In line with expectation, 43.5% of the gold was found to be associated with sulphides, 31.75% with carbonaceous matter, 9.7% with carbonates and a meager 8.8% was available as free-milling in the flotation concentrate. Despite the very fine grind of 92% passing 45 µm, the diagnostic study recorded 6.26% of gold embedded in silicates. The diagnostic study result confirms the refractory nature of the ore and justifies the decision to subject the flotation concentrate to a BIOX pretreatment step. The oxidative pretreatment step is targeted at freeing the gold locked up in sulphides and some carbonates. The diagnostic study on BIOX CIL tailings revealed gold association profile in the order of carbonaceous matter > quartz > free-milling > sulphides > carbonates as compared with the flotation concentrate, which gave results in the order of sulphides > carbonaceous matter > carbonates > free milling > quartz.

The order of association validates the ability of the BIOX process to release gold in sulphides to an appreciable extent but the inability to deactivate carbonaceous matter rendering the latter the dominant gold career of 48.34 % in CIL Tailings. The Bogoso BIOX CIL circuit operates a hybrid carbon addition system intended to introduce adequate active carbon to the first leach tank and compete with preg-robbers. However, the plant still records high gold losses to preg-robbers due to the reduction in carbon concentration in the head tank from 40-19g/l during loaded carbon recovery. This plant observation is supported by results in Figure 4.12 where gold recovery is reduced with carbon concentration in the range of 20 g/l.

Quartz accounted for 17.12% of unrecovered gold even at a recorded grind of 93% passing 45 µm. Though the plant was designed for a grind of 80% passing 75 µm for BIOX, the target grind has been amended in part due to the poor leach recovery to 90% - 45µm. The fine grind also helps BIOX achieve good oxidation. Finer than 45 µm grind was not considered due to potential downstream viscosity, and settling challenges after bioxidation.

Also, 13.4% of the gold was free and available for leaching given adequate residence time. During the two-week sampling period, two of the six leach tanks were offline due to breakdowns. The circuit residence time had therefore reduced by about 33 % which likely accounted for the reduced recovery. Residual sulphides after BIOX treatment with grade of 0.42% accounted for 11.51% of the gold losses and gold in carbonates was 9.65%.

CYANIDATION LEACH OPTIMISATION

Cyanide Consumption. The trend of cyanide dosage optimisation and its attendant gold recovery is illustrated in Figure 4 The figure shows metal recovery increasing to 90.4% with progressive additions of cyanide until 7 kg/t NaCN. Beyond cyanide addition of 7kg/t until 15 kg/t, only marginal increases in recovery were observed. Recovery increase of 0.06 % was recorded with extra cyanide consumption of 7.7 kg/t. This is consistent with the expectation as high cyanide dosage results in high consumption (Hackl and Jones, 1997).

An economic benefit analysis in Table 2 shows that at design concentrate tonnage, the recovery increase of 0.06% translates into about 17g of gold per day, a revenue gain of $658 @ gold price of $38.58/g. The extra 7.7 kg/t cyanide consumption however translates into a production loss of $18 990 @ cyanide price of $3000/t). The net loss in revenue is thus $18 332.

Apart from the revenue loss, the excess cyanide addition will result in high levels of WAD and thiocyanide (SCN) cyanide in tailings water which will require treatment before discharge into the environment. The cyanide dosage is therefore optimized at 7 kg/t with leach recovery of 90.4%. BIOX plants with automatic cyanide control allows it to operate between

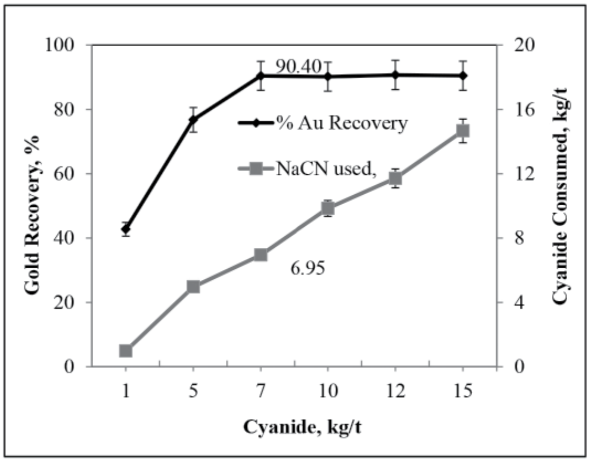

Figure 4. Gold dissolution vs. cyanide consumption.

Feed Tonnes, t/day	822
Grade, g/t	34.6
Recovery Increase, %	0.06%
Addition Gold Output, g/day	17.06
Additional Revenue, $/day	***658***
Extra Cyanide Consumption, kg/t	7.7
Extra Cyanide Consumed, t/day	6.33
Price of Cyanide, $/t	3000
Revenue Loss Due to Extra Cyanide, $/t	***18,990***
Net Loss in Revenue	**18,332**

Table 2. Cost analysis of increased cyanide consumption.

8 – 12 kg/t (Anon, 2013). The Bogoso BIOX® plant has recently installed new TAC1000 automatic cyanide titrators to reduce the cyanide consumption and optimise the dosage.

The results presented confirms that the higher the dosage of cyanide, the higher the consumption. High cyanide consumption has been the subject of much study and has widely been attributed to the presence of cyanicides in the BIOX® products (Hackl and Jones, 1997). The cyanicides have largely been ascribed to elemental sulphur and other intermediate sulphur oxidation species that may react with cyanide to form thiocyanate (SCN-). Several studies have confirmed the presence of elemental sulphur in the oxidation process of pyrite (Sasaki et al, 1995; Xu and Schoonen, 1995; Schippers et al, 1996).

Iron and arsenic precipitates formed in the BIOX® process also contribute to the increased cyanide consumption (Hackl and Jones, 1997; Miller and Brown, 2005; Ciftci and Akcil, 2010). The residual iron, arsenic and other dissolved metals in solution after the CCD wash will also contribute to high cyanide consumption (Mudder et al, 2001). Indeed, currently running BIOX plants around the world experience high cyanide consumption during periods of lower than desired percent sulphide oxidation (SOX) and CCD washing efficiency (Anon, 2013). From this perspective, it is therefore logical, that high sulphide oxidations must be targeted in addition to efficient washing in the CCD circuit to remedy the situation. Very accurate automatic cyanide controls will also prevent wastage.

Carbon Concentration and Preg-robbing Index (PRI). Due to the fact that the sample being treated is double refractory, the efficiency and amount of activated carbon used has an influence on recovery resulting from competition with carbonaceous materials. Before considering the effect of varying amounts of carbon on recovery, it was important to establish the effect of no carbon on leach recovery. Leach recovery tests were therefore conducted with and without carbon to establish the