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Enviornmental Effects of Metal Mining Biotechnological Asspects of Water Contamination and Remediation

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Abstract: *The role of chemolithotrophs, for example, Acid thiobacillusferroxidase in the generation of acid rock drainage from abandoned sulfidic mines and tailing dumps is examined. Case studies as for an Indian copper mine and mill tailings are shown. Acid production potentials of mined sulfide ores and tailings within the sight of A. ferroxidase are set up and it is indicated that calcareous gangue effectively neutralized bacterial acid generation. The role of sulfate reducing bacteria in the remediation of acid rock drainage is brought out.*

***Key Word**:Acid thiobacillusferroxidase, Bioremediation, Mine wastes, Acid generation, Acid production potential, Sulfate reducing bacteria.*

I. Introduction

Many types of microorganisms including autotro-phic and heterotrophic bacteria, fungi and yeasts inha-biting the earth's crust and soils bring about several biochemical and geochemical reactions such as oxida-tion–reduction, complexation and precipitation. They readily interact with various mineral forms producing inorganic and organic acids leading to dissolution of metal ions and their transport across water tables. Be-sides biological activities, abiotic mechanisms involv-ing chemical and geochemical factors can be invoked in sulfide mineral oxidation and subsequent acid generation and heavy metal dissolution (Natarajan, 1998;Kuyucak, 2002). It is well known that acid rock drain-age (ARD) emanating from abandoned mines, waste rock piles and mine wastes such as tailing dumps is essentially due to microbial activity.

Bacterial iron and sulphur cycles in nature are of great significance in the biodissolution of minerals. Since most of the nonferrous metals occur as their sulfides, the bacteria–iron–sulphur cycle in nature could throw light on the nature of occurrences of different sulfide minerals and the role of microorganisms in their dissolution (Aube et al., 1995; Bechard et al., 1994).

Sulfate-reducing bacteria play an important role in the formation of certain sulfide minerals, especially, pyrite. Other microbes play an active role in the oxidation of several metal sulfides, regardless of the mode of their origin (Kleinmann and Hedin, 1993; Kuyucak, 1998,2001). In nature, both iron and sulphuroxidisingThiobacillus group of bacteria are associated with mineral sulfides, which serve as energy sources for the microbes. Biooxidation of pyrite and sulphur leads to the formation of sulphuric acid containing Fe^{+++}, which subsequently dissolve various toxic metal ions through its solvent action. Biogenic reactions involving sulfide mineral dissolution of relevance to acid rock drainage include:

$$2FeS_2 + 2H_2O + 7O_2 \xrightarrow{\text{bacteria}} 2FeSO_4 + 2H_2SO_4$$

$$4FeSO_4 + O_2 + 2H_2SO_4 \xrightarrow{\text{bacteria}} 2(Fe_2SO_4)_3 + 2H_2O$$

Depending on the pH of the environment, precipita-tion of iron oxyhydroxides would occur.

In the present investigation, detailed studies were undertaken on representative samples from an Indian abandoned copper mine and tailing dump with the following major objectives:

1. Characterisation of the tailing and ore samples from mining sites.
2. Isolation and identification of the autotrophic and heterotrophic bacteria from water, ore and tailing samples.
3. Assessment of the acid consumption and acid pro-duction potentials of typical tailing samples from the chosen mining sites.
4. Studies on sulfate reduction and metal precipitation using sulfate reducing bacteria as a demonstration of bioremediation.

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II. Experimental materials and methods

2.1. Tailing samples

About 50 kg of copper tailing sample was collected from the Ingaldahl copper mines, Chitradurga district, Karnataka, India. The d_{50} size of the as-received sample was found to be 85 μm using a Malvern Mastersizer 3000 particle size analyser.

2.2. Acid production potential test procedure

The acid production potential of the tailing samples was assessed by carrying out agitation leaching and column leaching tests.

For the agitation leaching tests, 5 g of the tailing sample was pulped to 100 ml using distilled water in a 250 ml Erlenmeyer flask. The suspension was agitated in a Remi orbital shaker at 250 rpm at room temperature (28 F2 8C). Fully grown cells of Acidithiobacillusferrooxidans were inoculated to the suspension both in the absence and in the presence of 9 K medium devoid of iron. Sterile blanks without bacteria were maintained as control samples. The parameters moni-tored include pH, redox potential, bacterial cell number, ferrous, ferric and copper concentrations. The bacterial cell count was determined using a Petroff Hauser count-er attached to a Leitz phase contrast microscope (Labor-lux K Wild MPS 12). The ferrous and total iron concentrations were analysed using the o-phenanthro-line method in a Shimadzu model UV 260 uv-visible spectrophotometer (Vogel, 1989). The copper concentration was analysed using a Thermo Jarrell Ash Video 11E atomic absorption spectrophotometer.

In the case of the column leaching tests, the columns were packed with 150 g of the tailing sample on a glass wool support. The liquid level was maintained at a height of 2 cm above the bed of the tailings. The L/D ratio was fixed at 3. The same test conditions as de-scribed in the agitation leaching tests were followed.

Table 1:

Bacteria isolated from tailings dump and water samples

Sample	pH	E_h mV	Growth media	Bacteria isolated	pH		E_h mV	
					Initial	Final	[illegible]	[illegible]
[illegible]	4.4	385	9 K medium	Acidithiobacillus ferrooxidans	3.5	2	280	549
			Starkey [illegible] medium	Thiobacillus thioparus	7	5.2		–
			Basal medium	Acidithiobacillus thiooxidans	3	1		–
Tailing (gold ore)	[illegible]	300	9 K medium	Acidithiobacillus ferrooxidans	1.8	2	275	545
			Starkey [illegible] medium	T. thioparus	7	6.4		–
			Basal medium	Acidithiobacillus thiooxidans	2	0.5		–
Tailing (copper ore)	7.7	75	9 K medium	Acidithiobacillus ferrooxidans	1.5	2.1	280	456
			Basal medium	Acidithiobacillus thiooxidans	2	0.7		–
B	7.2	250	Modified Baar's medium	[illegible] spp.	7.5	7.2	240	332
[illegible] (water sample)	2.5	530	Silverman and Lundgren (9 K)	Acidithiobacillus ferrooxidans	1.5	2	360	650
				Leptospirillum ferrooxidans	1.5	1.9	370	670
			Starkey [illegible] medium	Thiobacillus thioparus	7	6.4		–
			Basal medium	Acidithiobacillus thiooxidans	2	0.5		–

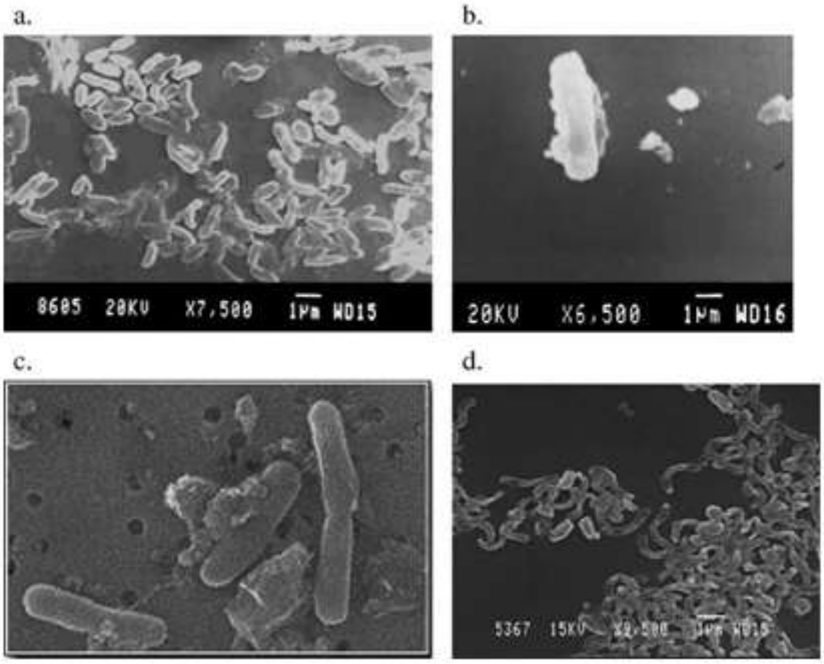

Fig. 1. a. A. ferrooxidans isolated from the copper tailing dump. b. sulfate reducing bacteria isolated from the copper tailing dump. c. T. thioparus isolated from the copper tailing dump. d. Leptospirillumferrooxidans isolated from the mine water.

2.3. Sulfate reduction studies

The cells of sulfate reducing bacteria, Desulfotoma-culumnigrificans, were added to Modified Baars me-dium and spiked with the desired metal ion. The cells were grown at 37 8C in glass serum bottles filled with 100 ml of the medium and sealed with black butyl rubber stopper under nitrogen atmosphere. The bottles were incubated at 200 rpm in a Remi orbital shaker. Samples for cell number and concentrations of sulfate and copper were taken by sterile hypodermic syringe and needle and assayed immediately.

III. Results & Discussion

The details of bacterial isolation and isolated che-molithotrophs and SRB are illustrated in Table 1.

Typical morphological features of isolated bacteria implicated in acid production, water pollution and bio remediation are shown in Fig. 1(a–d). The ore body essentially consisted of chalcopyrite and pyrite besides the presence of significant calcareous gangue.

Acid production potentials of mined ores as well as waste tailings containing copper and iron sulfides in the presence and absence of A. ferrooxidans were established using agitation leaching tests (shake flasks) as well as column leaching experiments. It was observed that acid production from the sulfide containing ores and tailing samples was stimulated only in the presence of Thiobacillus group of bacteria. The ore and tailing samples contained significant quantities of acid con-suming calcite gangue, which helped in efficient neu-tralization of biological acid production.

Bacterial sulfate reduction using anaerobic bacteria has been successfully applied to remove heavy metals and sulfate from acidic wastewaters. The major appli-cation of sulfate reducing bacteria (SRB) to effluent water treatment is based on their ability to reduce sulfate to sulfide, which then reacts with most metals to form insoluble sulfides.

Tests using sulfate reducing bacteria indicated that significant removal of dissolved copper, iron and other base metals could be achieved from acidic effluents, which get precipitated as their corresponding sulfides. Similarly through bacterial sulfate reduction acid water could be effectively neutralized.

Typical results showing sulfate reduction and copper removal from acidic mine effluents using sulfate reduc-ing bacteria are shown in Fig. 2(a–b).

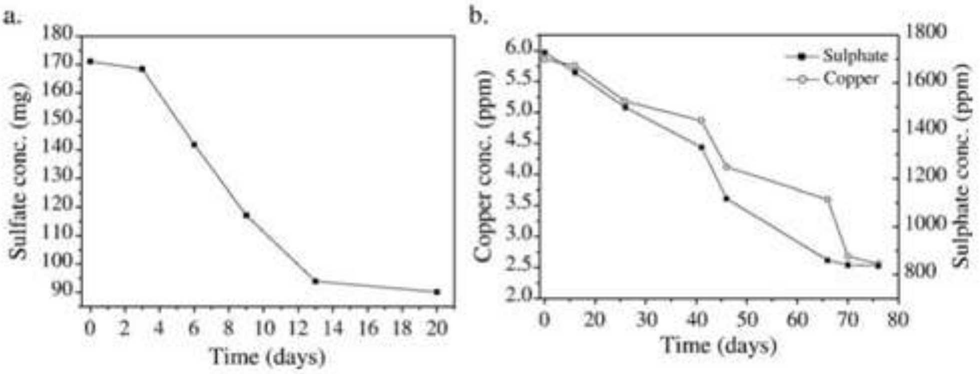

Fig. 2. a. Sulfate reduction and removal by sulfate reducing bacteria.
b. Copper removal from acidic effluents by sulfate reducing bacteria.

IV. Conclusion

Major conclusions based on the study are outlined below:

a. Mine wastes as well as tailings harbour many iron and sulphuroxidising chemolithotrophs.

b. The ubiquitous presence of such autotrophic bacte-ria in the mine wastes leads to acid production through biooxidation and subsequent heavy metal dissolution and contamination of ground and sur-face waters.

c. It is possible to establish the acid production poten-tials as well as the environmental impact of waste ore bodies.

d. Sulfate reducing bacteria could be effectively used to detoxify heavy metal ion containing acidic effluents.

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