

# Effects of Quebracho Tannin on Recovery of Colloidal Gold from Bioleached Wash Liquor\*

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## Abstract

Gold occurs in some concessions as submicron particles in pyrite and arsenopyrite, which is processed in a flotation concentration to obtain gold enriched sulphide concentrate. The concentrate is then treated in a biological oxidation step to oxidize the sulphides, liberate the occluded gold and make them amenable for cyanidation. The oxidized sulphide concentrate with high acidic content is washed in Counter-Current Decantation (CCD) thickeners to obtain thickened slurry, from which gold is recovered by cyanidation and wash liquor which is considered as tailings. The wash liquor from the CCD thickeners of a typical BIOX plant in Ghana, Golden Star Resources Limited, carries away 0.57 g/L of gold to tailings. This paper considered effects of Quebracho Tannin (QT) on recovery of gold from the oxidized flotation concentrate wash liquor. The effect of Quebracho Tannin on Total Suspended Solids (TSS) was also established. This research established that the gold lost to tailings was not soluble in the effluent but was mainly in the form of colloidal particles. Application of Quebracho Tannin to CCD effluent showed a substantial decrease in the loss of gold to tailings. About 0.13 g of gold was recovered from the CCD effluent per tonne of ore treated. An optimum QT dose of 0.05 g/l was determined from laboratory test giving a 21.25 % reduction in the Total Suspended Solids (TSS) and a 45.79 % reduction in the gold loss to tailings. When the 0.05 g/l dose was applied on the plant the TSS reduced by 53.51 %.

**Keywords:** Quebracho Tannin, Pyrite, Arsenopyrite, Gold processing, Colloidal particles.

## 1 Introduction

Golden Star Resources Limited (GSRL) is a gold processing company in Bogoso, Ghana. Gold occurrence in the company's concession is primarily as submicron particles in pyrite and arsenopyrite. The company employs Bacterial Oxidation (BIOX® Process) to oxidize the sulphides to liberate gold from its flotation concentrate. Once gold is liberated by the oxidation process, cyanide leaching could be done (Marsden and House, 2006; Ahmed-Salim, 2009; Gaudin, 1939; Wills and Napier-Munn, 2006).

After the biological oxidation, the oxidized sulphide concentrate with high acidic content is washed in Counter-Current Decantation (CCD) thickeners to obtain thickened slurry, from which gold is recovered by cyanidation and wash liquor which is considered as tailings. While the oxidation process is very effective, about 0.57 g/t of gold has been washed at the Counter Current Decantation (CCD) section into the neutralisation tailings since commissioning of the plant. The way gold was lost at the section was unknown as it was not determined during the feasibility studies. It was realized that, colloidal particles were present in the Counter Current Decantation Overflow (CCDO) after washing the bio-oxidation product (Shaw, 1992; Fridrikhsberg, 1986; Cosgrove, 2005).

There have been several research on Quebracho Tannin (QT). The stability of colloidal particles are

affected by QT (Malešev and Kuntić, 2007; Traw and Nancy, 2010; McRae and Kennedy, 2011; Okuda and Ito, 2011; Atanassova and Christova-Bagdassarian, 2009). Symes (2009) also showed that, QT has effects on colloidal gold. This paper considers recovery of gold from the oxidized flotation concentrate wash liquor with the aid of Quebracho Tannin (QT).

## 2 Materials and Methods Used

### 2.1 Materials

Quebracho Tannin (QT) used in this research was obtained from Nowata Mining Chemical Manufacture and Supply (NMCMS). Water samples for the analysis were also obtained from the CCD Overflow (CCDO) at GSRL.

### 2.2 Characterisation of Materials

Water samples from the CCDO were analysed for thiocyanate and gold using UV Spectrometer and Varian Spectra AA 55B AAS respectively. Particle Size Distribution (PSD) of the colloidal particles in the CCDO was determined using filter paper with 11 µm, 2.5 µm and 0.45 µm pore sizes. Adsorption of gold in the CCDO using activated carbon (AC) was investigated. The characterisation results of QT were obtained from the MSDS of the product as supplied by NMCMS.

### 2.3 QT – CCDO Interaction

QT concentration or strength used for all the analysis was 10%. Three dissimilar tests were conducted to determine the effect of QT on colloidal gold loss reduction. In the first test, 0.25 g/l, 0.5 g/l and 1 g/l of QT were used. For the second test, 0.1 g/l, 0.2 g/l and 0.4 g/l of QT were used and in the third test, 0.05 g/l, 0.1 g/l and 0.2 g/l of QT were used. The residence time used was 78 minutes.

### 2.4 Analytical Method

The percentage reduction of gold and TSS after applying QT was determined using equation 1 as follows:

$$R = \frac{C_o - C_e}{C_o} \times 100\% \quad (1)$$

Where: R = Percentage reduction of gold loss/TSS

$C_o$  = Initial concentration of gold loss/TSS

$C_e$  = Final concentration of gold loss/TSS after QT addition.

## 3 Results and Discussion

### 3.1 Characteristics of CCDO Sample

Due to the complexity of hydrometallurgical processes, characterisation of the CCDO was required. Gold being very stable, will dissolve only in oxidizing solutions containing complexing ligands such as cyanide, thiosulphate, thiourea, thiocyanate and halides. Due to the redox potential and pH of CCDO, only thiocyanate and thiourea could complex dissolved gold in the waste liquor. However, results from UV Spectrometer show that, the concentration of thiocyanate is below the detection limit.

It was realised from the test that, gold loss at the CCD section cannot be reduced profitably using activated carbon. Table 1 shows the results obtained after the AC-CCDO interaction. The highest and lowest percentage of gold captured by the fresh AC was 45% and 21.05% respectively. Similar trend was observed from the barren carbon where 30% and 5.26% was recorded as the highest and lowest percentage gold captured. Symes (2009) reported from his work that, any reagent, with high surface area and is stable in acidic environment,

can holdup colloidal gold from waste liquor. The gold particles captured by the AC can therefore be attributed to the high surface area of the AC. It was realised that, gold captured were physically held onto AC since thorough wash in distilled water led to its release.

Fig. 1 shows the PSD of the CCDO suspended particles. The PSD test revealed that, 80% of the suspended particles passes 7.2  $\mu\text{m}$  and 50% passes 1.6  $\mu\text{m}$ . The suspended particles are therefore colloidal. Colloidal gold particles that get locked up in the fine suspended gangue material cannot be recovered because of the poor settling properties. The results in Fig. 2 reveal that, suspended particles existing between 2.5  $\mu\text{m}$  and 0.45  $\mu\text{m}$  contains the highest amount of gold. This can be attributed to the large surface area of those particles.

Fig. 2 shows the particle size fractions of suspended particles in the CCDO and their gold contents.

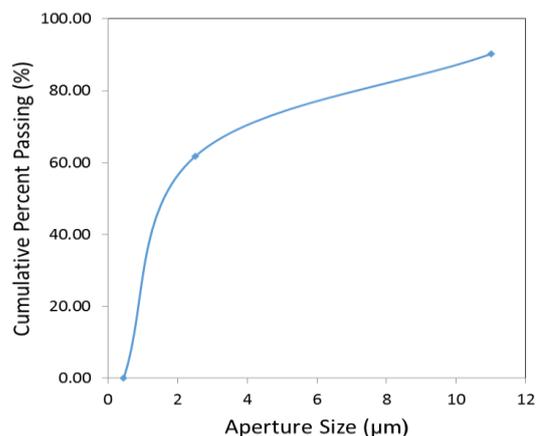
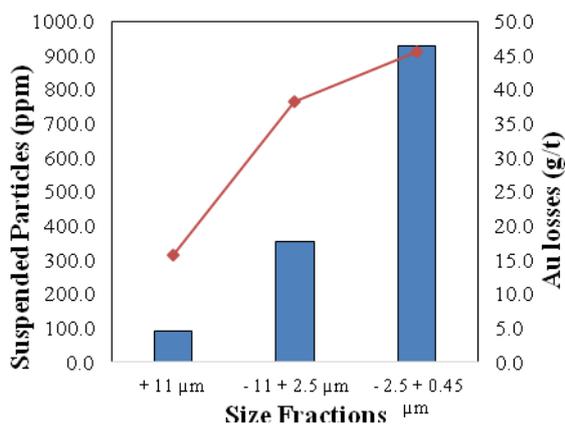


Fig. 1 PSD of suspended particles in the CCDO

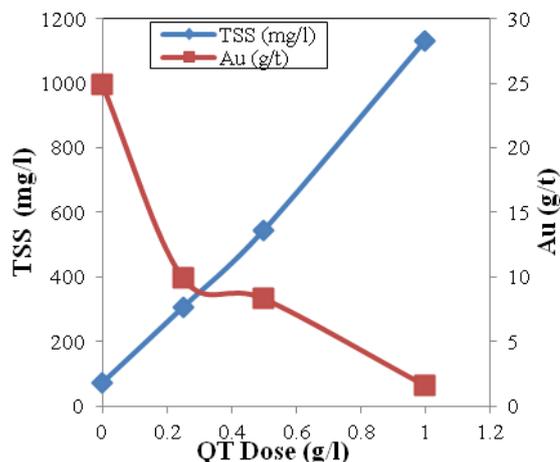
### 3.2 Characterisation of QT

Results of typical analysis obtained from NMCMS shows that, 70% of QT is of polyphenolic (flavonoid) content. Table 2 shows the typical analysis of QT. Research shows that, flavonoids exhibit antioxidative properties through chelating with transition metals, primarily Fe (II), Fe (III) and Cu (II), which precipitate in reactions generating free radicals (Malešev and Kuntić, 2007).

The chelation of flavonoid with iron may lead to partial precipitation of iron which can help reduce colloidal gold loss.



**Fig. 2 Distribution of Suspended Particles in CCDO and their Gold Content**



**Fig. 3 Effect of 0.25 g/l, 0.5 g/l and 1.0 g/l QT Dose on TSS and Gold Recovery**

**Table 1 Results of Fresh and Barren AC-CCDO Interaction to Determine AC's Effect on Reducing Colloidal Gold Loss**

Test	Gold in CCD Liquor (Head Grade)	Gold Remaining in CCD Liquor after Fresh Carbon Contact	Percent Gold Remaining in CCD Liquor	Gold Remaining in CCD Liquor after Barren Carbon Contact	Percent Gold Remaining in CCD Liquor
	Ppm	Ppm	%	Ppm	%
1	0.2	0.15	75.00	0.17	85.00
2	0.19	0.15	78.95	0.18	94.74
3	0.22	0.15	68.18	0.2	90.91
4	0.1	0.06	60.00	0.07	70.00
5	0.2	0.11	55.00	0.16	80.00
AVERAGE	0.18	0.12	67.43	0.16	84.13

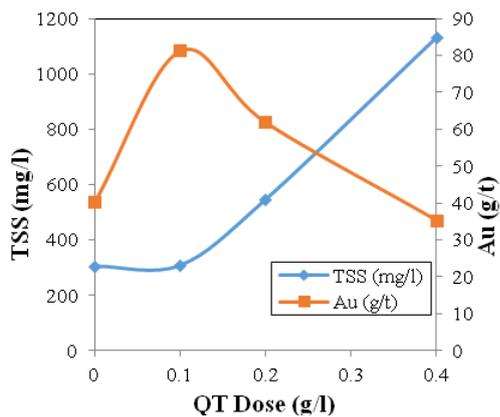
**Table 2 Typical Analysis Carried Out On Quebracho Tannin Sample NL 4648**

Analysis	Result
Moisture	6%
Polyphenolic (Flavonoid) Content	70%
Non-Phenolic Content	23%
Water Insolbles	<1%
Mineral Ash	1-5%
pH	4.4 – 4.6
Viscosity of 50 % solids solution (25°C)	1500 – 2500 cP
Gel Time at 100°C (10 % paraformaldehyde on solids)	480 – 520 sec

### 3.3 Effect of QT on TSS and Gold Recovery

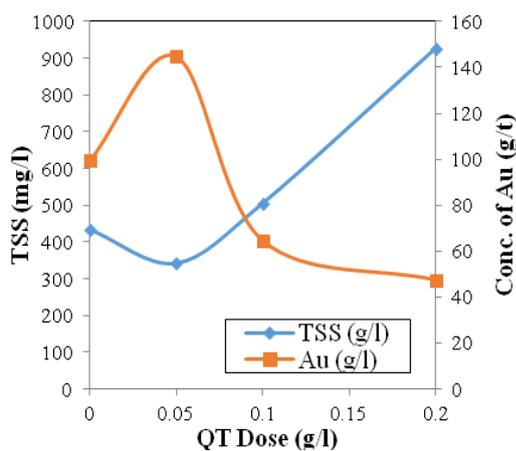
The concentration of QT needed to reduce colloidal gold loss is very important. From the first QT dosage test, where 0.25, 0.5 and 1.0 g/l were used as shown in Fig. 3, TSS increased in direct proportion to increase QT dosage. Gold content of the settled suspended particle also reduced as the QT dosage increased.

In the second test, increase in TSS was not significant when 0.1 g/l QT dose was used (Fig. 4). At the same point, the gold loss reduced by 103.25 % with respect to case where no QT was added. Taking 0.2 g/l dose, the TSS increased as the gold loss reduced by 53.98%. Therefore, 0.1 g/l dose was the best result in the second test. However, consistent trend was not observed when the test was repeated several times.



**Fig. 4 Effect of 0.1 g/l, 0.2 g/l and 0.4 g/l QT Dose on TSS and Gold Recovery**

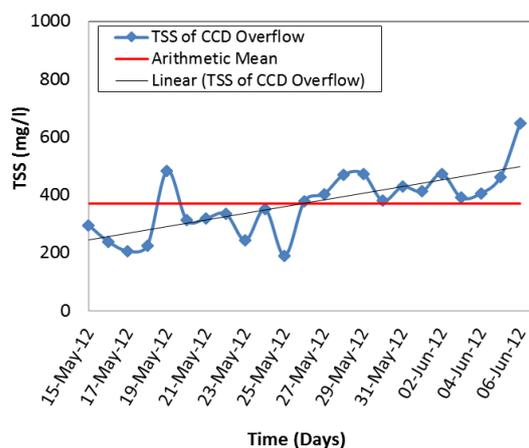
In the third test, 0.05 g/l dose of QT gave consistent and good results for TSS and gold loss reduction. The TSS was reduced by 21.25 % while gold loss reduced by 45.79 % (Fig. 5). The inconsistency of the 0.1 QT dose could be witnessed in the third test where the TSS increased and the gold loss also increased.



**Fig. 5 Effect of 0.05 g/l, 0.1 g/l and 0.2 g/l QT Dose on TSS and Gold Recovery**

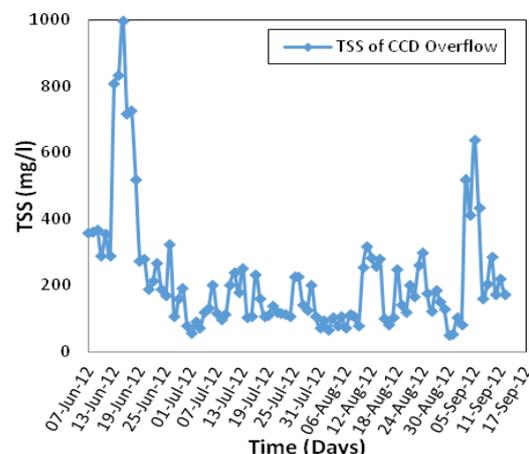
### 3.4 Introduction of QT at the CCD Section

Before QT was introduced at the CCD section, TSS of the CCDO generally increases with time. Fig. 6 shows the situation in the CCD before QT introduction. On introducing QT at the CCD section of GSRL, interesting results were obtained.



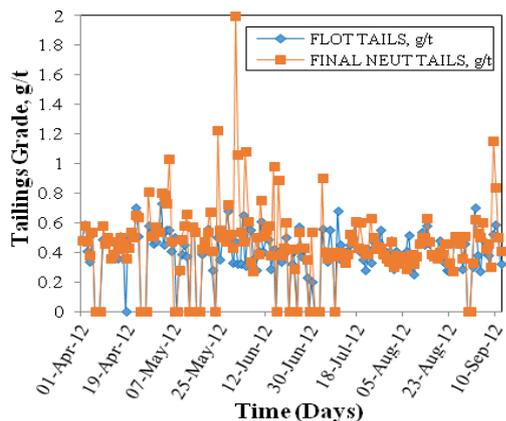
**Fig. 6 TSS of CCDO before Using QT**

There was continuous reduction of TSS in exception of days where there was sliming in the CCD's (13<sup>th</sup> to 18<sup>th</sup> June, 2012 and 3<sup>rd</sup> to 6<sup>th</sup> September, 2012). Fig. 7 shows the results of TSS obtained after introducing QT at the CCD section. TSS reduced to almost 50 %. These results suggest that, the QT was acting as a flocculant in reducing the TSS of the CCDO.



**Fig. 7 TSS of CCDO after Introducing QT**

Besides the effect of QT on TSS, the grade of gold in the neutralisation tailings also reduced showing a positive impact of QT. Fig. 8 shows grade comparison of neutralisation and flotation tailings after QT introduction. Before the introduction of QT, the gold grades of the neutralisation tailings were always higher than the flotation tailings due to colloidal gold loss. After introducing QT at the CCD section, gold grade of neutralisation tailings is almost equal to the flotation tailings. Daily analysis gave an average gold savings of 0.13 g/t when QT was introduced on the plant. The research showed that, QT does not have negative effect on gold recovery.



**Fig. 8 Comparison of Gold Grades of Neutralisation and Flotation Tailings**

## 4 Conclusions

From this research, it was determined that gold loss at CCD was not soluble in the CCDO but suspended as colloidal particles. Due to their poor settling velocity, they report in the neutralisation tailings.

The use of QT at the CCD section resulted in substantial decrease in the loss of gold to neutralisation tailings. About 0.13 g/l of gold was recovered from the CCDO in addition to the originally recovered gold at the CIL section.

There was no negative impact of QT on the gold recovery. QT dose, as small as, 0.05 g/l was found optimum for the reduction of TSS to about 21.25% for bench scale and 53.51% for plant scale, and gold loss, to about 45.79 %.

QT therefore has the efficacy to reduce colloidal gold loss at the CCD of GSRL and consequently aid recovery of the colloidal gold.

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