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DESORPTION OF GOLD AND SILVER FROM ACTIVATED CARBON

DESORPSI EMAS DAN PERAK DARI KARBON AKTIF

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ABSTRACT

Experiments of gold and silver elution were conducted using several parameters, either fixed or varying parameters. Ethanol volume, temperature and percent solid belonged to varying parameters while loaded carbon, stirring rate, concentrations of NaOH and NaCN served as fixed parameters. The experiment results showed that the optimum condition for such a process included 20% of ethanol volume, 80°C of temperature and solid fraction of 25%. Using such condition, the experiment was conducted for 10-hour contact time and yielded the highest desorption percentages for gold and silver, namely 80.10 and 70.73% respectively. The derived contents of gold and silver were 295.16 and 159.38 ppm while their achieved weights were 56.080 and 30.601 µ g. The fact that the achieved contents of gold and silver was close to the requirements for electrowinning process, it is suggested that the next process using a semi-continue one in terms of gaining a result that satisfies the requirement for electrowinning.

Keywords: loaded carbon, electrolyte, electrowinning, cake, bullion, gold and silver

ABSTRAK

Beberapa parameter digunakan untuk uji coba elusi emas dan perak, baik yang bersifat tetap maupun berubah. Parameter berubah yang digunakan meliputi volume etanol, temperature dan persen padatan sedangkan parameter tetap terdiri atas karbon termuat, kecepatan pengadukan, konsentrasi NaOH dan NaCN. Serangkaian uji coba yang dilangsungkan selama 10 jam menghasilkan kondisi optimum sebagai berikut: volume etanol 20%, temperatur percobaan 80°C dan persen padatan 25%. Pada kondisi tersebut, diperoleh kandungan Au dan Ag masing-masing sebesar 295,16 dan 159,38 ppm dengan berat masing-masing 56,080 and 30,601 µ g. Hampir mendekati kandungan emas dan perak terperoleh dengan persyaratan kandungan untuk proses elektrowining, disarankan untuk melakukan uji coba secara semi-kontinu agar hasil yang diperoleh memenuhi persyaratan elektrowining.

Kata kunci: karbon kaya, elektrolit, elektrowining, cake, bullion, emas dan perak

INTRODUCTION

Activated carbon, also called active carbon, activated charcoal or activated coal is a form of carbon that has been processed to make it extremely porous and thus to have a very large surface area available for adsorption and chemical reactions and a network of submicroscopic pores where adsorption takes place. The material used for this purpose comes from various carbonaceous source materials that are converted to activated carbon through physical modification and thermal decomposition in a furnace, under a controlled atmosphere and temperature (Bhattacharyya, 2013).

The use of activated carbon is normally for purifying liquids and gasses, but it is also utilized to recover gold and other precious metals. The materials have been proven to maximize recovery efficiencies by reducing gold loss and minimizing carbon consumption when used for carbon-in-leach (CIL), carbon-in-pulp (CIP) and carbon-in-column (CIC) gold extraction techniques. Highly activated carbon

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is used in the dissolved gold recovery process, either by introducing it directly into the CIL (carbon-in-leach) tanks or into separate CIP (carbon-in-pulp) tanks after leaching. The activated carbon absorbs the dissolved gold from the leach slurry thereby concentrating it onto a smaller mass of solids. The carbon is then separated from the slurry by screening and subjected to further treatment to recover the adsorbed gold (Andrade de Lima, 2007).

Of the various gold ore processing, cyanidation is the most common method used in the leaching of gold from the ore. Such a process involves the dissolution of gold-containing ores in dilute cyanide solution in the presence of lime and oxygen. The common processes for recovery of the gold solution include carbon adsorption, Merrill-Crowe process, electrowinning and ion-exchange/solvent extraction. Activated carbon has been found to be an efficient adsorbent of the gold cyanide complex and a variety of processes based on this reaction have been developed. The effectiveness of the processes is, however, dependent on the development of efficient means for desorbing the gold from the loaded carbon (Elnathan, 2007; Sayiner, 2014).

Desorption is a phenomenon whereby a substance is released from or through a surface. The process is the opposite of sorption, either adsorption or absorption. In gold desorption, gold and silver ions are released from loaded carbons by contacted them with NaOH and NaCN-containing solvent. The CN^- of NaCN presses out the gold and silver ions from the active carbon surfaces (Griffin, 1982; Sayiner, 2014). The ability of CN^- to depress aurocyanide $[Au(CN)_2]^-$ relates to CN^- activity within the solution; the higher CN^- activity rate, the faster the ion leaves the solvent (Lunga, 2006; Radulescu *et al.*, 2014). The mechanism of gold-silver ions release during desorption process includes CN^- leaving from the solution.The CN^- abandons the solution phase and goes to active carbon and depresses the $Au(CN)_2^-$ and $Ag(CN)_2^-$ free from active carbon surface (van Deventer and van der Merwe, 1994).

The organic solvent, either ethanol or acetonitrile, is able to increase CN^- and $Au(CN)_2^-$ activities. As a result, the released $Au(CN)^{2-}$ into solvent turns out to be more effective. Such an organic solvent is a surface activator that can reduce the surface activity of an electrolyte and generates easily wetted-carbon. As a result, the desorption rate develops faster. The organic solvents that are commonly applied include methanol - CH_3OH, ethanol – $(CH_3)_2O$, acetone - $(CH_3)_2CO$ and acetonitrile - CH_3CN would affect on the enhancement of gold desorption from the loaded carbon and its desorption rate. The increase of organic solvent around 20% into desorption solvent containing 10% NaCN and 1% NaOH results in faster desorption around 82 – 95% compared to the process without adding the organic solvent (Heinen, Peterson and Lindstrom, 1980; Espiell *et al.*, 1988). Based on that phenomenon, therefore, the present work applies the gold desorption using such condition as follows:

- ethanol concentration 10 -20%;
- temperature 30 – 85°C;
- %solid 25 – 35%;

The three mentioned condition belongs to changing parameters while the fixed ones include loaded carbon (100 g), stirring rate (150 rpm), NaOH 1% and NaCN 0.2%

METHODOLOGY

Cyanidation process produces dissolved gold and silver. To get a loaded carbon or gold-bearing carbon in a carbon-in-leach (CIL) process, the active carbon is included in a slurry and serves as the adsorbent for gold and silver. Later, the loaded carbon will release the metals, both gold and silver, through desorption process. Gold-silver in rich solution is then extracted through electrowinning process to yield a cake. Such a cake is then smelted to get Au/Ag bullion. Figure 1 showed the instruments used in desorption experiments.

The mechanism of gold-silver ions release during desorption process is shown in Figure 2. CN^- leaves the solution phase and attaches into active carbon to depress the $Au(CN)^{2-}$ and $Ag(CN)^{2-}$ free from active carbon surfaces (van Deventer and van der Merwe, 1994). Experiments for gold-silver desorption process from activated carbon employed several parameters either fixed or changeable. Loaded carbon, stirring rate, the concentration of NaOH and NaCN belonged to fixed parameters while ethanol volume, % solid and temperature served as the changeable ones.

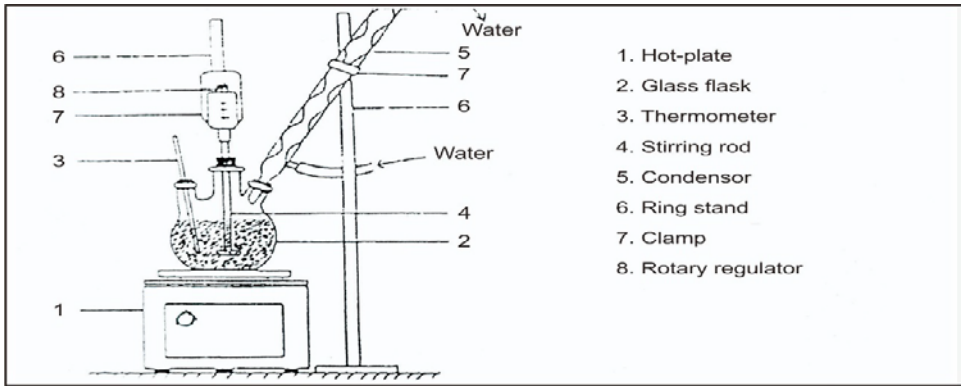


Figure 1. Instrument for gold-silver desorption experiments

The procedures for the experiments was conducted by weighing 100 g loaded carbon and preparing desorption solution with a composition of NaCN = 0.1%, NaOH = 1% and ethanol (20%). The next step was transferring the loaded carbon and desorption solution into a glass flask related to determined % solid and then heating the flask above determined temperature, namely 30, 60, 80°C. The optimum was 80°C. Stirring was conducted during heating at constant temperature (80°C) and determined time. It was stopped when the determined time (10 hours) had been accomplished. Product material was then filtered to get the filtrates. Gold and silver were then determined by analyzing around 5 to 10 ml filtrates.

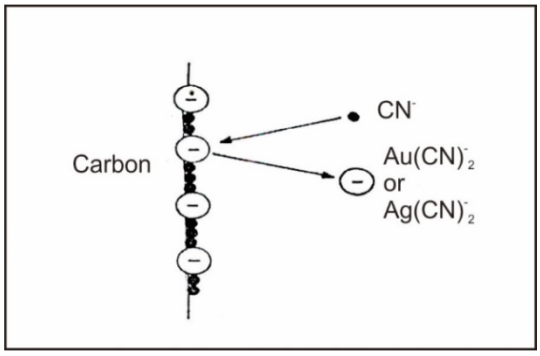


Figure 2. Desorption mechanism for gold and silver ions

RESULTS AND DISCUSSION

Desorption procedure used a different particle size of activated carbons with gold cyanide for subsequent elution experiments as set-up in Figure 1. Coarse granular activated carbons were usually washed several times with water and dried overnight at 110°C in an oven. Dried coarse activated carbons were then crushed using a mortar and pestle and then wet-screened to different particle size fractions as shown in Table 1. After the wet screening, the different size fractions were again dried overnight at 110°C in an oven.

Table 1. Activated carbon particle size fractions for gold elution

Particle size fractions (mesh)	Weight (%)
+10	2,60
-10+14	22,26
-14+16	25.40
-16+28	30,05
-28+35	18,60
-35	1,09
Total	100,00

Desorption experiments were conducted in batches and designed into three trials that based on changeable parameters, namely ethanol volume (10, 15, 20%), temperature and % solid (20, 30, 35%). The experiments employed results of cyanidation test from CIL process. Such a CIL process was conducted for 32 hours that related to its optimum condition while the feed for CIL came from Knelson concentrates that retained Au and Ag contents of 700,100 g/t, Ag = 432,60 g/t respectively.Other parameters served as the fixed ones. Those were loaded carbon, the concentration of NaOH and NaCN as well as stirring rate. Depended on the applied changeable parameters, sometimes the ethanol volume, temperature and % solid also performed as the fixed constraints. Table 2 shows the experiment condition for gold-silver desorption study.

Results of the experiments for gold desorption using ethanol volume as varying parameters are illustrated in Figure 3. It can be seen that the desorbed gold increased from 26.83 to 78.80% when the ethanol volume changed from 10 to 20% so did the desorbed silver. In general, results of such tests have shown a concentration of about 20 to 30 percent by volume of the alcohol and 10-hour contact time to be the optimum condition for ethanol volume with insignificant desorption increase at higher alcohol concentrations. Information regarding Au and Ag grades of loaded carbon was as follows: Au = 288.44 ppm and Ag = 154.18 ppm performing gold and silver weights of 54.804 and 29.294 µ g respectively. The three figures show that the longer the experiment time the more increase the results for either contents, weights and desorption of gold and silver. Increasing % ethanol from 10 to 20% results in increasing the contents, weights and desorption of gold and silver (Kohl, 2010; Bhattacharyya, 2013).

Table 2. Experiment condition for gold desorption.

Experiments		Variable	
1	Changes	Ethanol volume (%)	10, 15, 20
	Fixed	Loaded carbon (g)	100
		Temperature (°C)	80
		% solid	35
		Stirring rate (rpm)	150
		[NaOH]	1%
		[NaCN]	0,2%
2	Changes	Temperature (°C)	30, 60, 85
	Fixed	Loaded carbon (g)	100
		Ethanol volume (%)	20
		% solid	35
		Stirring rate (rpm)	150
		[NaOH]	1%
		[NaCN]	0,2%
3	Changes	% solid	25, 30, 35
	Fixed	Loaded carbon (g)	100
		Ethanol volume (%)	20
		Temperature (°C)	30
		Stirring rate (rpm)	150
		[NaOH]	1%
		[NaCN]	0,2%

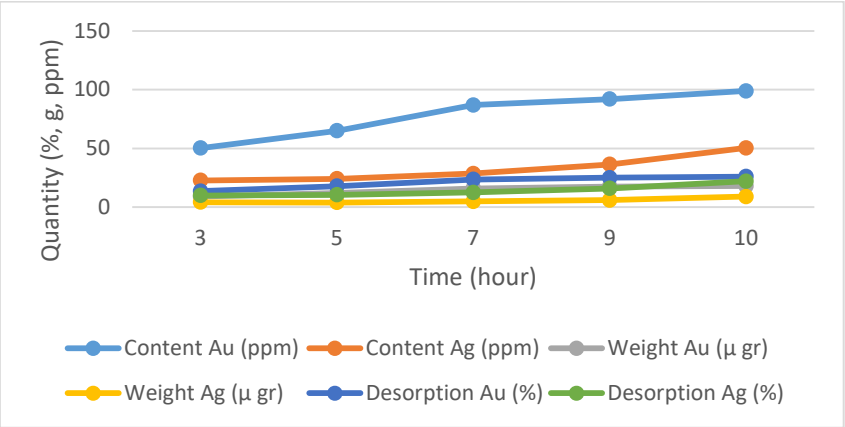
Nakahiro *et al.* (1992) studied the effect of the alcohol use on gold elution suggested that ethanol and propylene glycol with NaOH or Na_2S were effective for eluting the gold from activated carbon loaded gold. Especially, Au was completely eluted by ethanol with NaOH under an optimum condition, i.e., 50 vol% of ethanol, 0.4N of NaOH, 75°C and 2hr. So far, the experiments did not analyze the eluted gold within each fraction, however, Bhattacharyya (2013) who conducted a research dealt with aurodicyanide desorption from activated carbon analyzed the gold content within each fraction of activated carbon and found that coarser activated carbon provided more eluted gold compared to the finer one. Ethanol served as a surface activator that decreased the surface tension of the electrolyte to the active carbon. The decrease of surface tension resulted in facilitating the active carbon to be wetted by desorption solvent. As a result, the contact between the solution and carbon active was getting better and the achieved desorption rate became larger.

The experiment results showed that the highest desorption for gold and silver was 80.10 and 70.73% respectively. The optimum condition of the experiments was as follows: 20% ethanol volume, 80°C temperature and 10-hour contact time.

The effect of particle size on gold adsorption and elution from activated carbon in alkaline solution has also been studied by Elnathan (2007) in order to understand the nature of gold losses on fine activated carbons, to improve the rate of gold recovery and to develop an innovative way of treating preg-robbing gold ores. He found that granular activated carbon (GAC) continued to be the favored route for gold recovery in cyanidation plants, yet gold losses on fine activated carbons and the attendant high carbon inventories were substantial and continued to be a problem. Referring to such the fact, the elution process mostly uses coarse carbon active materials, from 850 to 425 microns.

Results of experiments using temperature as a varying parameter are shown in Figure 4. The maximum desorption percentages for gold and silver are 80.10 and 70.73% respectively. The optimum conditions to reach such figures include 9 to 10 hours of contact time, 80°C of temperature, 25% of percent solid and 20% of ethanol concentration. The average desorption percentage for silver is higher than that of the gold at changeable temperatures (30 – 50°C) except at 3-hour contact time. A contact time between 3 – 5 hours and experiment temperature of 80°C also provide high silver desorption percentage. However, when the contact time was increased to 7 – 10 hours, the silver desorption percentage was smaller than that of the gold one. This implied that the

increase of temperature and contact time affected highly gold and silver desorption (Espiell *et al.*, 1988).



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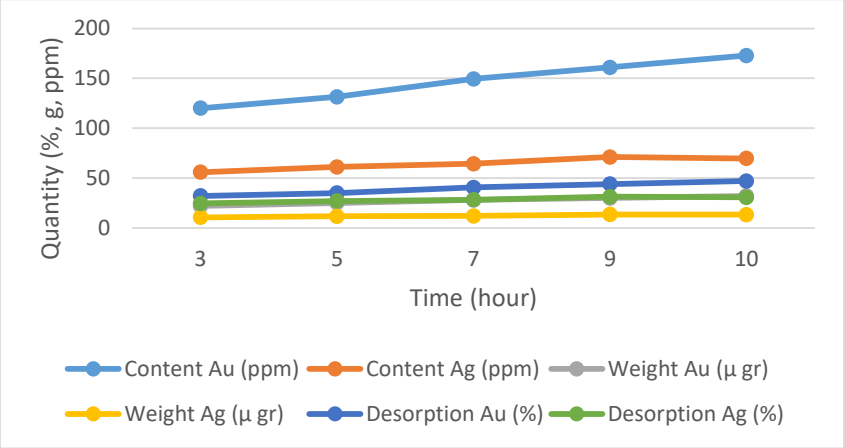

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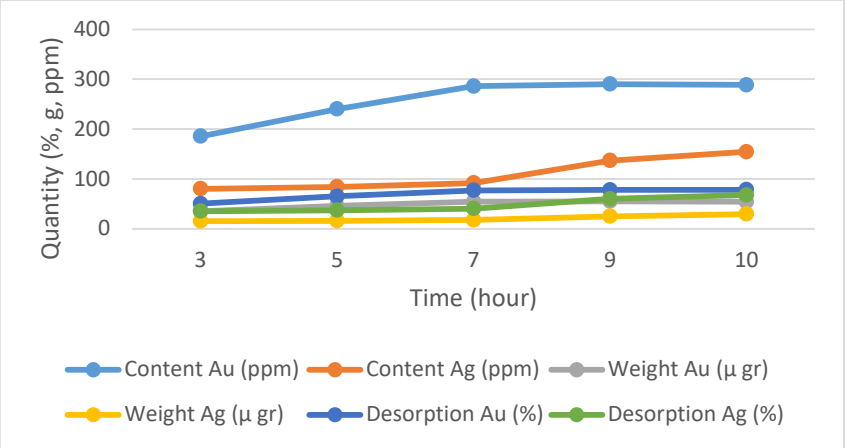

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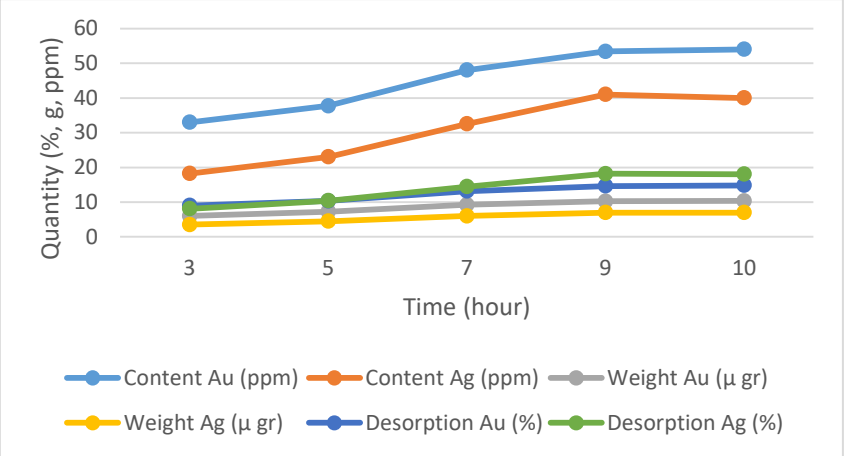
Figure 3. Results of gold-silver desorption using ethanol as a varying parameter; ethanol 10% (a), ethanol 15% (b), ethanol 20% (c)



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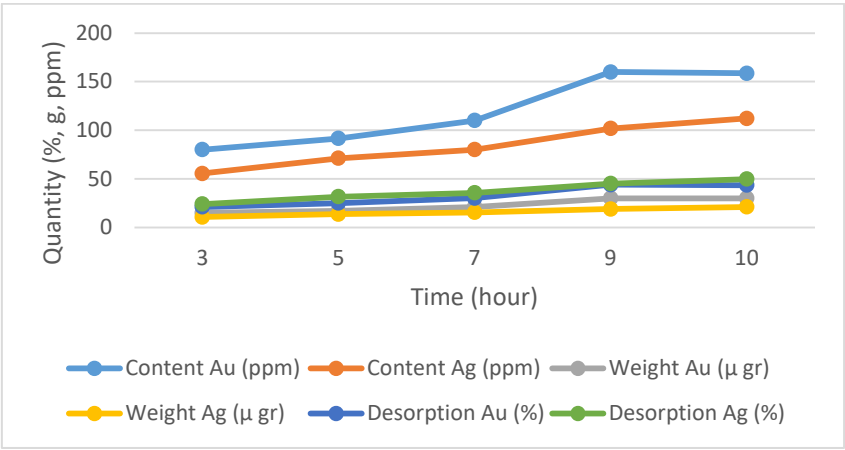

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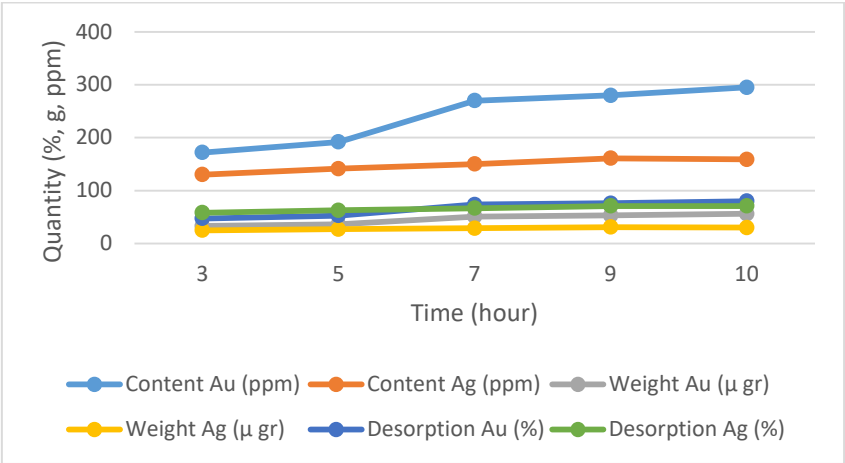

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Figure 4. Results of gold-silver desorption using temperature as a varying parameter; temperature: 30°C (a), temperature: 50°C (b), temperature: 80°C (c)

The elution temperature has been suggested to be the most important factor that influences Au elution recovery (Oladele, 2015). Of other elution factors, such as the concentration of NaOH-NaCN, ionic strength and organic solvent elution, temperature significantly affects the elution rates.The increase of elution temperature results in changing the equilibrium that favors desorption due to the adsorption belongs to an exothermic process. Referring to the experiments that use temperature as a varying parameter, the desorbed gold and silver increase along with the length of contact time and temperature increase. Absorbing power of activated carbon to adsorb gold reduces with an increase in temperature which determines the rate of elution. van Deventer and van der Merwe (1994) described that significant elution recovery was obtained at pre-treatment temperature of 100°C than at 25°C.

Figure 5 shows the experiment results using a solid fraction as a varying parameter. Started with percent solids of 25% and continued to 35% and 10-hour contact time, the percentage of desorbed Au decreased from 78.54 to 67.63% while the silver decline from 18.05 to 70.73%. It appeared that the bigger the solid fraction, the lesser the desorbed gold and silver. In this case, it seemed that solid fraction of 25% was the best condition for gold and silver desorption. Effect of percent solids in the extraction of gold and silver had been studied by Parga, Valenzuela and Díaz (2012). His research reveals that the bigger the % solid the smaller the gold and silver extractions. Parga, Valenzuela and Díaz (2012) assumed that the increased apparent viscosity of the slurry impeded good oxygen dispersion in the system. Three experiments regarding gold desorption using % solid as a varying parameter confirms Parga et al.'s statements. The achieved gold and silver contents, as well as their weights and desorption, becomes smaller when the % solid gets higher.

CONCLUSIONS AND SUGGESTIONS

Increasing solid fractions seems a bad idea as the desorption results go down, namely from 78.54 to 67.63% for gold and from 78.54 to 67.63% for silver when the % solid is increased from 25 to 35%, while the increase of ethanol volume as a varying parameter results in improving the percentage of gold and silver desorption so does the temperature. The final achievement of desorbed gold and silver using ethanol volume as a varying parameter is 78.28 for gold and 67.72% for silver while using temperature as a varying parameter yields desorbed gold and silver of 80.10 and 70.73% respectively.

Referring to the three experiments that performed ethanol volume, % solids and temperature as varying parameters; it can be concluded that optimum condition for desorption process included 20% of ethanol volume, 80°C of temperature and solid fraction of 25%.To get the maximum results, the experiment were 80.10 and 70.73% respectively. Gold and silver contents at such condition comprised 295. 16 and 159.38 ppm while their achieved weights were 56.080 and 30.601 µ g.

Gold losses will occur when the size of activated carbon is relatively fine. Referring to such a case, a granular activated carbon (GAC) is favorable for gold elution. The use of GAC size for gold elution ranges from 850 to 425 microns.

The requirement for conducting electrowinning is above 95% gold desorption. Referring to the fact that the highest yielded gold desorption from the experiments is 80.10, it is suggested to accomplish a series experiments in a semi-continue method.

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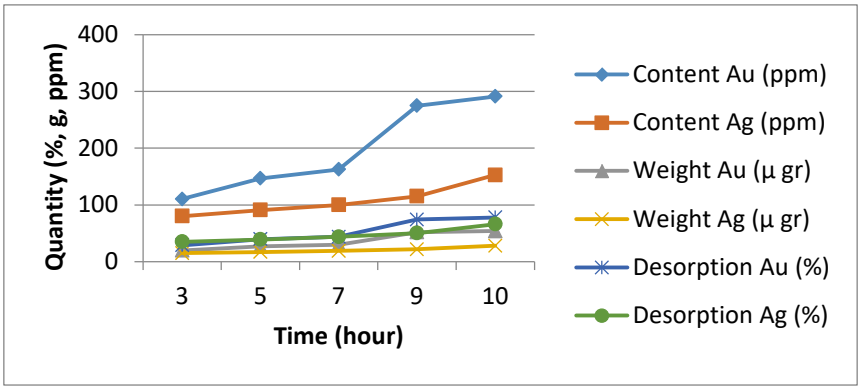

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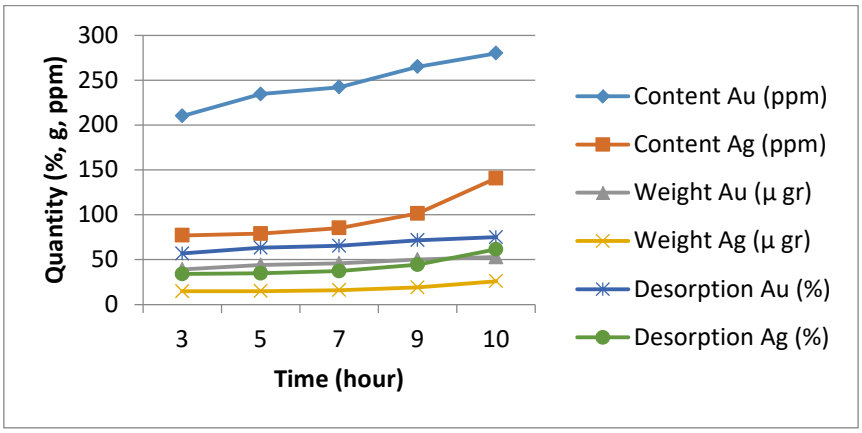

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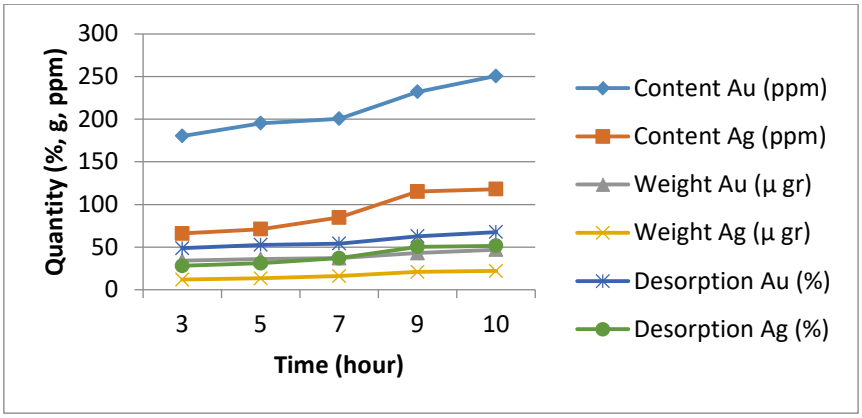

(c)

Figure 5. Results of gold-silver desorption using % solid as a varying parameter; % solid: 25 (a), % solid: 30 (b), % solid: 35 (c).

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