preg-robbing index. The results of preg-robbing index and carbon optimisation are shown in Figures 5 and 6 respectively.

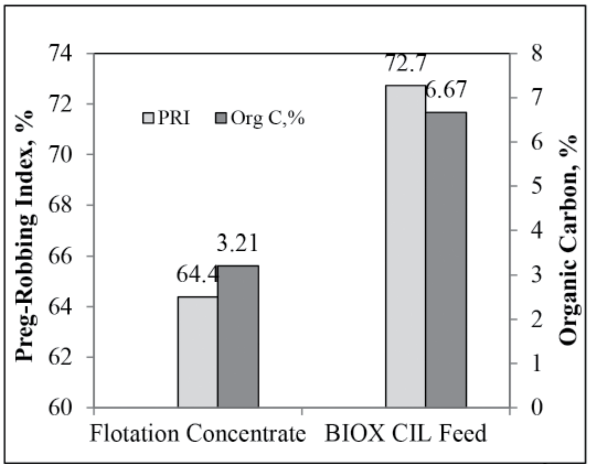

Figure 5. Preg-robbing indices for flotation concentrate and BIOX® CIL feed.

Both samples of pre- and post-BIOX concentrates are highly preg-robbing as the preg-robbing characteristics of the BIOX concentrate did not reduce after subjecting the flotation concentrate to BIOX® treatment but rather increased from 64.4% to 72.7%. Evidently, the BIOX process does not degrade carbonaceous matter in double refractory ores (Brierley and Kulpa, 1993; Amankwah et al, 2005; Yen et al, 2008). In their paper on preg-robbing of gold from cyanide and non-cyanide complexes, Ofori-Sarpong and Osseo-Asare (2013) reported a higher percentage of preg-robbing by BIOX® product (BIOX® CIL feed) than BIOX® feed (Flotation Concentrate), and attributed it to the presence of carbonaceous matter even after bioxidation.

The PRI and organic carbon grades of flotation concentrate rather increased after BIOX treatment, possibly due to carry-over of dead bacterial cells attached to ore particles, acting as carbonaceous matter and/or as a result of dissolution of sulphur leading to a resultant increase in the percentage of organic carbon, total carbon and gold as evident in Table 1.

As can be seen in Figure 6, recovery was 31.9% when leaching was conducted without carbon and 77.4% when 20 g/l activated carbon was added. Further appreciable increase in recovery was recorded at 30 and 40 g/l carbon additions with only marginal recovery increases at 50 g/l carbon. Optimum carbon concentration is therefore between 40 - 50 g/l. From the foregoing, it is concluded that below 40 g/l carbon addition, preg-robbing becomes severe and hence impacts negatively on leach recovery.

In fact, experience on the Bogoso BIOX CIL circuit has shown that leach recovery is reduced when carbon concentration in the head tank falls below 35 g/l. Operating at carbon profiles above 35 g/l however results in maintaining a huge inventory of carbon and hence a large gold lockup in the circuit. This is associated with low carbon loadings and low rate of gold output per elution. The later consequence can only be forestalled by the installation of rather large elution and regeneration circuits (Beer, 1994; Amankwah et al, 1998; Lunt and Weeks, 2005).

Unpublished comparative data reported by licensed users of the BIOX technology in 2013 show carbon concentration of 30–80 g/l being maintained among the various operations (Anon, 2013). This is widely attributed to the preg-robbing

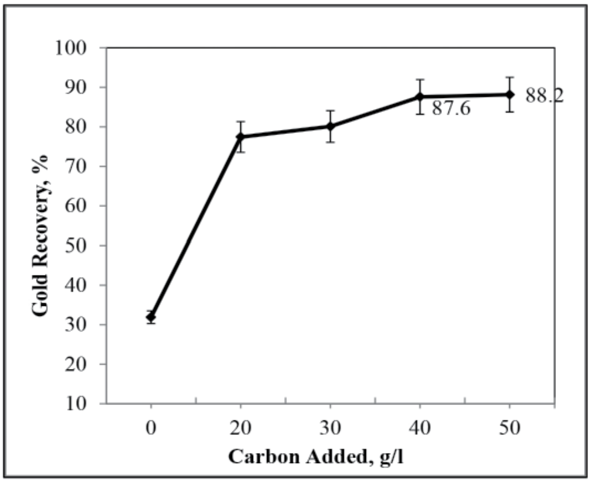

Figure 6. Carbon optimisation tests on biox cil feed samples.

characteristics of the ores being treated. The sensitivity of the leach circuit to sufficiently active carbon further requires faster carbon advance rates. This results in high carbon attrition rates and hence higher carbon consumption (MacIntyre, 2005; Adam, 2009).

Results from the Bogoso plant carbon activity tests show that the activity of carbon reduces by 40% as it is being advanced to the head tank. This renders the carbon uncompetitive with the organic carbon. To present carbon of much higher activity in the head tank, 20% of regenerated carbon is added to the front tank per regeneration cycle. The leach circuit therefore follows the process flow as shown in Figure 7. In this arrangement, regenerated carbon is introduced simultaneously at the head tank and the last leach tank

This technique minimises the preg-robbing impact of the residual organic carbon contained in the BIOX product. In practice, the addition of the regenerated carbon to the front tank is scheduled to coincide with the end of loaded carbon recovery. This is to replenish the concentration of carbon in the head tank with active carbon.

This hybrid carbon movement system was adopted to combat the high preg-robbing characteristics of the ore and has proven to reduce gold losses much better than the conventional CIL counter current carbon movement system.

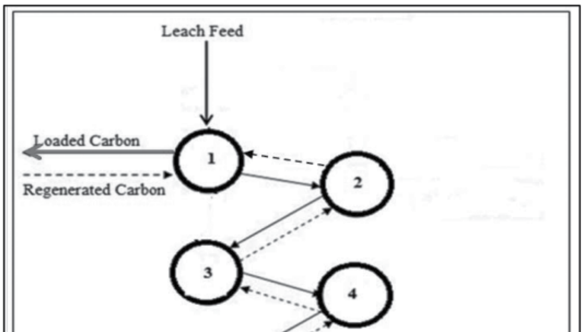

Figure 7. Schematic diagram of the bogoso BIOX CIL leach flow configuration.