FOCUS
Alclair® 3000 – Development of new flocculants

07 – 11

www.mining-solutions.basf.com
Welcome letter from Mining Solutions

Well-known products – fascinating new applications

Mineral beneficiation in South Africa

Polymer-modified tailings deposition

FOCUS
Alclar® 3000 – Development of new flocculants

03
04
05
06
07 – 11
Letter from Mining Solutions

The mining industry faces many challenges and issues relating to the use of water and the impact of exploration, extraction and disposal activities on the environment. These include minimizing water consumption and maximizing recovery, reducing land areas consumed by tailings disposal and minimizing the cost and time required to rehabilitate such land.

As part of the leading chemical solutions provider to the mining industry, we in Research & Development focus on key ores that have the highest demand for innovation, such as advanced extraction reagents as an alternative to smelting and leaching. We will also drive process innovation that is applicable in multiple ores, such as efficient grinding aids, improved flocculants and magnetic flotation.

Our three dedicated Research & Development centers in Perth/Australia, Tucson/USA and Ludwigshafen/Germany aim to help mining operations find solutions for their challenges.

Our team develops innovations that ensure the sustainability of existing deposits and reduce energy consumption and water reuse at mines around the world. The mining sector also benefits from improvements in the performance of existing minerals processing plants, for example by increasing efficiency and yield, improving product quality and minimizing operating costs.

We believe that interdisciplinary and international collaboration with scientific experts and partners can strengthen and extend our own research capabilities and together create a greater impact on the mining industry as a whole. This is why we work closely with universities (e.g. PhD sponsorship) and research institutes (e.g. multi-sponsor industry projects) or undertake joint development projects with valued partners all around the world.

Three recent commercialized examples are our new Antiprex® E – the efficient descaling solution for the mining industry – our new Lupromin® FP A 212, a high-performance collector for phosphate flotation and our Alclar® 3000 a new flocculant with extended washer performance.

Mine with us and the chemistry is right!

Dr. Christian Rein
Head of Global Development
Mining Solutions
Can chemistry that is normally used in oilfields or for detergents also be used for mining applications? How can products that are developed by BASF’s Central Research Units be adapted to the requirements of the company’s Mining Solutions business? The answers to these questions can shortly be provided by the new Mining Solutions Technology Transfer Laboratory.

Located at the BASF site in Ludwigshafen, Germany, the laboratory has the capability of simulating real mineral processing unit operations. It is equipped with grinding mills, flotation cells and agglomeration machines (briquetting and pelletization) as well as all the associated ore sample handling and measurement equipment. The future focus of the Technology Transfer Laboratory will be on mining applications in flotation, briquetting and pelletization as well as solid-liquid separation.

**Example: Coal binding**

The processing of fine coal particles into briquettes is a major challenge for the mining industry. Due to their degree of fineness, coal fines cannot directly be used in power plants and have therefore not been processed further. Nowadays mining countries such as Australia and South Africa are left with millions of tons of coal fines, a serious environmental problem. In the laboratory in Ludwigshafen, different chemicals suitable are tested for suitability to bind these fine coal particles into briquettes, enabling their use in power plants. With this technology, the huge amount of coal fines could be modified and at the same time environmental problems could be solved.

“The first trials have been very promising”, said Adrian Villanueva, Global Development group for Mining Solutions at BASF. “We were very surprised to see that chemistry normally used for paper coating can be adapted to serve as a coal binder.”

**Outlook: Further potential applications**

“For flotation, which is another typical mining application, we are testing products from other BASF divisions such as Care Chemicals, Petrochemicals or Intermediates”, said Alexej Michailovski, Technical Service BASF Mining Solutions Europe. “We are still in the early stages and there remains a huge number of BASF products that we are yet to test for potential application in mineral processing.”

BASF’s Mining Solutions business contributes to mineral beneficiation in South Africa

Mining in South Africa has been the main driving force behind the history and development of Africa’s most advanced and richest economy. To date, South Africa is currently the world’s fifth largest producer of gold and coal, the largest producer of chrome, manganese, platinum, vanadium, vermiculite and the second largest producer of ilmenite, palladium, rutile and zirconium. The country is also the third largest supplier of iron ore to the world’s largest user of iron ore, China – and the third largest producer of iron ore overall.

Today, mining in South Africa contributes an average of 20% to South Africa’s gross domestic product (GDP), of which about 50% is contributed directly. Mining also boasts total annual income exceeding 23.1 Billion USD. It is one of the country’s major employers, with more than one million people in mining-related employment.

In 2012, BASF initiated a test work at Mintek, a research institution in mineral and metallurgical field, to agglomerate ferrochrome fines into pellets using BASF binders. Ferrochrome fines represent around 5% of Run of Mine (ROM) during the mining process in South Africa.

The positive results obtained during this test using BASF binders address the above challenges in such a way that:

- Mining companies can recover lost production and increase their production.
- Some health risks for the community around the mine sites are eliminated.
- Land occupied by the ore fines will be freed and used for community settlement, farming or more mining activities.
- The use of BASF binders will reduce contaminants, thus reducing energy consumption.
- For some mining companies, the environmental challenge is paramount to the economic incentives.

Picko Reclamation placed the first order in July 2014 after conducting successful tests in the agglomeration of mineral fines.

This project has opened a new line of business for BASF’s Mining Solutions business in South Africa that contributes to sustainability of the mining sector by:

- Cleaning the mining environment in South Africa.
- Reducing energy use in the mining sector or furnaces.
- Reducing waste around mining and mine communities.
- Building the local economy and helping to sustain jobs in after-mining operations.
- Supporting and improving the quality of products through the involvement of local service providers (waste recycling companies).

This successful story can be applied in other countries with similar environmental and mining waste challenges.
Polymer-modified tailings deposition – ongoing testing and potential storage efficiency opportunities

The emerging technology known by various names such as in-line flocculation, polymer modified tailings deposition or more commercially as Enhanced Tailings Disposal (ETD), is the subject of growing interest from mining operations. Business drivers for its implementation can include a variety of site-specific, material-dependent operational challenges, as well as the more general desire to improve efficiency at tailings storage facilities (TSFs).

Polymers can modify the behavior of tailings in a variety of ways, one of which is through rheological adjustment. This can often result in a steepened beach, which with careful design and the use of natural or man-made landforms can result in the potential for significant reductions in the volume of initial embankment construction material. These opportunities are the subject of a number of ongoing large-scale operational trials, likely to become the subject of future papers. Other advantages are, however, inextricably linked with the technology: Reduced segregation, improved water release, less long term settlement and improving permeability and subsequent consolidation behavior. Thorough understanding of these improvements can allow for appropriate design and operational management, which can then allow the operator leverage to improve long term operational performance.

This paper describes some scoping-level testing that focused on potential time-related opportunities that may lead to more efficient tailings management. Subject to site-specific constraints, there may be a cost-effective opportunity to defer future capital expenditure required for the construction of a subsequent facility, or construction of the next raise of the embankments.

Increased consolidation rates may also lead to improved trafficability and thus more efficient rehabilitation. Whilst not going into specific detail concerning operational or construction costs, the paper presents high-level results of testing and consolidation modeling, demonstrating a combination of opportunities for improved tailings performance through:

- Accelerating and increasing overall water release
- Improving the rate of consolidation
- Reducing the rate of rise
- Reducing the amount of post depositional settlement

The implications of the data and modeling are discussed in the context of potential business opportunities, which can be broadly described as the ‘time value of volume’. 

To read the full paper click here
INTRODUCTION

Despite the Bayer process being 121 years old, it continues to evolve and develop to suit the different bauxites being processed. The business imperative to generate more production from existing assets has been a major driving force behind changes to the Bayer process. Modern alumina refineries are driven harder than ever and the alumina and caustic concentrations in the liquors are being pushed to higher levels in an effort to get more yield from each liter of caustic in the circuit. These changes are likely to continue because refineries are still not operating at the theoretical yield limit [1], although some are getting closer.

As well as the drive for higher yield, refineries are having to process lower grades of bauxite with higher levels of impurities. This results in higher loads on mud washing circuits and higher impurity levels in the Bayer liquor. The constraints of the current business cycle mean that refineries are trying to process these lower grades of bauxite with minimal capital investment. This means that mud washing circuits are having to work harder with larger mud flows, higher concentrations of dissolved compounds entering mud washing and larger concentration differences down the washer train.

The flocculants used in mud washing circuits today are high molecular weight copolymers of polyacrylate and polyacrylamide. The acrylate groups provide a negative charge to the polymer that helps it bind to mud particles and to unfold in the caustic Bayer liquors [2]. These types of synthetic flocculant have been used since the 1970s when they replaced the use of starch and other natural polymers in mud washing circuits. The use of these synthetic flocculants allowed lower flocculant dose rates and better densities in mud washing circuits.

EFFECTS OF CHANGING WASHER CONDITIONS

For flocculants in red mud washing, the changing conditions have been challenging. The larger differences in alumina and caustic concentrations down the mud washing train have led to different flocculants being used at different parts of the washing circuit to optimize washer performance at each part of the washer train. This requires extra equipment to prepare the different flocculants, or removes back-up systems where they are converted to dose a second flocculant, thus jeopardizing the availability of the washer circuit.

The changes in the chemistry of the liquor in the mud washing circuit have been significant. Caustic concentrations in the lead washer have increased from levels of about 150 – 180 g/l (as Na₂CO₃), prior to the 1980s to as high as 200 – 240 g/l today. And alumina levels have increased from levels of about 90 – 140 g/l (as Al₂O₃) prior to the 1980s to as high as 160 – 200 g/l today. This increase in the concentrations of caustic and alumina has increased the ionic strength of the liquor in the washers.

These chemistry changes have created a more difficult environment for flocculants to operate. The higher ionic strength liquors are not as good at solvating the polyacrylamide flocculants. As a result, the flocculants do not unfold to the same degree as they did in the lower ionic strength liquors. As the physical mode of action of the flocculants is to attach to the surface of mud particles and form polymer bridges between them, a flocculant that retains some degree of coiling and does not unfold to the same degree will not be able to form polymer bridges to the same degree. In addition to the shorter span of the floc bridges formed, the lower degree of unfolding means that less of the charged groups on the polymer are exposed and available for bonding to the mud particles. Thus the degree of binding of the floc to the mud particles is also reduced and the efficiency of flocculation is lessened.

The operational response to this reduction in floc efficiency is to increase the dose rate of the flocculant. However, this can generate its own set of problems. The higher concentration of partially coiled polymer particles in the mud does not allow the mud particles to be compacted closely together and changes the rheology of the mud. This effect can reduce the underflow density achievable from mud washers, especially the last washer. In severe cases, a high amount of polymer left in the mud can lead to a structured mud with a higher shear strength that
is more difficult to pump and thus reduces the capacity of the mud washing circuit. Additionally, overdosing of flocculant can lead to floc carry-over in the washer overflow, which can impact filtration process downstream.

RESPONSES TO CHANGES IN WASHER CONDITIONS

To combat these effects, flocculant manufacturers have modified their products to provide flocculants that work better at the higher caustic and alumina concentrations found at the front-end of mud washing trains. These changes have included increasing the charge on the polymer to allow better unfolding. The flocculants that have proved successful have been high-charge polymers with typically 100% charge rates. This approach to improving flocculant performance produced reagents that worked better on the front-end washers.

The second-generation flocculants with higher charge show an improvement in the settling rate and the mud density compared to the first-generation flocculants, especially in front-end conditions. However, for back-end conditions, the improvement in performance is not as great. Chart 1 shows the variation in performance of the second-generation flocculant HP20. Refinery liquors from front-, mid- and back-end washers were used in settling jar tests.

In this case, the best performance is in the mid-train washers with the front-end washers showing the poorest performance. Because of this variation from refinery to refinery, operators often use a different flocculant for the thickeners and front-end washers from the back-end washers with the cut-over point varying from refinery to refinery.

Despite the improvement in performance achieved with the second-generation of flocculants, the continual change in the operating conditions of the mud washing trains saw a decline in their performance as the ionic strength of the liquors increased further.

Development of Alclar® 3000 series flocculants

It was thought that flocculants for the even stronger liquors used by refineries could be improved by a combination of optimizing the charge on the polymers and by optimizing the molecular weights of the polymers. The intent was to produce polymers that would unfold in the high-strength conditions of the first washers but would not provide so much structure to the mud that they were unsuitable for the back-end washers.

A series of polymers with differing charges and molecular weights were screened using liquors typical of leading washers. Table 1 shows the dose rate of these polymers required to achieve a settling rate of 15 m/hr and the compaction achieved at that dose rate for liquors from two different refineries. It is clear that flocculants A&B were the best-performing polymers in these conditions. These two polymers became the Alclar® 3000 series flocculants, with A being designated Alclar® 3000 and B being designated Alclar® 1706.

<table>
<thead>
<tr>
<th>Flocculant sample</th>
<th>Refinery 1 TA 185 g/L</th>
<th>Refinery 2 TA 183 g/L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dose (g/T)</td>
<td>Compaction (g/L)</td>
</tr>
<tr>
<td>A</td>
<td>46.3</td>
<td>259</td>
</tr>
<tr>
<td>B</td>
<td>35.7</td>
<td>253</td>
</tr>
<tr>
<td>C</td>
<td>50.5</td>
<td>252</td>
</tr>
<tr>
<td>D</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>E</td>
<td>68.9</td>
<td>222</td>
</tr>
</tbody>
</table>

Table 1: Screening of potential flocculants

continued on page 09
When comparing these two polymers to previous-generation polymers, as in charts 2 and 3, it is clear that they have superior performance across the whole washer train. While being the highest performing polymers in all stages, they have the best performance over the entire washer train. These polymers have been trialed at several refineries in different parts of the world.

Chart 2: Comparison of Alcalt® 3000 series flocculants with second-generation flocculant in front-end washer liquor, TA 177 g/l.

Chart 3: Comparison of Alcalt® 3000 series flocculants with second-generation flocculant in back-end washer liquor, TA 46 g/l.

Mud washers

continued on page 10
PERFORMANCE IN THE PLANT

Table 2 summarizes the performance of the Alclar® 3000 flocculant against previous-generation flocculants in a range of washer conditions for a refinery in the Americas. Table 3 shows the performance of Alclar® 3000 flocculant in an Australian refinery. Again, the Alclar® 3000 flocculant is the best overall performing flocculant and showing improved underflow density with no deterioration in other operating parameters.

Having one flocculant that can be used for the entire washer train has several operational advantages for a refinery. It provides for a simpler operation with less variety of chemical additives, thereby reducing the opportunity for errors and variations in production. It also allows all existing polymer dosing equipment to be used for a single flocculant. This can increase the usable floc dosing capacity of the equipment to allow for treating higher mud flows with existing equipment. It can also provide an increased degree of redundancy in the polymer dosing equipment by converting two systems for two polymers into two systems for one polymer.

<table>
<thead>
<tr>
<th>Flocculant</th>
<th>Dose (g/T)</th>
<th>Torque (%)</th>
<th>Density (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gen’ II Floc’</td>
<td>Alclar® 3000</td>
<td>Gen’ II Floc’</td>
</tr>
<tr>
<td>Lead washers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>47.9</td>
<td>46.3</td>
<td>52</td>
<td>55</td>
</tr>
<tr>
<td>Front-end washers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37.5</td>
<td>42.5</td>
<td>52</td>
<td>51</td>
</tr>
<tr>
<td>Mid-train washers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40.9</td>
<td>48.3</td>
<td>53</td>
<td>52</td>
</tr>
<tr>
<td>Back-end washers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>79.2</td>
<td>70.3</td>
<td>36</td>
<td>36</td>
</tr>
</tbody>
</table>

Table 2: Performance in plant of Alclar® 3000 vs. Generation II flocculant

The Alclar® 3000 series flocculants have also shown some promising results when used in thickeners in combination with hydroximate flocculants. The Alclar® 3000 series flocculants do not have the particle scavenging capabilities of the hydroximate polymers and do not produce such good clarities in the overflows as the hydroximates. But they do produce better underflow densities than the hydroximates. Interestingly, the combination of the two polymers produces the best overall performance, with good clarity, settling rate and underflow density. And the dose rates needed for the dual polymer flocculant system for thickeners are lower than either flocculant alone. Using Alclar® 3000 series flocculants in combination with hydroximate flocculants can improve the performance and lower the flocculant cost for thickeners.

Table 3: Performance in plant of Alclar® 3000 vs. Generation II flocculant
CONCLUSIONS

The choice of which flocculant system to use in any particular washer train will depend on many factors, including, the bauxite being used, the type of mud washing equipment being used, the chemistry of the liquors, the demands placed on the refinery and the flocculant make up equipment available. Through the optimization of the molecular weight and charge of the polymer, BASF has produced a series of flocculants that allow refinery operators greater flexibility in how they operate their mud-washing circuits so that they can better meet the challenges of producing more alumina from poorer-quality bauxites with minimal capital expenditure on their plant.

REFERENCES