Biological iron and sulfate control in mining waters

Jaakko Puhakka
Tampere University of Technology

Comprehensive sulfate management in cold mining waters, Oulu, March 21, 2018
Objectives

• To develop an integrated process comprising a fluidized-bed reactor (FBR) and a gravity settler for precipititative removal of iron and sulfate from bioleach liquors

  1. Partial removal from bioleaching circuits
  2. Removal from bioleaching effluent streams
Fluidized-bed reactors for iron oxidation at TUT

FBR configuration
Various biomass carriers used in FBR’s

**Various biomass carriers:**
- Activated carbon (=AC)
- Diatomaceous earth (Celite)
- $\text{Al}_2\text{O}_3$ (Compalox)
- Jarosite flocculated with InChem flock D 33

**Criteria for carrier selection:**
- Biomass hold-up capacity
- Chemical and mechanical durability
- Iron-oxidation rates
- Material costs
Bacterial communities developing on the carrier materials (DGGE)

1. No readable sequence data obtained

2. *Leptospirillum ferriphilum* (99-100 % similarity)

3. “*Ferrimicrobium acidophilum*” (99-100 % similarity)
Process developed for iron and sulfate control

1: Feed pump
2: FBR
3: Base addition
4: Settling tank
5: Aeration pump
6: Aeration unit
7: Recycle pump
8: System effluent
9: Precipitate removal

(Not drawn to the scale)
Feed solution:

• Barren heap bioleaching solution from which valuable metals (Cu, Zn, Ni, and Co) had been recovered
• Initial pH ~3
• Initial redox ~200-340 mV
• Initial Fe$^{2+}$ ~6-8 g/L
Removal of excess iron from bioleach circuit liquors
FBR performance at various HRTs

Feed: ○
FBR effluent: •
FBR performance at various HRTs

Iron oxidation rate, g Fe$^{2+}$/L·h

Oxidation, %

Dissolved oxygen, DO$_2$, mg/L

Redox, mV

HRT, h

Rate

Efficiency (%)

HRT, h

Time, d

Iron oxidation rate, g Fe$^{2+}$/L·h

Oxidation, %

Dissolved oxygen, DO$_2$, mg/L

Redox, mV

HRT, h

Time, d
Precipitation of iron in the gravity settler at different FBR HRTs

Partial removal of iron from bioleach circuits
Removal of iron and sulfate from bioleaching effluent streams
Operational conditions during the experimental periods with pH adjustment:

- pH adjustment with KOH
- pH adjustment with CaCO$_3$

<table>
<thead>
<tr>
<th>pH adjustment</th>
<th>pH 2.5</th>
<th>pH 3.0</th>
<th>pH 3.5</th>
<th>pH 3.2</th>
<th>pH 3.0</th>
<th>pH 2.8</th>
<th>pH 2.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (d)</td>
<td>0</td>
<td>30</td>
<td>60</td>
<td>90</td>
<td>120</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>HRT</td>
<td>HRT = 2 h</td>
<td>HRT = 5 h</td>
<td>HRT = 2 h</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0±1.5 g Fe$^{2+}$/L in the feed</td>
<td>14±0.5 g Fe$^{2+}$/L in the feed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HRT = 2 h  HRT = 5 h  HRT = 2 h
Feed and effluent Fe\textsuperscript{2+} concentrations during the pH adjustment
Iron oxidation and precipitation rates and efficiencies

**Iron oxidation rate**, g Fe\(^{2+}/L\)-h

**Iron precipitation rate**, mg/L-h

**Oxidation efficiency, %**

**Precipitation efficiency, %**

**KOH**

<table>
<thead>
<tr>
<th>pH</th>
<th>2.5</th>
<th>3.0</th>
<th>3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CaCO\(_3\)**

<table>
<thead>
<tr>
<th>pH</th>
<th>3.2</th>
<th>3.0</th>
<th>2.8</th>
<th>2.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rates

Efficiencies
Sulfate concentration in the FBR feed, effluent, and precipitated sulfate, and precipitated mol ratio of [Fe]:[S]

Theoretical mol ratio of [Fe]:[S] of pure jarosite with the idealized formula of $XFe_3(SO_4)_2(OH)_6$, where $X = Na^+, K^+, NH_4^+$ or $H_3O^+$

- FBR feed
- Effluent
- Precipitated sulfate
An X-ray diffractogram of precipitate from gravity settler without pH adjustment

All peaks with labeled $d$-values (in Å) represent Na- and H$_3$O-jarosites
Precipitates - pH adjustment with KOH

**Natro jarosite, NaFe$_3$(SO$_4$)$_2$(OH)$_6$**

**Jarosite, hydronian (K,H$_3$O) Fe$_3$(SO$_4$)$_2$(OH)$_6$**

**Goethite (α-FeOOH)**

<table>
<thead>
<tr>
<th>pH</th>
<th>2</th>
<th>2.5</th>
<th>2.5-3.0</th>
<th>3.0</th>
<th>3.0-3.5</th>
<th>3.5</th>
</tr>
</thead>
</table>
Precipitates - pH adjustment with CaCO$_3$

- **Brushite** $\text{CaPO}_3(\text{OH})_2\text{H}_2\text{O}$
- **Jarosite synthetic** $\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$
- **Jarosite, hydronian** $(\text{K},\text{H}_3\text{O})\text{Fe}_3(\text{SO}_4)_2(\text{OH})_6$

**Gypsum** $(\text{CaSO}_4\cdot2\text{H}_2\text{O})$

<table>
<thead>
<tr>
<th>pH</th>
<th>3.2</th>
<th>3.0</th>
<th>2.8</th>
<th>2.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 g Fe$^{2+}$/L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

The integrated process consisting of an FBR combined with a gravity settler in the recycle line can be applied for:

1) **Iron control** (partial removal) in bioleaching applications to prevent the accumulation of dissolved iron in leaching circuits. The process can be optimized for **efficient and high-rate iron regeneration**

2) **Treatment of bioleaching effluents** for high-rate and high-efficiency iron and sulfate removal as stable end products