Recent advances in BIOX® technology

J. VAN NIEKERK
Gold Fields Ltd, South Africa

The past number of years has seen a sharp rise in the gold price. This has led to renewed activity in the gold sector and especially in refractory orebodies that are not economically feasible at lower gold prices.

There have, historically, been a total of eleven BIOX® plants commissioned worldwide, with eight currently in operation. The most recent plants to be commissioned were Bogoso and Jinfeng in 2007 and Kokpatas in Uzbekistan in 2008.

Design of the Bogoso BIOX® plant was started by Minproc in 2005. The design throughput of the sulphide BIOX® circuit is 820 tpd concentrate at a feed sulphide sulphur grade of 20%. The Bogoso BIOX® plant has the largest biooxidation reactors with a live capacity of 1 500 m³ each.

Plant design on the Jinfeng project started in 2005 and the engineering was performed jointly by Ausenco and Nerin. The BIOX® plant has a design capacity of 790 tpd concentrate at 9.4% sulphide sulphur.

The Kokpatas plant will be the largest BIOX® plant in the world with a phase 1 design concentrate treatment capacity of 1 069 tpd at 20% sulphide sulphur. The throughput will be doubled during phase 2. Interestingly, unlike other BIOX® plants, this plant will use a resin-in-pulp circuit for gold recovery, but the design will allow the plant to be converted to carbon-in-pulp if required.

The future growth of the technology is certainly also very good, with two new projects currently in the engineering phase, the Amantaytau project in Uzbekistan and the Mayskoye project in Russia.

There are a number of major R&D projects currently under investigation with some very positive results. Most R&D is focused on the main capital and operating cost items in the process, but there are also projects focused purely on process optimization and improvement.

Introduction

The BIOX® process for the pretreatment of refractory gold concentrates has been in commercial operation for the last 20 years. It has grown from a small-scale start at the Fairview Gold Mine to a mature, worldwide recognized technology with a total installed concentrate treatment capacity of 4 507 tons per day of concentrate. At current production rates a total of 1.5 million ounces of gold will be produced in 2009 using the BIOX® process.
Growth of the technology

The BIOX® technology started off as a 10 ton per day pilot plant operating in parallel with old Edwards roasters at the Fairview plant in South Africa. The process proved to be robust and the capacity of the BIOX® section was increased in 1991 to treat the full 35 tpd concentrate. The capacity of the plant was again increased in 1994 and 1999 to the current design capacity of 62 tpd.

The second BIOX® plant was the Sao Bento plant in Brazil in 1990. The first BIOX® licence was sold in 1991 for the application of the technology at the Harbour Lights project in Western Australia. This was quickly followed by Wiluna in 1993 and Ashanti in 1994/1995. Ashanti was a major breakthrough for the technology, confirming the ability of the process to be scaled up to any throughput rate using the modular design. Ashanti also proved the robustness of the technology and the suitability of the technology to remote locations.

A total of eleven BIOX® plants was commissioned over the last 20 years with five new plants commissioned in the last three years. Table I gives a summary of the current and historical BIOX® plants and the concentrate treatment capacities.

Figure 1 shows the installed concentrate treatment capacity, in ton per day concentrate, for all the BIOX® plants worldwide. After commercialization of the technology in 1991 the installed concentrate treatment capacity increased quickly with the commissioning of the five plants in quick succession. However, with the drop in the gold price in the middle 1990s, there was a marked slowdown in the interest in the BIOX® technology with only one low capacity plant commissioned between 1995 and 2005.

Interest in the technology started to increase again from ~ 2003 with the increase in the gold price. This led to the commissioning of five new BIOX® plants between 2005 and 2008. During 2009 there will be a total of eight BIOX® plants in operation with a combined installed concentrate treatment capacity of 4 500 tpd. The total estimated gold production from BIOX® operations for 2009 will be over 1.5 million ounces (> 47 tons of gold).

Table I
A summary of the commercial BIOX® operations

<table>
<thead>
<tr>
<th>Mine</th>
<th>Country</th>
<th>Concentrate treatment capacity (tpd)</th>
<th>Reactor size (m³)</th>
<th>Date of commissioning</th>
<th>Current status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fairview</td>
<td>S.Africa</td>
<td>62</td>
<td>340</td>
<td>1986</td>
<td>Operating</td>
</tr>
<tr>
<td>Sao Bento</td>
<td>Brazil</td>
<td>150</td>
<td>550</td>
<td>1990</td>
<td>C&amp;M*</td>
</tr>
<tr>
<td>Harbour Lights</td>
<td>Australia</td>
<td>40</td>
<td>160</td>
<td>1991</td>
<td>Decommissioned</td>
</tr>
<tr>
<td>Wiluna</td>
<td>Australia</td>
<td>158</td>
<td>480</td>
<td>1993</td>
<td>Operating</td>
</tr>
<tr>
<td>Ashanti</td>
<td>Ghana</td>
<td>960</td>
<td>900</td>
<td>1994</td>
<td>Operating</td>
</tr>
<tr>
<td>Coricancha</td>
<td>Peru</td>
<td>60</td>
<td>262</td>
<td>1998</td>
<td>C&amp;M*</td>
</tr>
<tr>
<td>Fosterville</td>
<td>Australia</td>
<td>211</td>
<td>900</td>
<td>2005</td>
<td>Operating</td>
</tr>
<tr>
<td>Suzdal</td>
<td>Kazakhstan</td>
<td>196</td>
<td>650</td>
<td>2005</td>
<td>Operating</td>
</tr>
<tr>
<td>Bogoso</td>
<td>Ghana</td>
<td>820</td>
<td>1 500</td>
<td>2007</td>
<td>Operating</td>
</tr>
<tr>
<td>Jinfeng</td>
<td>China</td>
<td>790</td>
<td>1 000</td>
<td>2007</td>
<td>Operating</td>
</tr>
<tr>
<td>Kokpatas</td>
<td>Uzbekistan</td>
<td>1069</td>
<td>900</td>
<td>2008</td>
<td>Operating</td>
</tr>
</tbody>
</table>

a) The volume of the two primary reactors at Fairview
b) The Mine is under care and maintenance
c) Mining operations were completed and 1994 and the plant decommissioned
d) Operations were temporarily stopped in 2008
e) Care and maintenance
There are also currently four projects under engineering and construction, two expansions to existing facilities and two new projects that will increase the installed BIOX® treatment capacity to over 6,500 tons per day concentrate by 2012. The capacity can potentially continue to grow to over 8,500 tons per day concentrate by 2015 based on projects currently in the various stages of testwork and development.

**Detailed description of the new BIOX® plants**

This section will give a brief introduction to the three new BIOX® plants, Bogoso, Jinfeng and Kokpatas.

**The Bogoso BIOX® plant**

The Bogoso Gold Mine, owned by Golden Star Resources, is located in south-west Ghana approximately 200 km west of the capital city Accra. The first set of batch amenability tests on Bogoso concentrate was performed at Gencor Process Research in 1996. The results from the initial batch tests were very encouraging and continuous BIOX® pilot-plant testwork was performed in 1998 at SGS—Lakefield Research Africa on two bulk concentrate samples from the Bogoso deposit.

The Bogoso BIOX® plant has a design capacity of 820 tons per day of concentrate at a sulphide sulphur grade of 20%.

The BIOX® plant consists of two modules, each module consisting of seven BIOX® reactors, followed by the CCD washing circuit, solution neutralisation and the carbon-in-leach circuit for gold recovery. Construction of the Bogoso Sulphide Expansion Project (BSEP) began on 13 June 2005 with GRD Minproc awarded the contract for the design and construction of the plant. The inoculum build-up and commissioning of the BIOX® plant started late in 2006 and was completed mid 2007 with the production of the first BIOX® treated gold.

The BIOX® technology achieved a new milestone at Bogoso with the successful commissioning of the largest BIOX® reactors. The plant also uses a closed circuit evaporative cooling system. Although the capital cost of this option is higher than the conventional open circuit system, it is expected that the operating cost (including maintenance) will be lower for the closed circuit due to better control of the water quality flowing through the cooling coils. Inoculum build-up at Bogoso was expedited by receiving 24 m³ of active inoculum from AngloGold Ashanti’s Sansu BIOX® plant, enabling the inoculum build-up process to start directly in a 100 m³ reactor.
The Jinfeng BIOX® Plant

The Jinfeng gold deposit, owned by Sino Gold Limited, is located in the Guizhou Province, approximately 240 km south-west of the provincial capital Guiyang, in the Peoples Republic of China.

Batch BIOX® testwork on Jinfeng concentrate samples started in 2002 at SGS Lakefield Research Africa. The concentrate samples proved to be amenable to biooxidation pretreatment, achieving high sulphide oxidation and gold recovery results. The batch testwork was followed up by a continuous BIOX® pilot-plant test programme in 2003.

The first process design package was delivered to Sino Gold Limited in 2003 following the successful completion of a BIOX® licence agreement for the use of the BIOX® technology for the Jinfeng deposit. The plant was designed to treat up to 790 tons per day of concentrate at a sulphide sulphur grade of 9.37% in two BIOX® modules, each module comprising eight 1 000 m³ reactors. The retention time across the BIOX® reactors is four days at the design feed rate. The biooxidation section is followed by a standard CCD washing circuit, solution neutralization and a carbon-in-leach circuit for gold recovery.

The Jinfeng Bankable Feasibility Study was completed in March 2004 and construction of the plant began in February 2005. Inoculum build-up started in April 2006 with the first gold poured in March 2007.

Jinfeng is currently one of the largest gold mines in China. Optimization of the Jinfeng mine is ongoing to increase gold production to optimal levels. Jinfeng mine is also faced with major logistical challenges, especially during the wet season with an average rainfall of 1.2 m annually, accompanied by landslides and wind storms.

Currently the Jinfeng project is consistently achieving operational performance at or above design parameters. The Jinfeng BIOX® plant is performing exceptionally well with sulphide sulphur oxidation well above design as well as BIOX®/CIL gold recovery above design parameters.

The Kokpatas BIOX® plant

The Kokpatas Mine is located in the Kyzylkum desert, 32 km north-east of the town of Uchkuduk in Central Uzbekistan. The deposit is owned and operated by the Navoi Mining and Metallurgical Combinat, the largest gold producer in Uzbekistan. Ore will be supplied from various open pits, including the Daugystau deposit some 140 km from Kokpatas.

Laboratory test work conducted by GENCOR Process Research (GPR), on samples from the Daugystau and Kokpatas pits, indicated that the sulphide ore is amenable to upgrading by sulphide flotation. Pretreatment of the flotation concentrate by the BIOX® Process liberated the gold sufficiently to improve gold dissolution during cyanidation to over 90%.

Pilot-scale flotation and BIOX® test work conducted in South Africa in 1994 confirmed the positive results of the laboratory test work and provided sufficient data for the design of a full scale sulphide treatment plant. In 1997, similar test work was performed at GPR’s facilities in South Africa on a 15 ton ROM ore sample from the Kokpatas sulphide deposit, and excellent results were achieved.

Following the conclusion of a licence agreement between NMMC and Biomin Technologies S.A. for the supply of the BIOX® technology, a BIOX® plant was designed to treat flotation concentrate from the Kokpatas deposit during phase 1 of the project. The design concentrate treatment capacity of phase 1 of the project is 1 069 tpd. During phase 2 the plant capacity will be increased to 2 137 tpd to incorporate flotation concentrate from the Daugystau deposit. This is made possible by the modular design of the biooxidation section of the BIOX® plant.
The phase 1 BIOX® plant consists of four modules. Each module has three primary reactors and three secondary reactors. The counter current decantation thickeners (CCDs) were sized to accommodate the Phase 2 capacity of the plant. During Phase 2, four additional BIOX® modules will be added and the neutralization plant capacity increased. The supply capacity of cooling water and air will also be increased accordingly.

The detailed design of the phase 1 BIOX® section was performed by Institute O’zGeotexli in Uzbekistan with equipment fabrication, construction and the electrical installation performed by local contractors. Civil works on the BIOX® reactor foundations for phase 1 started during July 2005. Commissioning of phase 1 began mid-2008 and is expected to be completed early 2009 after the delivery of the final equipment.

**New BIOX® projects under development**

There are currently four BIOX® projects in various stages of design or construction. Two of these are expansions to existing BIOX® plants while the other two are new BIOX® projects.

The Suzdal BIOX® plant in Kazakhstan is expanding the capacity of the treatment plant from 196 tpd concentrate to over 520 tpd concentrate. This will be achieved by duplicating the existing BIOX® circuit and adding additional cooling and blower air capacity. The solids concentration in the feed will also be increased slightly to ensure that sufficient residence time is maintained in the BIOX® reactors. A new CCD circuit will be constructed and the number of neutralization reactors will be increased to cater for the higher concentrate throughput.

The Kokpatas plant in Uzbekistan has started with the planning for phase 2 of the project, to double the treatment capacity of the plant to 2,163 tpd concentrate. This will be achieved by duplicating the phase 1 BIOX® circuit. The CCD circuit was sized for phase 2 during phase 1 while additional neutralization reactors will be added. The blower and cooling tower capacity will also be increased as required to cater for the increased aeration and heat loads.

The Amantaytau project is also located in central Uzbekistan near the town of Zarafshan. The project will also be implemented in two phases. The phase 1 BIOX® plant will have a design capacity of 376 tpd concentrate, increasing to 564 tpd in phase 2. The sulphide sulphur grade in the concentrate can be as high as 36% due to the high in situ ore sulphide grades.

The Mayskoye project is located in the Chukotka region in Russia. The BIOX® plant will have a design capacity of 350 tpd concentrate. The extreme climatic conditions in this region will pose a number of engineering challenges, starting with a relatively short shipping window in the summer months. The ambient temperature also only exceeds freezing point for two months of the year.

**BIOX® at sub-zero temperatures**

The Suzdal BIOX® plant is located near the town of Semey in Kazakhstan. The BIOX® plant has a design capacity of 196 tpd concentrate at a sulphide sulphur grade of 12%. The BIOX® section consists of 6 x 650 m³ reactors, configured in the standard three primary and three secondary reactor configuration.

The extreme climatic conditions experienced at Suzdal made the design of the plant very interesting. The design had to take hot, humid conditions during summer into consideration and ensure that the cooling towers can deliver the required duty under these conditions.

The bigger problem, however, was to design for the winter conditions when the temperatures could go as low as—45°C, without taking any wind chill into consideration. For this reason the bulk of the plant is located inside a building with only the BIOX® reactors and the cooling towers outside the building. The walkways on top of the BIOX® reactors were covered to protect the operators from the extreme conditions when taking samples.
The BIOX® process is exothermic and extensive modelling was performed to ensure that sufficient heat is produced by the process to maintain the temperatures in the BIOX® reactors even at the coldest conditions. The modelling indicated that the BIOX® reactors would still have to be cooled even at the coldest conditions. Significant planning also went into planning for power failures and unplanned stoppages to ensure that the reactors do not freeze if standing for too long.

The Suzdal BIOX® plant has now operated through three winters and has performed very well. So far no problems were experienced with maintaining the temperature in the primary reactors even at reduced sulphur feed rates in the first year than initially anticipated. Suzdal has certainly proven that BIOX® is not only a viable technology to consider for sub-zero temperature applications, but that it holds certain advantages over other processes. The advantage lies in the modular design of the plant and the number of reactor stages. Even if one or more of the reactors is off-line the rest of the process plant does not have to be stopped and can continue to operate as normal. For other refractory processes, if the treatment process is stopped for any length of time, the rest of the processing plant must also stop, a situation that can be catastrophic at sub-zero conditions.

The performance of the Suzdal BIOX® plant has certainly proven beyond a doubt that the BIOX® technology can be used successfully at sub-zero conditions.

Research and development

The BIOX® process has been commercially in operation for nearly 20 years. Throughout this period Gold Fields has maintained a strong focus on research to improve the efficiency of the process and the design of the commercial reactors. Maintaining an active research and development program is critical to ensure the long-term viability of the technology. For this reason Gold Fields has developed a strategic research and development programme to address the main capital and operating cost items in the BIOX® process. The programme is being implemented in stages, focusing on the highest priority items first.

Figure 2 shows a breakdown of the capital cost for a typical BIOX® plant. The graph indicates that the stainless steel for the BIOX® and neutralization reactors will make up approximately 35% of the installed equipment cost, followed by the agitators at approximately 27% and the blowers at 13%.

The operating cost breakdown for four operating BIOX® plants is shown in Figure 3 and the reagent cost breakdown in Figure 4. It can be seen that between 40% and 50% of the opex cost is for power and between 30% and 45% for reagents.

The reagent cost breakdown for the same four plants is shown in Figure 4. It can be seen the bulk of the cost is for pH control, accounting for ~ 70% of the reagent cost, but can vary from as low as 40% to as high as 85% depending on the relative reagent cost and consumption rates. This includes both BIOX® pH control and neutralization of the acid solution.

Nutrient cost is usually fairly low at less than 20% and can be as low as 4% after a dedicated nutrient optimization programme is completed. The exception is plant B where the nutrient cost is exceptionally high, but this is a factor of low neutralization cost and the fact that the plant was fairly recently commissioned and must still undergo nutrient optimization. The remainder of the reagents is usually less than 10% of the overall reagent cost.

The cost for cyanide leaching of the BIOX® product is not included in the operating cost given above. Analyses of the CIL operating cost for the same four BIOX® plants indicate that reagents make up between 70% and 90% of the operating cost, with cyanide accounting for 65% of the reagent cost.
Figure 2. Breakdown of the installed equipment cost for a BIOX® plant

Figure 3. Operating cost breakdown for four BIOX® plants

Figure 4. Reagent cost breakdown for four BIOX® plants

Four research and development areas were identified based on the capital and operating cost structures described above:

- Development of an improved agitation system
- BIOX® process optimization, focused on BIOX® retention time reduction and reagent cost savings
• Evaluation of alternative materials of construction
• Cyanidation optimization.

A number of projects were identified based on these main R&D areas and are progressively being implemented. The main projects currently underway are described in more detail below.

**Development of an improved agitation system**

Axial flow impeller technology in biooxidation reactors is conventionally based on the concept of down pumping. The impeller circulates the slurry in a downward motion with the objective of increasing the gas retention time in the reactor. Alternative agitation systems are being developed in an effort to reduce the overall power input required for aeration and air dispersion. One of the options under investigation is the use of an up-pumping axial flow impeller in biooxidation reactors.

An extensive laboratory-scale test programme was conducted where a range of different impeller combinations was tested in a 500 l reactor using the Lightnin A310, A315 and A340 impellers. Different combinations of these impellers were compared with each other and the A315 was used as a benchmark with the main objective to reduce the power per unit volume and reducing the air demand while still maintaining high levels of oxygen mass transfer.

The configuration that performed the best in the laboratory test programme was scaled up to a 20 m³ test reactor at Fairview BIOX® plant. The selected configuration was tested under the same conditions as in the laboratory determining the power numbers, oxygen mass transfer and power per unit volume, using the A315 as a benchmark. The final stage was to test the impeller under BIOX® conditions by operating the test reactor as a primary BIOX® reactor. The Fairview BIOX® plant personnel have been a tower of strength in making this test work possible. Results to date are looking very promising in achieving the main objectives.

**BIOX® process optimization**

There are a number of factors that determines the rate of sulphide oxidation. These include both BIOX® operating parameters and concentrate characteristics. The BIOX® process has been in operation for 20 years and the operating conditions are well defined. However, we have seen from results of the operating BIOX® plants that the BIOX® bacteria are capable of handling conditions outside the standard operating parameters. It was decided to start a project to investigate the effect of changing certain operating conditions or concentrate characteristics on the performance of the process. The objectives of the programme were to reduce the BIOX® retention time, and thereby capital cost and to reduce the reagent consumption rates.

Due to the number of potential parameters to investigate, a structured programme was set up. The initial set of tests focused on the effect of following parameters:

- BIOX® feed density variation
- Effect of fine grinding of the concentrate
- Effect of BIOX® liquor removal to control the ferric iron concentration in the primary reactors and
- Effect of pH in the final biooxidation stages.

The test work was performed in a 120 l continuous pilot plant located at the Fairview BIOX® plant. The pilot plant was operated for a total of 6 months using a bulk Fairview concentrate sample collected over a seven-day period as feed. Batch amenability tests were also performed on the concentrate samples using similar conditions as in the pilot plant. In future the test programme will be expanded to include other parameters.
Materials of construction

Stainless steel for the BIOX® reactors is one of the main capital cost items for any new BIOX® plant. For this reason Gold Fields is continually evaluating the performance of various and potentially cheaper stainless steel grades under BIOX® conditions. Various coatings for mild steel are also tested as a coated mild steel reactor may have cost benefits, provided the coating can withstand the operating conditions in a BIOX® reactor. The testwork includes both anaerobic conditions, typically found in the CCD thickeners, as well as aerobic conditions found in the BIOX® reactors.

Three sets of test racks were prepared and installed at the Fosterville BIOX® plant in Australia. Test samples from a number of steel grades were included in the racks, including 304, 316, 317, 2205 and LDX2101. A number of mild steel samples, coated with different coatings were also installed. Samples will be removed after 6, 12 and 24 months for evaluation. Fosterville was selected as the test site due to the relatively high chloride content of the water, averaging approximately 600 ppm.

Combination mesophile and thermophile biooxidation process

Test work has shown that the use of high temperature or thermophillic micro-organisms can allow almost complete oxidation of all the intermediate sulphur species, thereby significantly reducing thiocyanate formation during the cyanidation of the biooxidation product. This will result in significantly lower cyanide consumption during leaching with potentially no loss in gold recovery. The use of thermophillic micro-organisms does, however, come at a price.

- **Increased capital cost**—the micro-organisms (thermo-acidophillic archaea) operate in a temperature range of 65–80°C, and this increases the corrosive nature of the acidic bio-leaching slurry. Standard austenitic stainless steel grades cannot be used for this application and more exotic materials of construction such as duplex stainless steels or acid lined concrete tanks are required for the manufacturing of the reactors. The process operates at reduced solids concentrations, but this is traded off with faster reaction kinetics.

- **Increased operating cost**—the equilibrium solubility of oxygen in water is very low at these high temperatures and oxygen enrichment of the air introduced into the slurry is required to achieve the required mass transfer rates in the reactors. Water consumption is also increased due to increased evaporation rates at the higher operating temperatures, and oxygen enrichment may be required to reduce the volume of air flowing through the reactors.

A combination mesophile and thermophile process was proposed to make the best use of the advantages of the different microbial strains. In this process the mesophilic BIOX® bacteria are used for the primary oxidation stage to achieve approximately 70% sulphide oxidation. This is then followed by a thermophile oxidation stage to complete the oxidation, targeting the intermediate sulphur species. A number of batch and continuous test work programmes using this process were completed over the last five years.

A large-scale thermophile pilot-plant test work program was completed at the Fairview BIOX® plant to test the process under conditions expected to be encountered during full-scale operation and to generate data for the design of a commercial scale thermophile plant at Fairview. This included using daily overflow samples from the primary reactors at Fairview as feed to the thermophile plant. The pilot plant was operated for 6 months testing various parameters to optimize the process. Daily oxidation values were monitored as well as subsequent gold recovery and cyanide consumption during leaching of the oxidized product.
The results from the test programme were very encouraging, indicating that a very short retention time is required in the thermophile stage to maintain bacterial activity and achieve the required sulphide oxidation. The plant was able to operate at higher solids concentrations than initially expected, and it was found that no solution removal stage is required between the BIOX® and thermophile stages. Sulphide oxidations similar or better than the BIOX® plant were maintained and similar gold recoveries were achieved at substantially lower cyanide consumption rates.

Conclusions

The BIOX® technology has been commercially in operation for more than 20 years. The technology has proven itself to be robust and ideally suited for remote locations. The recent interest in the technology, as evidenced by the number of BIOX® projects recently commissioned or in development, confirms that the technology offers significant advantages over other refractory processes.

The combined installed treatment capacity of the eight operating BIOX® plants across the world is currently 4 500 tpd with an expected 1.5 million ounces of gold to be produced using the BIOX® technology in 2009.

Recent operating experience at the Suzdal plant has confirmed the applicability of the BIOX® technology to projects located in cold climates. BIOX® again offers certain advantages over other treatment processes, including high plant availabilities and the ability to operate continuously even with a number of reactors offline.

Gold Fields also manages a structured research and development programme to ensure continuous development of the technology. The programme is focused on the main capital and operating cost items, namely power for aeration and agitation, BIOX® retention time and cyanide consumption.

---

Jan van Niekerk

Senior Consultant: Metallurgy (Refractory Gold),
Gold Fields Ltd, South Africa

Jan van Niekerk started his career in 1995 at Gencor Process Research. He spent the early part of his career on various BIOX® projects, including a number of BIOX® continuous pilot plant tests. He spent a short period of time at Beatrix Gold Mine to gain operational experience until the forming of Gold Fields Ltd from the gold assets of Gencor and Gold Fields of South Africa. He then returned to the BIOX® department at Gold Fields’s corporate office. There he was still involved in testwork, but also started to get involved in the design of BIOX® plants and giving assistance to operating plants. He was involved in the commissioning of the Tamborache plant in Peru and was the BIOX® representative for the testing, design and commissioning of the Fosterville BIOX® plant in Australia. In 2006 he was promoted to the head of the BIOX® department within Gold Fields overlooking all aspects of managing the technology.