Biohydrometallurgical Process to Produce the Coagulant Ferric Sulfate from the Pyrite Present in Coal Tailings

INTRODUCTION

• The Brazilian coal reserves are about 30 billion tons;
• Associated with the coal there are undesirable compounds as pyrite;
• About 50 to 70% of the mined material is discharged as tailing.

Flowchart of Process

R.O.M Coal Preparation

Coal Tailings

Flowchart of Process

COKE Energy Generation

Coal

Flowchart of Process

AIM OF THE WORK

Production of an iron rich chemical coagulant (ferric sulfate) from the pyrite present in coal tailing deposits.

Production routes for Ferric Sulfate

Metals Scrap + Sulfuric Acid → Ferric Sulfate

Coal Tailing + Bacteria → Ferric Sulfate

The main AMD generation reactions

2FeS₂(s) + 7O₂ + 2H₂O → 2Fe²⁺ + 4H⁺ + 4SO₄²⁻

4Fe²⁺ + O₂ + 4H⁺ → 4Fe³⁺ + 2H₂O

FeS₂(s) + 14Fe³⁺ + 8H₂O → 15Fe²⁺ + 2SO₄²⁻ + 16H⁺

2FeS₂(s) + 15/2O₂ + H₂O → Fe₂(SO₄)₃ + H₂SO₄

The Brazilian coal field of Santa Catarina is highly impacted with AMD and it is considered one of the most polluted areas in Brazil.

PRODUCTION ROUTES FOR FERRIC SULFATE

Metals Scrap + Sulfuric Acid → Ferric Sulfate

Coal Tailing + Bacteria → Ferric Sulfate

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COAGULATION

• The main reagents used as coagulant are the aluminum sulfate, aluminum chloride, ferric sulfate and ferric chloride;

• Currently, there is a trend to replace the aluminum salts for iron salts (the presence of residual amounts of aluminium in drinking water has been controversially implicated to neurological diseases);

• The ferric chloride is a highly corrosive reagent;

• So, the ferric sulfate is a good option.

EXPERIMENTAL

1. COAGULANT PRODUCTION

• A pyrite concentrate obtained from coal tailings containing 23% pyrite was used in the experiments;

• The material was crushed and sieved to reach the granulometry between 2 and 6 mm;

• The leaching conditions were: sterile, non-sterile, inoculated, and inoculated + micronutrients;

• The bacteria inoculums were 10 mL of an acid mine drainage (AMD) obtained from the coal site, containing $6.8 \times 10^5$ cells/mL of *A. ferrooxidans*.

• After eight weeks of leaching, the liquor was evaporated to reach the iron concentration of 9 - 12%.

2. COAGULANT CHARACTERIZATION

Total iron, Fe$^{3+}$, Fe$^{2+}$, sulfate, other metals, TDOC, pH.

3. COAGULANT APPLICATION

• Studies involving water treatment were carried out with raw water from Guabara Lake (Porto Alegre, RS, Brazil) using a conventional Jar Test apparatus;

• The reagents used were the ferric sulfate (FS) produced from coal tailings and two commercial reagents, ferric sulfate (PFS) and aluminum sulfate (PAS);

• The raw water and treated water was analyzed for pH, turbidity, color, metals (Fe, Al, Mn and Zn), hardness, and sulfate.

LEACHING COLUMNS

Acidithiobacillus ferrooxidans

MPN of suspended cells of *A. ferrooxidans* as a function of leaching time.

Total Iron and Sulfate

Concentration of iron and sulfate as a function of leaching time.
Acidithiobacillus ferrooxidans

Photos of Scanning Electron Microscopy showing the attached cells of A. ferrooxidans.

Coagulants Produced

Characteristics of FS coagulant produced by the bioleaching of coal tailing (column 1 to 4) after evaporation and the commercial PFS.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe, g.L⁻¹</td>
<td>95.7</td>
<td>96.4</td>
<td>112.4</td>
<td>122</td>
<td>115</td>
</tr>
<tr>
<td>SO₄²⁻, g.L⁻¹</td>
<td>168</td>
<td>176</td>
<td>178</td>
<td>182</td>
<td>131</td>
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<tr>
<td>pH</td>
<td>1.4</td>
<td>1.3</td>
<td>0.8</td>
<td>0.7</td>
<td>1.8</td>
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<tr>
<td>Al, g.L⁻¹</td>
<td>1.3</td>
<td>1.1</td>
<td>1.6</td>
<td>3.1</td>
<td>4.4</td>
</tr>
<tr>
<td>Ca, g.L⁻¹</td>
<td>1.0</td>
<td>1.3</td>
<td>1.6</td>
<td>2.7</td>
<td>5.7</td>
</tr>
<tr>
<td>Mn, g.L⁻¹</td>
<td>1.7</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Zn, mg.L⁻¹</td>
<td>22.9</td>
<td>23.6</td>
<td>26.1</td>
<td>24.1</td>
<td>22.4</td>
</tr>
<tr>
<td>TOC, mg.L⁻¹</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.2</td>
<td>0.8</td>
<td>104</td>
</tr>
</tbody>
</table>

Coagulants Produced

Parameter Column 1 Column 2 Column 3 Column 4 Commercial
Fe, g.L⁻¹ 95.7 96.4 112.4 122 115
SO₄²⁻, g.L⁻¹ 168 176 178 182 131
pH 1.4 1.3 0.8 0.7 1.8
Al, g.L⁻¹ 1.3 1.1 1.6 3.1 4.4
Ca, g.L⁻¹ 1.0 1.3 1.6 2.7 5.7
Mn, g.L⁻¹ 1.7 1.6 1.6 1.6 1.6
Zn, mg.L⁻¹ 22.9 23.6 26.1 24.1 22.4
TOC, mg.L⁻¹ <0.1 <0.1 0.2 0.8 104

Water Treatment Tests

Fases of the coagulation and sedimentation in water treatment.

BEFORE
Color: 44 Hazen
Turbidity: 81 NTU

AFTER
Color: 2 Hazen
Turbidity: 0.4 NTU

Water Treatment Tests

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw Water</th>
<th>Treated With FS coagulant Column 4</th>
<th>Treated With PFS</th>
<th>Treated With PAS</th>
<th>Brazilian standards for drinking water</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.8</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>6.0-7.0</td>
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<tr>
<td>Turbidity, NTU</td>
<td>86</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
<td>1</td>
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<tr>
<td>Color (Hazen)</td>
<td>44</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>1</td>
</tr>
<tr>
<td>Hardness, mg.L⁻¹</td>
<td>22</td>
<td>183</td>
<td>134</td>
<td>86</td>
<td>500</td>
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<tr>
<td>Fe, mg.L⁻¹</td>
<td>&lt;0.1</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
<td>0.3</td>
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<tr>
<td>Al, mg.L⁻¹</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.2</td>
</tr>
<tr>
<td>Mn, mg.L⁻¹</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.1</td>
</tr>
<tr>
<td>Zn, mg.L⁻¹</td>
<td>0.04</td>
<td>0.02</td>
<td>0.02</td>
<td>0.15</td>
<td>5</td>
</tr>
<tr>
<td>Sulfates, mg.L⁻¹</td>
<td>&lt;7.8</td>
<td>273</td>
<td>83</td>
<td>60</td>
<td>200</td>
</tr>
</tbody>
</table>

Water Treatment Tests

So...

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Our Products from Coal Tailings
Leamet/UFRGS

Others products in which Biohydrometallurgy is used.

**BIOHYDROMETALLURGY PROCESS**

- Ferric Sulfate
- Ferrous Sulfate
- Magnetite
- Pigments

CONCLUSION

- Through the biohydrometallurgical process studied in this research, it was possible to obtain a coagulant rich in ferric sulfate from the coal tailings;
- The acidophilic bacteria intensified the process of pyrite oxidation reducing the leaching time and energy consumption;
- The water treatment tests proved that this coagulant was at least as effective as the coagulants conventionally used in water treatment plants;

CONCLUSION

- The process has environmental benefits, because it reduces the volume of waste and decreases the amount of pyrite in the material, minimizing the potential for generation of acid mine drainage.
- In the Brazilian coal field areas, the concentration of pyrite and the production of ferric sulfate coagulant could provide economical incomes for the mining companies and avoid costs incurred in acid effluent treatment.

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Angéli Viviani Colling
angeli.colling@ufrgs.br

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