Predicting the Extent of Preg-robbing Based on the Maturity of Carbonaceous Gold Ores

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Darteh, F. K., Abdul-Wasiu, M., Boateng, A. and Ofori-Sarpong, G. (2020), "Predicting the Extent of Preg-robbing Based on the Maturity of Carbonaceous Gold Ores", *Proceedings of 6th UMaT Biennial International Mining and Mineral Conference*, Tarkwa, Ghana, pp. 433-438.

Abstract

Sulphides and carbonaceous materials are among the major materials considered to cause refractoriness in the processing of gold ores. The presence of carbonaceous materials in gold ores is a source of worry to gold mining companies due to its ability to interact with and adsorb auro-cyanide complexes during cyanidation, with a consequent decrease in overall gold recovery, termed as preg-robbing. The degree of preg-robbing is reported to depend on the type of carbonaceous materials and the extent to which the precursors have undergone maturation. This paper builds on a previous research which investigated the degree of preg-robbing of different carbonaceous materials with standard gold solution. The present paper simulated carbonaceous gold ores by dosing varying percentages (0%, 1%, 2%, 3%) of various carbonaceous materials (woodchips, charcoal, activated carbon) into oxide ores and leaching the ores by cyanidation process. The results show that the ores with no carbonaceous materials had very high cyanidation recoveries (>90%), more than 10 folds with respect to the ores dosed with activated carbon. In general, the simulated carbonaceous ores recorded recoveries ranging from 10% to 90% lower than the control without carbonaceous inclusions. The wood chips which had the lowest maturity imposed the lowest degree of preg-robbing, and thus recorded the highest gold recovery after the control. The preg-robbing ability decreased in the order of activated carbon (88-100%), charcoal (64-86%) and wood chips (10-42%), which individually depended on the amount of carbonaceous material present. The results affirm a high degree of dependence of preg-robbing potential of carbonaceous gold ores on the degree of maturity of the resident carbonaceous materials.

Keywords: Carbonaceous materials, Preg-robbing, Oxide ore, Auro-cyanide

1 Introduction

Gold from prehistoric times has been considered a very precious metal and the medieval alchemist considers gold as a metal of perfection (Adams, 2005). Regardless of the fact that gold concentration in the earth is very low (the average concentration is 0.005 g/t, which is lower than other metals) (Marsden and House, 2006), gold has not ceased to be a metal of grave interest. In this sense, obtaining gold has transitioned from picking of gold nuggets through various recovery processes to the current conventional methods being used, of which cyanidation is the most prominent commercial extraction method.

Cyanidation, however, works best on free-milling ores where with optimum particle size reduction, gold can be easily recovered from the ore. The reason being that the mineral of interest is unattached chemically to other minerals in the parent rock. Refractory ore on the other hand as the other class of gold ores, has been the long occurring problem in terms of its treatment and recoveries since the mineral of interest is encapsulated (sub-microscopically or surface bound) in other minerals. Sulphides, carbonaceous matter, tellurides and organic carbon are the contributors to refractoriness in gold ores, of which sulphides and carbonaceous matter are the major (Adams, 2005; Ofori Sarpong *et al.*, 2013). Sulphur in sulphides engulf the tiny and fine gold particles affecting cyanidation such that leaching reagents do not get direct contact with the gold particles hence resulting in low recoveries (refractoriness). Although sulphides causing refractoriness in gold ores is a major concern, occurrence of gold in solid solution with sulphides is very important because as stated by Marsden and House (2006), for example, an ore containing 1% by weight of arsenopyrite and a gold grade of 10 g/t could have all the gold present in solid solution with the arsenopyrite.

Carbonaceous matter on the hand, affects recoveries in cyanidation in the sense that they compete with activated carbon to adsorb aurocyanide complexes from gold solution, a phenomenon known as preg-robbing (Abotsi and Osseo-Asare, 1986; Quach *et al.*, 1993; Ofori-

Sarpong *et al*., 2010). Carbonaceous matter consists mainly of elemental carbon which adsorbs gold from solution, and thus behaves like activated carbon, humid acids which may form complexes with gold, and hydrocarbon which more or less has no interactions with gold (Ofori-Sarpong *et al*., 2013; 2017). According to Ofori-Sarpong *et al*. (2010), the two main harmful effects of carbonaceous matter in gold ores are the fact that gold is confined in the matrix of carbonaceous matter making it difficult to release, and the adsorption of dissolved gold from pregnant solution. This results in very low recoveries in the cyanidation process. Various reports indicate that the degree of preg-robbing has direct correlation with the level of maturity and how well the graphitic structure of the carbonaceous material is developed (Jones *et al*., 1989; Ibrado and Feurstenau, 1992; Stenebraten *et al*., 2000; Ofori-Sarpong *et al*., 2010; 2013). The various carbonaceous materials may include woodchips, pieces of charcoal, fine barren carbon and carbonaceous ore (Schimtz *et al*., 2001).

In mining, the various carbonaceous matter comes into the processing circuit through different means. Woodchips source from the degradation of the timber used for roof supports in underground mines and/or roots of vegetation cleared for surface mining. These woodchips in the leaching circuit may blind or block inter-stage screens causing an overflow of pulp and loaded carbon. This flattens the carbon activity profile and the efficiency of the gold adsorption is declined as explained by Gray (2006). The woodchips however have not undergone any form of graphitisation hence has very low maturity. Gold mining has transitioned into zones which deviate from typical oxide ores to mineralized zones where coalified form of carbonaceous matter is encountered (Adam *et al*., 2014). Rocks are formed from the gradual deposition of skeleton of animals, remains of plant and silt which is transformed by ice, river or wind. These plants and animal remains get buried and, under high temperature and pressure, undergo a coalification process to produce coal and carbonaceous matter in gold ores. These carbonaceous matter present in the ore can be represented by charcoal since they are formed through similar process (Amanya *et al*., 2017). There is some form of graphitisation associated with this type of carbonaceous matter hence some form of maturity as compared to the woodchips. Activated carbon, even though, is very important in cyanidation process, can be classified as a preg-robbing material when it undergoes abrasion during transport in processing and becomes fine. After desorption of gold from loaded carbon, the barren carbon is transferred to the kiln for regeneration. The purpose of regeneration is to improve the activity of the carbon to adsorb gold cyanide complexes. Reactivation is necessary because during the period that the carbon is in contact with the pulp it becomes progressively poisoned and loses its activity (Marsden and House, 2006). In the course of regeneration, some of the carbon disintegrates to produce fine particles. The fine particles produced have a high surface area to adsorb aurocyanide complexes, however, it is difficult to recover gold from the fine particles, rendering it highly preg-robbing (Ofori-Sarpong *et al*., 2010).

All these detrimental effects of carbonaceous material inclusions in gold ores cause many mining companies to lose a lot due to the low recoveries encountered. In a previous related work, Amanya *et al*. (2017) used standard gold solution to study the preg-robbing effect of various carbonaceous materials. After a 24-hr contact time, the authors reported adsorption capacities in grams of gold per tonne of carbon at 30-65 for wood chips, 320-370 for charcoal, 410-420 for barren carbon and 580-650 for activated carbon. Using a gold-containing carbonaceous solid material will better represent a situation that is close to reality. Thus, this present work sought to investigate the extent to which simulated carbonaceous gold ores would preg-rob aurocyanide complexes during cyanidation, and by extension, the decrease in overall gold recovery.

2 Materials and Methods Used

2.1 Materials Used

An oxide ore and samples of various carbonaceous materials (wood chips, charcoal and activated carbon), sodium cyanide (NaCN), hydrochloric acid (HCl), nitric acid (HNO_3) and lime were obtained from the Minerals Engineering Laboratory of University of Mines and Technology, UMaT, Tarkwa.

2.2 Method

2.2.1 Sample Preparation and Bottle Roll Test

The bulk oxide ore sample was passed through the three (3) stages of crushing (Primary, Secondary, and Tertiary) using the jaw, cone and roll crushers for each stage respectively and further milled to obtain 80% passing 106 µm screen size. The various carbonaceous materials (woodchips, charcoal and activated carbon) were also ground to 80% passing 106 µm screen size. A 12-kg material was sampled from the bulk material prepared and was further split until 3 representative samples were obtained from the bulk with each weighing 4 kg using a riffle sampler. Each of the 4-kg sample was again divided into four (4) portions with the riffle sampler to obtain 1-kg sample each. Each of the 1-kg oxide sample was blended with different amounts of carbonaceous material (0 g, 10 g, 20 g and 30 g) to respectively generate 0%, 1%, 2% and 3% percentages of carbonaceous materials in the ores. The blends were subjected to cyanidation using the bottle roll test approach at 50% solids, pH of 11 and cyanide strength of 300 mg/l. Solution samples from each test were taken at hours of 1, 2, 4, 8, 16 and 24 of agitation. The solid residues were thoroughly washed and dried.

2.2.2 Aqua Regia of Solid Residue

A 50-g mass of the dried residue from each setup was weighed into a Pyrex beaker. Aqua regia was prepared by adding HCl and HNO_3 in the ratio 3:1 respectively with 75 ml of HCl and 25 ml of HNO_3 to each residue in each beaker. The beakers were heated on an electric burner for 10 minutes to speed up the reaction. The mixtures were then filtered, and the concentration of gold in each filtrate was determined using the Varian AA240FS Atomic Absorption Spectrometer (AAS) at the Minerals Engineering laboratory of the University of Mines and Technology UMaT, Tarkwa.

2.3 Analysis of Data

Results from AAS was analysed using Equations 1 and 2 respectively to determine the recovery of gold in solution at each time and percentage of aurocyanide adsorbed from solution onto each carbon. The percentage adsorption unto each carbon was compared with the controls at each time interval by subtracting the gold in solution at a specific time from the gold in solution for the control at that same time expressed as a percentage.

$$\%\,Recovery = \frac{Au(t)}{Au(@24)_{control}} * 100 \qquad (1)$$

$$\%Adsorbed = \frac{Au(t)_{control} - Au(t)_{carbon}}{Au(@24)_{control}} * 100 \qquad (2)$$

where;

$Au(t)_{control}$ = Gold in solution at time, t for the control experiment

$Au(t)_{carbon}$ = Gold in solution at time, t for the setup doped with carbon

$Au(@\ 24)_{control}$ = Gold in solution at the 24th hour

for the control experiment

3 Results and Discussions

This paper assessed the variations in the preg-robbing characteristics of the various simulated carbonaceous ores based on their level of maturity. The following sections present and discuss the results obtained after carrying out the experiments.

3.1 Gold in Solution after Cyanidation

Figures 1 to 3 depict the results of the recovery of gold in solution at time intervals for percentages of 0, 1, 2 and 3 of each carbonaceous material after 24 hours of cyanidation. For all three figures, it was observed that the controls had the highest gold in solution since there was no carbonaceous matter present, and cyanidation recovery increased with time. However, setups with carbonaceous materials present had lower gold in solution with time compared with the one without carbonaceous material although it increased with time as well. Woodchips had higher cyanidation recovery after the control followed by charcoal and then activated carbon with values of 57.6–69.8%, 13.7–25.8% and 0.2–4.7% respectively at the end of the 24th hour which correlates negatively with increasing percentage of Carbonaceous matter (CM) present. Thus, the higher the percentage of CM, the lower the gold in solution since the gold was adsorbed unto the carbon. With activated carbon as seen in Figure 3, there was virtually no gold in solution. This is because fine activated carbon has very high adsorption capacity, and hence, picks up aurocyanide complexes as it is leached into solution. This ascertains the fact that the presence of carbonaceous materials has a devastating effect on gold in solution.

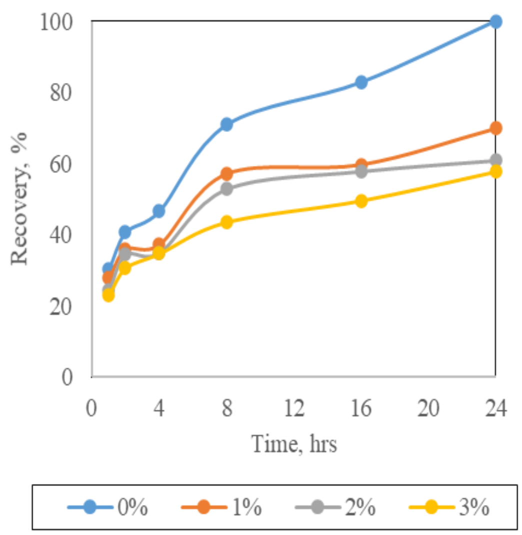

Fig. 1 Cyanidation Recoveries as a Function of Time from Gold Ores Containing Various Percentages of Woodchips

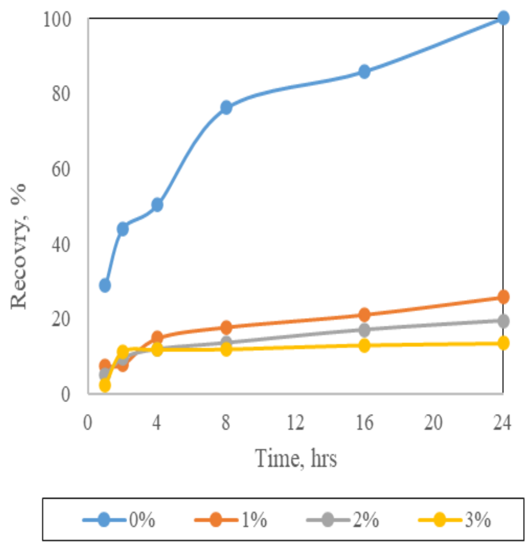

Fig. 2 Cyanidation Recoveries as a Function of Time from Gold Ores Containing Various Percentages of Charcoal

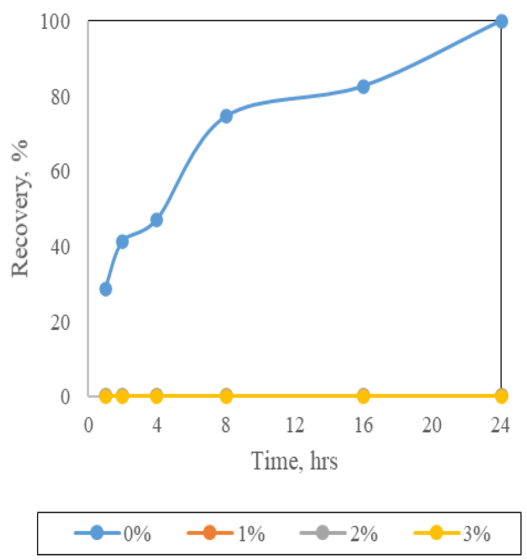

Fig. 3 Cyanidation Recoveries as a Function of Time from Gold Ores Containing Various Percentages of Activated Carbon

3.2 Gold Adsorbed unto Carbonaceous Matter

As stated in the previous section, gold in solution decreases with the presence of carbonaceous material, and hence, it is evident that the dissolved gold was adsorbed by the carbonaceous matter present. The results obtained shows that over the kinetic period, woodchips, charcoal pieces and activated carbon adsorbed about 10–42%, 64–84% and 88–100% respectively. This shows an increased in the preg-robbing activity from woodchips << charcoal pieces << activated carbon. Figure 4 depicts the gold adsorbed unto each of the various carbonaceous material in the respective percentages at the end of the 24th hour cyanidation. The observation made on this figure outlines woodchips with the least gold adsorbed yielding about 42% recovery unto the 3% dose, 38% and 30% unto the 2% and 1% doses respectively. These lower recoveries were recorded because these woodchips have not undergone any form of graphitisation, hence, low maturity. Charcoal had quite a high recovery unto its surface with about 74%, 80% and 86% recovery unto 1%, 2%, and 3% doses respectively at the 24th hour. This is because it has undergone some form of coalification and graphitisation, and hence, considered as having a moderate or medium maturity. Fine activated carbon has undergone carbonisation and activation, and hence, had very high activity and capacity. It therefore adsorbed almost every aurocyanide complex right from start of the leaching process to the 24th hour with percentages of about 95%, 98% and 99.8% in the 1%, 2%, and 3% doses respectively. This observation explains the order of decreasing cyanidation recovery from control>> woodchips>>charcoal>>activated carbon because the extent of preg-robbing was in direct correlation with the level of maturity of the various carbonaceous materials. This same trend was recorded at each time interval when kinetics was monitored. It was also observed that the higher the percentage of carbonaceous matter present, the higher the preg-robbing ability for all the various carbonaceous matter present.

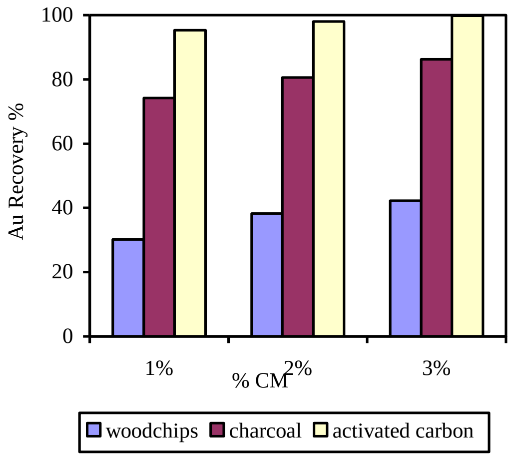

Fig. 4 Preg-robbing of Gold onto Carbonaceous Matter in Cyanidation of Carbonaceous Gold Ores

As per classification of the preg-robbing characteristics reported by Adam *et al.* (2014), the preg-robbing ranges obtained for the various maturity levels of carbonaceous matter over the contact time period can be grouped to be in the ranges as in Table 1.

Table 1 Classification of preg-robbing characteristics of gold ores

Maturity level	% Robbed	Classification
low	10–42	*Mildly preg-robbing*
medium	64–86	*moderately-high preg-robbing*
high	88–100	*highly preg-robbing*

4 Conclusions

This paper reports on the investigations channeled at predicting the extent of preg-robbing based on the maturity of carbonaceous gold ores. The results showed that woodchips which had the lowest maturity gave the lowest degree of preg-robbing, and hence, the highest cyanidation recovery after the control. The preg-robbing ability increased from woodchips (10–42%), charcoal (64–86%) and activated carbon (88–100%) over the kinetics period, which was individually dependent on the amount of carbonaceous material present. This paper therefore concludes that lowly matured carbonaceous gold ores will have high cyanidation recovery compared to the moderately/mediumly matured and then highly matured with the extent of preg-robbing in the reverse order. Preg-robbing effect of low maturity carbonaceous material will be mildly preg-robbing, medium maturity will be moderately-high preg-robbing and high maturity will definitely be very highly preg-robbing. Consequently, it is imperative to characterise carbonaceous gold ores to ascertain the extent of maturity because even low maturity carbonaceous material can adversely affect gold recovery. Pretreatment and other measures must be put in place to prevent these carbonaceous materials from entering the leaching circuit so as to reduce preg-robbing effect and maximise recovery.

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