Introduction

- The main coal mines in Brazil are located in the South States of the country.

• Resources of coal in Brazil are approximately 32 billion tons, but only 2% have been extracted.

• The beneficiation of coal in Brazil generates a great volume of tailings (from 50% to 70%).

• In the composition of coal tailings it is found pyrite (FeS₂), which is the responsible mineral for the production of the acid mine drainage (AMD).

Generation of AMD

Acid mine drainage (AMD) is generated from the pyrite present in coal tailings that in contact with oxygen and water oxidize generating a solution with:

- low pH;
- high contents of iron;
- sulfate and other dissolved metals.

Area with generation of acid mine drainage (AMD)
**How to solve this problem ??**

General Objective

Production of ferrous sulfate by hydrometallurgical process!

Main Objective

- To develop a route for the production of ferrous sulfate n-hydrated crystals \( \text{FeSO}_4 \text{ nH}_2\text{O} \) from pyrite present in coal tailings.

**Pyrite Oxidation and Bacterial Action**

The bacterial action can increase the oxidation of pyrite (2) by a factor of \( 10^6 \).

\[
2\text{FeS}_2(s) + 7\text{O}_2(aq) + 2\text{H}_2\text{O} \rightarrow 2\text{Fe}^{3+} + 4\text{H}^+ + 4\text{SO}_4^{2-} \quad (1)
\]

\[
4\text{Fe}^{2+} + \text{O}_2(aq) + 4\text{H}^+ \rightarrow 4\text{Fe}^{3+} + 2\text{H}_2\text{O} \quad (2)
\]

Then, it increases the amount of ferric iron in acid mine drainage (AMD). These bacteria come from the genus Acidithiobacillus and Leptospirillum.

**Possible Uses of Pyrite**

- Sulfuric Acid (traditional use)
- Coagulants (emerging technology)
- Pigments (emerging technology)
- Magnetite (emerging technology)
- FERROUS SULFATE (emerging technology)

**Uses of Ferrous Sulfate \( \text{FeSO}_4 \)**

Ferrous sulfate has great use in our daily lives, in the health area, agriculture, industry, among others.

- Drugs
- Fertilizers
- Wastewater Treatment
**Uses of Ferrous Sulfate (FeSO₄)**

Ferrous sulfate can be found in several states of hydration:

- FeSO₄·H₂O (mineral: szomolnokite)
- FeSO₄·4H₂O (mineral: rozenite)
- FeSO₄·5H₂O (mineral: siderotil)
- FeSO₄·7H₂O (mineral: melanterite)

**Experimental Methodology**

**Experimental Planning Scheme**

1. **1st step**
   - Production of Extract Rich in Fe³⁺
   - Columns: 1, 2, 3 columns

2. **2nd step**
   - Conversion of Fe³⁺ to Fe²⁺ and Ferrous Sulfate Crystallization
   - Columns: 1 (Control), 2 (3 UV Lamps), 3 (10 UV Lamps)

**Experimental Methodology: 1st STEP**

Production of the Extract Rich in Iron

- Leaching Column
- Coal Tailing (60% of pyrite)
- Underflow
- Recirculation Pump

**Picture of the leaching reactor**

**Experimental Methodology: 2nd STEP**

Conversion of Fe³⁺ to Fe²⁺

- UV Lamps

**Picture of Photoreactor**

**Experimental Methodology: 2nd STEP**

Crystallization of Ferrous Sulfate

- Purified with ethyl alcohol

**Results: 2nd STEP**

- Studies of Conversion of Fe³⁺ to Fe²⁺

- XRD (X-ray Diffraction)
- SEM (Scanning Electron Microscopy)

**Designed and written by:** Authors and IMWA
Ferrous Sulfate Crystals

Results: 2nd STEP

Crystals of ferrous sulfate obtained in the columns 2 and 3.

Results

- The recovery of Fe in the form of melanterite in relation to the pyritic iron existing in the columns ranged from 7.5 to 9.0%.

<table>
<thead>
<tr>
<th>COLUMNS</th>
<th>FE melanterite</th>
<th>Fe melanterite / Extracted Fe$^{2+}$</th>
<th>Fe melanterite / Total Extracted Fe</th>
<th>Fe melanterite / Pyritic Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column 1 Control</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Column 2 UV-3 Lamps</td>
<td>75.0</td>
<td>50.0</td>
<td>9.0</td>
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<tr>
<td>Column 3 UV-10 Lamps</td>
<td>63.7</td>
<td>53.7</td>
<td>8.5</td>
<td></td>
</tr>
</tbody>
</table>

Conclusions

- The results showed that it is possible to produce ferrous sulfate heptahydrate from coal tailings using a leaching process under the action of ultraviolet radiation (UV).
- A new technology for commercial production of ferrous sulfate was developed using coal tailings as raw material, minimizing the environmental impact and making possible the development of a new product in coal mining in Brazil.

Acknowledgements

Thanks everybody for the attention!

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