

1 The BIOX™ Process for the Treatment of Refractory Gold Concentrates

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1.1 Introduction

Gencor has pioneered the commercialization of biooxidation of refractory gold ores. Development of the BIOX™ process started in the late 1970s at Gencor Process Research, in Johannesburg, South Africa. The successful development of the technology led to the commissioning of a BIOX™ pilot plant in 1984, followed by the first commercial BIOX™ plant at the Fairview mine in 1986 (van Aswegen et al. 1988). The BIOX™ process was fully commercialized in 1991 when the Fairview plant was expanded to treat the total concentrate production of the mine and the Edwards roasters were finally shut down.

Commissioning of a further three BIOX™ plants at Harbour Lights (Barter et al. 1992) in 1992, Wiluna (Stephenson and Kelson 1997) in 1993 and Sansu (Nicholson et al. 1993) in 1994 followed. Toward the end of 1990 a single BIOX™ tank was commissioned at the São Bento mine in Brazil (Slabbert et al. 1992) to operate also series with two pressure oxidation autoclaves. In 1998 the Tamboraque BIOX™ plant (Loayza and Ly 1999) was commissioned in Peru and concluded what could be considered as a first generation of commercial BIOX™ plants. For all these BIOX™ plants the technology was provided under a technology license agreement.

The robustness, simplicity of operation, environmental friendliness and cost-effectiveness of the technology has been demonstrated at all of these operations. The BIOX™ process has been a technical and economic success and offers real advantages over conventional refractory processes, such as roasting and pressure oxidation. Ongoing development work on bench and pilot scales, as well as on operating plants, is aimed at improving the efficiency and cost-effectiveness of the process even further.

When the interests of Gencor and Gold Fields of South Africa were merged in February 1998 to form the new Gold Fields, the BIOX™ process technology and its holding company, Biomin Technologies Limited were transferred to the new company. With the increase in the gold price, there has been a renewed interest in the development of refractory gold ore deposits and the application of the BIOX™ technology to treat such ores. The year 2005 can be considered to mark the development and commissioning of a new generation BIOX™ plants to treat refractory gold ore concentrates. Both the Suzdal

BIOX™ plant in Kazakhstan and the Fosterville plant in Australia were commissioned during May 2005. During 2006 and 2007, BIOX™ plants will be commissioned at the Jinfeng (China), Bogoso (Ghana) and Kokpatas (Uzbekistan) projects.

1.2 The BIOX™ Process Flow Sheet

The typical process flow sheet for the BIOX™ process is shown in Fig. 1.1. The sulfide concentrate from the flotation section of the plant is pumped to the BIOX™ stock tank. Flotation concentrate is thickened to a density of at least 50% solids to minimize carryover of flotation reagents to the BIOX™ reactors. A minimum sulfide-S concentration of approximately 6% is usually required to ensure adequate bacterial activity during the biooxidation stage.

A regrind circuit may be included in the circuit before the stock tank, especially when a portion of the concentrate is produced using flash flotation. The feed concentrate to BIOX™ is typically milled to 80% smaller than 75 μm with a minimum diameter of more than 150 μm . An increase in the grind size would reduce of particles with a sulfide oxidation rate and would result in a lower overall oxidation for similar BIOX™ treatment periods. Fine grinding to 80% smaller than 20 μm will enhance the sulfide oxidation rate but may influence the downstream processes negatively, for example to increase the settling area required or to increase the viscosity of the slurry.

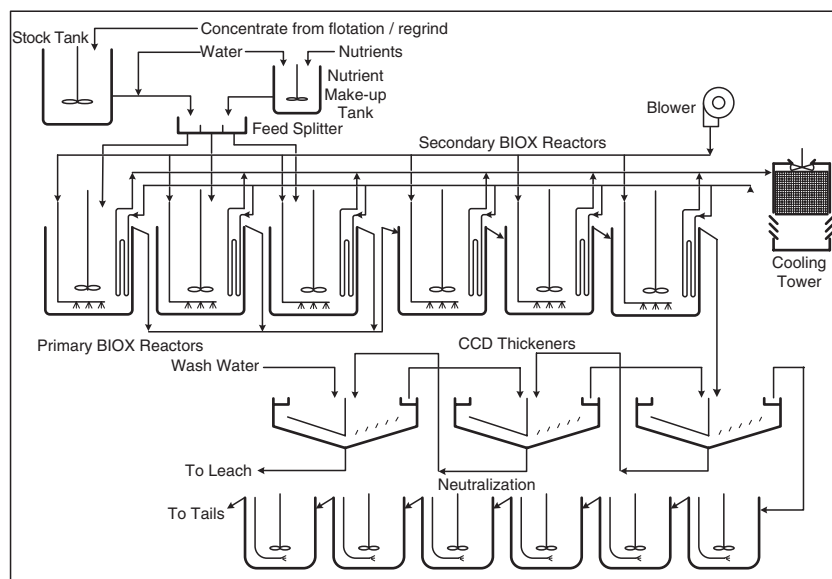


Fig. 1.1. Typical BIOX process flow sheet

A biooxidation plant typically consists of six equidimensional reactors configured as three primary reactors operating in parallel followed by three secondary reactors operating in series. The feed concentrate from the stock tank is diluted to 20% solids by mass before being fed to the primary BIOX™ reactors. The operating slurry solids content is determined mainly by the oxygen mass transfer requirement of the process. In cases of low sulfide-S concentrations, it may be possible to operate the reactors at a higher solids concentration.

The pulp residence time in the biooxidation reactors is typically 4–6 days depending on the oxidation rates achieved, and is a function of the sulfide-S content and mineralogical composition of the concentrate. Generally, half of the retention time is spent in the primary reactors to allow a stable bacterial population to be established and to prevent bacterial washout. Once a stable bacterial population has been established, a shorter retention time can be tolerated in the secondary reactors where sulfide-S oxidation is completed.

Nutrients in the form of nitrogen, phosphorus and potassium salts are also added to the primary reactors to promote bacterial growth. The standard addition rates and nutrient sources specified by Gold Fields are listed in Table 1.1. Low concentrations of nutrients are often present in the concentrate and this creates the opportunity to reduce the nutrient addition rates once stable operation has been achieved at the plant (Olivier et al. 2000).

The mixed culture of mesophilic bacteria used in the BIOX™ process can operate at temperatures ranging from 30 to 45°C. The pulp temperature in commercial reactors is controlled between 40 and 45°C. This temperature allows maximum sulfide oxidation rates to be achieved while minimizing cooling requirements. The oxidation of sulfide minerals is an exothermic process and the reactors must be cooled continuously by circulating cold water through a series of cooling coils installed inside the reactors. Evaporative cooling towers are used to remove heat from the cooling water.

A minimum carbonate content of 2% in the flotation concentrate is usually required to ensure that sufficient CO₂ is available in the concentrate to promote bacterial cell production. If no carbonate is present, limestone or CO₂(g) must be added to the primary reactors as a source of carbon for cell production.

Low-pressure air is injected into the BIOX™ reactors to supply oxygen for the oxidation reactions. It is extremely important that a dissolved oxygen concentration of more than 2 mg L⁻¹ be maintained at all times in the slurry.

Table 1.1. Standard nutrient addition rates and sources

Nutrient	Addition (kg t ⁻¹)	Source
Nitrogen	1.7	Ammonium sulfate, ammonium phosphate salts and urea
Phosphorus	0.9	Ammonium phosphates and phosphoric acid
Potassium	0.3	Potassium sulfate, hydroxide and phosphate salts

The supply and dispersion of the air is one of the main capital and operating cost components for a commercial biooxidation plant. This is discussed in more detail in Sect. 1.5.

The oxidation of pyrite produces acid, while the oxidation of arsenopyrite and pyrrhotite and the dissolution of carbonate minerals consume acid. Limestone and sulfuric acid are used to control the pH in the BIOX™ reactors within the optimum range of pH 1.2–1.8.

The BIOX™ product contains high concentrations of dissolved ions and must be washed in a three-stage countercurrent decantation (CCD) circuit before cyanide leaching. The washed BIOX™ product would normally contain less than 1 g L⁻¹ total iron in solution with a pH of 1–3. Iron removal is necessary before cyanide leaching to promote gold recovery and reduce cyanide consumption. The CCD wash thickener overflow liquor is neutralized in a two-stage process to pH 7–8 to produce a stable precipitate containing all the iron and arsenic. The final precipitates are stable and safe for disposal on a tailings dam.

The process requirements, engineering design and operation of the BIOX™ process are described in detail in the following sections of this chapter.

The BIOX™ process can also be integrated with other metallurgical processes to either increase the treatment capacity of an existing plant or to remove certain contaminants from the material being treated.

The São Bento operation in Brazil is a good example where the BIOX™ process was combined with an existing pressure oxidation plant to increase the capacity of the plant (Slabbert et al. 1992). In this application, BIOX™ was used as a preoxidation step to oxidize a portion of the sulfur before the material was fed to the autoclave, thereby reducing the sulfide-S loading on the autoclave. A total of three BIOX™ reactors were installed over a period, operating in parallel. Biooxidation was a quick and low-cost option to increase the capacity of the existing pressure oxidation plant.

The BIOX™ process can also be combined with other unit processes. The BIOX™ process can be used to remove arsenic or base metal contaminants from the concentrate feed to smelter operations. The arsenic can then be precipitated as a stable product suitable for land disposal. The configuration of the BIOX™ plant and the location in the process flow sheet can be selected to fit the specific application.

Recent testwork has also confirmed the ability of the BIOX™ process to treat arsenic trioxide produced during the roasting of arsenopyrite-containing concentrates. Arsenic trioxide is recovered as a dry powder from the roaster off-gas and disposing of it is both difficult and expensive owing to the toxicity of As(III). Pilot plant testwork and commercial scale plant experience indicated that the BIOX™ process can successfully oxidize the As(III) to As(V) in the BIOX™ reactors (Osei-Owusu 2001; van Niekerk 2001). The arsenic can then be precipitated as a stable ferric arsenate during neutralization.

1.3 Current Status of Operating BIOX™ Plants

Full descriptions of the eight BIOX™ plants mentioned in the “Introduction” have been described in a number of papers (Barter et al. 1992; Loayza and Ly 1999; Nicholson et al. 1993; Slabbert et al. 1992; Stephenson and Kelson 1997; van Aswegen et al. 1988). Table 1.2 gives a summary of the commercial BIOX™ plants, previously and currently in operation, as of late 2005. A short summary of the five operations currently in operation is presented in this section.

1.3.1 The Fairview BIOX™ Plant

The BIOX™ process has been in operation for 19 years at the Fairview mine in South Africa. The pilot plant was commissioned in 1986 to treat 10 t day⁻¹ in parallel with the aging Edwards roasters. The process proved to be robust and the capacity of the BIOX™ section was increased in 1991 to treat the full 35 t day⁻¹ concentrate. The capacity of the plant was again increased in 1994 and 1999 to the current design capacity of 62 t day⁻¹.

The reactor configuration at Fairview is not the standard BIOX™ configuration owing to the addition of new reactors with each expansion phase. The performance of the plant over the years has, however, proven the stability and adaptability of the process to varying concentrate characteristics and operating conditions (Irons 2001). The Fairview BIOX™ plant has played a vital role in the development of the process. The size of the operation and the close

Table 1.2. A summary of the commercial BIOX operations, currently and previously in operation, at the date of publication

Mine	Country	Concentrate treatment capacity [t day ⁻¹]	Reactor size [m ³]	Date of commissioning
Fairview	South Africa	62	340 ^a	1986
São Bento ^b	Brazil	150	550	1990
Harbour Lights ^c	Australia	40	160	1991
Wiluna	Australia	158	480	1993
Sansu	Ghana	960	900	1994
Tamboraque ^d	Peru	60	262	1998
Fosterville	Australia	211	900	2005
Suzdal	Kazakhstan	196	650	2005

^aThe volume of the two primary reactors at Fairview.

^bThe BIOX reactors are in care and maintenance due to concentrate shortages.

^cMining operations were completed in 1999 and the plant was decommissioned.

^dOperations were ceased in 2002 due to mining and financial difficulties.



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