Biotechnol. Bioeng. 19(5), 727-740 (1977).

Lizama, H.M. and Suzuki, I., Bacterial leaching of a sulphide ore by Thiobacillus ferrooxidans and Thiobacillus thiooxidans Part II: column leaching studies. Hydrometallurgy 22, 301–310 (1989).

Mathur, A.K., Viswamohan, K., Mohanty, K. B., Murthy, V.K. and Seshadrinath, S.T., Technical note: Uranium Extraction Using Biogenic Ferric Sulfate; A Case Study On Quartz Chlorite Ore From Jaduguda, Singhbhum Thrust Belt (STB), Bihar, India. Min. Eng. 13(5): 575-579 (2000).

Muiioz, J.A., Bkizquez, M.L., Ballester, A. and Gonzalez, F. 1995. A study of the bioleaching of a Spanish uranium ore, Part II: Orbital shaker experiments. Hydromet. 38:59-78.

Silverman, M.P. and Lundergren, D.G., Studies of the chemolithotrophic iron bacterium Ferrobacillus ferrooxidans, an improved medium and a harvesting procedure for accuring high cell yields, J.Bacter.77,642-647 (1959).

Tuovinen, O.H. and Hsu.C.J. Effect of pH, iron concentration, and pulp density on the solubilisation of uranium from ore material in chemical and microbiological acid leach solutions: Regression equation and confidence band analysis. Hydromet. 12,141-149 (1984).