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GOLD RECOVERY FROM WASTE FINE CARBON USING ACETONE AS SOLVENT (AMESMESSA GOLD MINE, ALGERIA)

Purpose. The aim of this work at the first stage is to develop a new method to recover gold from waste fine loaded activated carbon. At the second stage, a new method is to be developed using less energy and less hazardous chemicals to recover gold from fine and coarse activated carbon in all the process of gold ore treatment.

Methodology. The desorption of gold cyanide from the waste fine loaded activated carbon was processed by agitating the carbon on alkaline aqueous solution containing 20 % (v/v) of acetone (pH between 10 and 13) at room temperature.

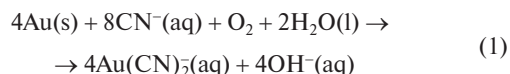
Findings. The application of the proposed method gave satisfactory results in terms of process efficiency, the time of operation and no use of hazardous chemicals such as cyanide. The efficiency is more than 96 %, the resident time – less than 3 h. As for the hazardous chemicals, there is no use of cyanide unlike in the conventional process.

Originality. The use of acetone as an organic solvent makes the gold cyanide desorption from activated carbon operated at room temperature and in short time better than any other conventional process.

Practical value. This method allows to recover easily and economically the gold entrapped into waste activated carbon existing in a mining plant at room temperature in an agitating tank, pH = 10–13 with an efficiency over 96 %. This method can be a good alternative for all gold recovery processes from activated carbon used nowadays.

Keywords: *gold stripping, activated carbon, gold sorption and desorption, gold mining, organic gold elution*

Introduction. The most widely used process, nowadays, to extract gold from ores is leaching by cyanide. This method includes two stages: extraction and recovery. At the first stage, the gold contained in ore dissolves in cyanide aqueous solution by complexation forming a pregnant solution from which gold will later be extracted. As demonstrated below by the equation of the gold dissolution [1–4].



At the second stage, the complex ions Au(CN)_2^- in solution adsorbed into activated carbon then desorbed in solution and the Gold Au was recovered by electrolysis. Adsorption via activated carbon is the main industrial procedure for Au(CN)_2^- recovery because of the high efficiency, abundant resources, and economic advantages [1, 5, 6].



The desorption or elution of gold is one of the principal unit processes in the CIP plant for the recovery of gold. Commercially, there are four main types of elution of gold from activated carbon: the Zadra procedure, the Anglo-American research laboratory (AARL) procedure, organic elution, and micron elution [7, 8].

In the Zadra elution process, a hot solution of 1 % weight/volume (w/v) sodium hydroxide and 0.2 % (w/v) sodium cyanide are recycled through a gold cyanide-loaded activated carbon bed for up to 72 h at 95–100 °C and atmospheric pressure to desorb Au(CN)_2^- . More recently a modified Zadra procedure operating at 140 °C in a pressured system has reduced the elution time to 10–12 h [7, 8].

In the AARL process, there are three main steps: a hot acid wash followed by a hot solution of caustic and cyanide (100–120 °C) pretreatment step of 30 min and afterward elution with hot de-ionized water (100–120 °C) at high pressure (200–

300 Kpa) [7–9]. In organic elution or alcohol stripping, a solution of 1 % NaOH and 0.1 NaCN mixed with aqueous organic solvent such as ethanol or methanol is used [6].

In the micron elution, loaded carbon is soaked in a caustic cyanide solution followed by eluting gold with acetonitrile, ethanol, or methanol vapor at 65–80 °C. Elution is completed in 4–6 h [8]. Some research publications have been directed toward the development of gold elution procedures that employ organic solvent such as acetone. The aqueous acetone elution in the presence of cyanide and at room temperature was described by (Muir and all), first time in 1985. The efficiency was 70 % after 24 h. After that, in 1988, Espiell and Roca studied the desorption of gold cyanide adsorbed into activated carbon using a mixture of dilute NaOH and different organic solvents; the desorption was performed in stirring flask, the highest gold desorption rate was obtained with water/acetone/OH- [6, 7]. In 1992, Vegter and Sandenbergh used an aqueous caustic acetone solution in the absence of cyanide; high rate of elution was obtained within two hours at 50 °C [6, 10]. Later in 2008, Soleimani and Kaghazchi [7] used a different solvent such as acetone and acetonitrile to desorb gold from granular activated carbon. The rate of desorption is higher than 80 % in less than 2 h, using 40 % of organic solvent, at ambient temperature, and in the presence of cyanide.

Waste loaded fine AC typically < 20 mesh (841 μm), can be lost in filtration steps and up in the process tailing. A survey of 36 mines found that 0.11 to 0.14 kg of Au per ton of AC remains uncovered, with up to 0.525 kg Au per ton AC in other individual cases [11].

Incineration is the process used, nowadays, to recover the remaining gold in waste fine AC. It is used to reduce the volume of the waste carbon as ash contains a nanoparticle of an electrum of gold and silver. The resultant metals can be recovered by many processes: smelting and gravity concentration on chemical leaching. The incineration and smelting need high energy, the gravity concentration process is very low [12]. For that reason, we need to investigate a new method to recover those precious metals from waste fine-loaded activated carbon.

Table 1

X-ray analysis of waste fine loaded carbon

Phase name	Content, %
Quartz	47(7)
Calcite	35(3)
Carbon (II) oxide	0.1(3)
Gold	0.50(3)
Silver	0.73(4)
Fe ₃ O ₄	1.28(12)
Hematite	3.19(18)
FeO (OH)	4.2(2)
Wuestite	3.8(2)
Litharge	0.17(6)
Tenorite	3.36(19)

Table 2

Screen analysis of waste fine carbon

Screen opening, μm	Average particle size	Weight fraction retained, %	Rate	Cumulative retained, %	Cumulative sieved, %
	Di, μm		%		
>1000	1,000	29.45	11.83	11.83	88.17
]710, 1000[	855	58.8	23.63	35.46	64.54
]425, 710[	567	32.67	13.13	48.59	51.41
]250, 425[	337	26.14	10.50	59.10	40.90
]106, 250[	178	35.9	14.43	73.52	26.48
]75, 106[	90.5	23.59	9.48	83.00	17.00
]45, 75[	60	27.59	11.09	94.09	5.91
<45	45	14.711	5.91	100.00	0.00
		248.851	100.00	100.00	0

This paper presents the results obtained in gold desorption using a mixture of acetone and caustic soda in the absence of cyanide at room temperature and atmospheric pressure. Different parameters were investigated such as acetone concentration, temperature, particle size of carbon, initial gold concentration in carbon and solution, carbon concentration, pH, and agitation speed.

Materials and methods. Site description and waste sample characterization. The samples of fine waste-loaded carbon; the subject of our study have been taken from the waste dump of the gold process plant in Amesmesa gold mine.

The Amesmesa gold mine is situated in the south of Algeria, 2,460 km south of the capital Algiers, and about 460 km in the south west of the city of Tamanrasset.

Many samples were analyzed by the Atomic Absorption Spectrometry (AAS) to determine the grade of gold. The mean value of gold in the waste carbon is 696 mg Au/kg (carbon).

X-ray analysis presented in Fig. 1 shows that, in addition to gold and silver, many other elements were adsorbed, during the process of gold ore treatment, by the waste fine and still entrapped into it. Such as silica, calcite, litharge, hematite ..., etc. Those elements are presented in Table 1. They are not subjects in this study. The desorption data presented later showed that the elements have no major effect on gold cyanide desorption.

Screen analysis of waste fine carbon presented in Table 2 shows that 88 % of particles are less than 1mm in size.

Reagents and materials. In the experiments, industrial pure activated carbon, Norit GCN612G, supplied by Cabot Corporation, was washed with distilled water to remove fines. After that, the carbon was oven-dried and sieved to different sizes. Before any test work the carbon was dried at 150 °C for two hours to remove any water adsorbed. Metallic gold with a purity of 99.99 % was donated by Amesmesa laboratory to prepare a solution of NaAu(CN)₂ at a concentration of 1000 ppm. This solution was used to load the carbon.

The analytical reagents used in the preparation of NaAu(CN)₂ from metallic Au are HCl (34 %), NaCN (98 %), HNO₃ (67 %) and NaOH (98 %).

The batch desorption experiments were performed in a magnetic stirrer, type Henna HI310, at a speed of 300 rpm, 1,000 ml beaker was used. A pH meter, type Thermo-electron corporation, was used for the measurement of pH and temperature. All tests were conducted at room temperature.

Agilent AA spectrometer is used for the determination of gold concentration in solution and carbon.

Preparation of Au(CN)₂ solution. The preparation of stock solution 1000 ppm of Au(CN)₂ was performed according to the Rajasingam method [10]. A solution of 1,000 ppm of Au(CN)₂ was prepared by dissolving 1 g of metallic gold (99.99 %) in 1,000 ml deionized water containing excess concentration of cyanide. The pH was adjusted by caustic soda at 12. The solution was aerated and stirred at ambient temperature until all the gold had dissolved, which took usually 48 h.

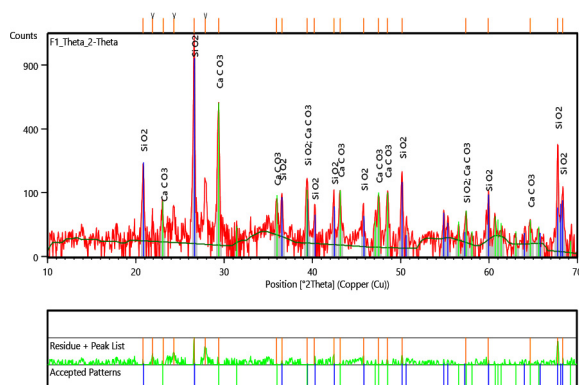


Fig. 1. X ray plot of waste fine loaded carbon

Finally, the concentration of this solution was checked by AAS (NovAA 800).

Loading of NaAu(CN)₂ into activated carbon. The 1 kg of virgin carbon was attritionated for 24 h and wet screened at plus 2 mm. This amount of carbon will be used as stock to prepare many samples of loaded carbon with different gold concentrations.

Five samples of 50 g each one from the stock carbon were exposed to different concentrations of gold solution Au(CN)₂ to get five samples of loaded carbon (0.5, 1, 2, 5 and 10 mg/kg; mg Au/kg carbon). The solution and carbon were kept in agitation for 12 h. After that, each sample of carbon will be screened and dried in an oven at 150 °C for 2 h.

Desorption experiments. Desorption of dicyanide of Gold from activated carbon was examined first by sorbing it into activated carbon at pH = 12 and then desorbing it in an aqueous solution containing acetone as follows:

Batch desorption experiments were carried out in a 1,000 ml beaker equipped with a stirring device when 500 ml of eluant solution (distilled water + acetone + NaOH) and 2.5 g of loaded carbon were put in contact for a minimum of 6 h. Different carbon concentrations (from 2 to 20 g/l), different loaded carbon initial concentrations (Au₀ from 0.5 to 10 mg/kg), different acetone concentrations (from 10 to 40 %), pH (from 10 to 13), and different sizes of carbon were used to investigate the influence of each parameter. All tests were conducted at room temperature and atmospheric pressure.

Results and discussion. Materiel and characterization. The BET surface area of used activated carbon is 985.32 m²/g and the BJH average desorption pore width is 3.8 nm. These two parameters were determined by nitrogen adsorption-desorption isotherm at 77 K using the BET equation and the density functional theory. The pH is 9.30 and the pzc is 8.09 as shown below in Table 3.

Gold sorption and desorption kinetics. The kinetics of the sorption and desorption were analyzed using the two kinetic models: pseudo-first order and pseudo-second order. The mathematic expressions are:

1. Sorption kinetics. Pseudo-first-order: The adsorption kinetic was studied with the empirical rate equation of Lagergren [13–16]. Its differential form is

$$\frac{dq_{ta}}{dt} = k_{1a}(q_{ea} - q_{ta}). \quad (3)$$

When solving equation (3) with boundary conditions ($t = 0$ to $t = t$ and $q_t = 0$ to $q_t = q_t$) we get the linear equation (4)

$$\ln(q_{ea} - q_{ta}) = \ln q_{ea} - k_{1a}t. \quad (4)$$

The value of q_e and k_1 are determined by applying this common accepted linear equation.

Pseudo-second order. The most commonly used equation of pseudo second order presented by Ho and al is used here [15, 18].

The equation has the following form

$$\frac{dq_{ta}}{dt} = k_{2a}(q_{ea} - q_{ta})^2, \quad (5)$$

integrating this for the boundary conditions $t = 0$ to $t = t$ and $q_t = 0$ to $q_t = q_t$, gives this linear form

$$\frac{t}{q_{ta}} = \frac{1}{k_{2a}q_{ea}^2} + \frac{t}{q_{ea}}, \quad (6)$$

when $q_{ta} = \frac{(C_{0a} - C_{ta}) \cdot V}{m}$.

2. Desorption kinetics. Based on the above representations the desorption equations will be as below [19]:

- pseudo-first order

$$\ln(q_{td} - q_{ed}) = \ln(q_{0d} - q_{ed}) - k_{1d}t; \quad (7)$$

- pseudo-second order

$$\frac{1}{q_{td} - q_{ed}} = \frac{1}{q_{0d} - q_{ed}} + k_{2d}t, \quad (8)$$

when $q_{td} = q_{0d} - \frac{C_{td} \cdot V}{m}$.

q_t is the loading at time t ; q_e is the equilibrate loading for sorbate or sorbing; q_0 is the initial loading at $t = 0$.

Table 3

Virgin activated carbon properties	
Used activated carbon properties	
Analysis/Properties	Value
pH	9.30
pH _{pzc}	8.09
BET surface area, m ² /g	985.32
Micropore area, m ² /g	688.26
External surface area, m ² /g	297.06
Micro-pore volume, m ³ /g	0.343887
Median pore volume, nm	0.4721
BJH adsorption average pore width, nm	4.4826
BJH desorption average pore width, nm	3.8034

k_1 is the rate constant for the first-order model; k_2 is the rate constant for second-order model; t is time; C_0 is the initial Au concentration of solution; C_t is the Au solution concentration at time t ; V is the volume of solution; m is the carbon mass.

The results in Figs. 2 and 3 show that the equilibrium time using 20 % of acetone in the stripping solution for fine carbon < 100 μm is less than 5 min. for the coarse carbon, the equilibrium is less than 1 hour when $T > 32$ °C and less than 2 h when $T < 32$ °C.

The results of calculated kinetic parameters in Tables 4 and 5 show that the data fit better with the pseudo-second-order model for both process adsorption and desorption. Chen Yulong and Vences-Alvarez [4,16] found that for the adsorption fit well with the pseudo-second-order model.

Equilibrium Isotherms models. The adsorption-desorption of gold cyanide on carbon has been studied by Langmuir and Freundlich isotherm, when the Freundlich equation (9) and Langmuir equation shown in equations (9 and 10) were used. The Langmuir isotherm fits better than the Freundlich isotherm. The linear equations are as below:

1. Freundlich

$$\ln(q_e) = \ln(k_f) + \frac{1}{n} \ln(C_e). \quad (9)$$

2. Langmuir

$$\frac{C_e}{q_e} = \frac{1}{q_m k_l} + \frac{C_e}{q_m}, \quad (10)$$

where q_m (mg/g) is the theoretical monolayer saturation capacity or maximum adsorption, and k_l (l/mg) is the Langmuir

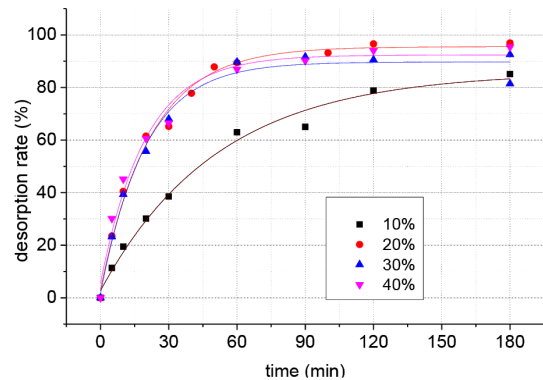


Fig. 2. Effect of acetone/water rate, Coarse carbon:

$T = 32-35$ °C; Agitation 300 tr/min; $C = 5$ g/l; pH = 13; $Q_0Au = 5$ mg/g; Carbon size]2;4[mm

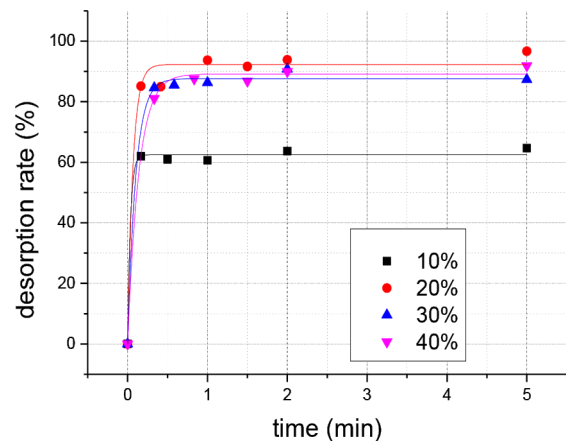


Fig. 3. Effect of acetone/water rate, Fine carbon:

$T = 30-35$ °C; Agitation 300 tr/min; $Q_0Au = 10$ mg/g; pH = 13; C Carbon = 5 g/l, Carbon size < 100 μm

Table 4

Adsorption data of kinetic parameters
(Particle size]2; 4[mm, $T = 27\text{ }^\circ\text{C}$, $\text{pH} = 10$; $C_c = 1\text{ g/l}$)

First-order kinetic model					
$C_0\text{Au}$, mgAu/l	10	20	50	75	100
$k_1 \cdot 10^{-3}$, min^{-1}	6.91	4.61	2.30	2.30	2.30
Q_e , mgAu/g C	1.69	2.14	3.11	3.37	3.74
Q_e exp, mg/g	4.94	9.58	22.78	28.77	36.84
R^2	0.98	0.99	0.98	0.97	0.96
Second-order kinetic model					
$C_0\text{Au}$, mgAu/l	10	20	50	75	100
$k_2 \cdot 10^{-3}$, $\text{mg} \cdot \text{g}^{-1} \cdot \text{min}^{-1}$	4.40	1.78	0.60	0.51	0.51
Q_e , mgAu/g C	5.13	10.00	24.39	30.30	37.04
Q_e exp, mg/g	4.94	9.58	22.78	28.77	36.84
R^2	0.99	0.99	0.99	0.99	0.99

Table 5

Desorption Data of kinetic parameters
(Particle size]2; 4[mm, $T = 31\text{ }^\circ\text{C}$, $\text{pH} = 13$; $C_c = 5\text{ g/l}$)

Pseudo first order			
Q_0 , mg/g	0.5	1	5
k_f , min^{-1}	0.011	0.010	0.018
Q_e , mg/g	-0.07	0.30	3.32
Q_e exp, mg/g	0.22	0.36	0.75
R^2	0.98	0.99	0.95
Pseudo second order			
Q_0 , mg/g	0.5	1	5
k_{2d} , $\text{mg} \cdot \text{g}^{-1} \cdot \text{min}^{-1}$	0.09	0.06	0.02
Q_e , mgAu/g C	0.20	0.27	0.76
Q_e exp, mg/g	0.22	0.36	0.75
R^2	0.96	0.99	0.99

constant related to the energy sorption. The k_f (1/mg) and $1/n$ are the Freundlich constants related to the sorption capacity and sorption intensity respectively. The parameter values of adsorption isotherm and desorption isotherm are shown in Tables 6 and 7 below.

Factors affecting desorption. Effect of organic solvent/water ration. Results with varying acetone concentrations are shown in Figs. 1 and 3. These two figures show that more than 93 % of gold is recovered from loaded carbon using only 20 % of acetone in solution at room temperature between 30 and 35 $^\circ\text{C}$, $\text{pH} = 13$. The equilibrium time is less than 1 min for fine carbon (size under 100 μm), and less than 1 hour for coarse carbon (size =] 100, 2000[μm). So, 20 % of acetone is much enough to desorb the gold. Soleimani and Kaghazchi [7] found that using 40 % (v/v) of acetone to water solution gives between 51 and 90 % of gold recovery in three loading/stripping cycles.

Effect of pH of solution. The process was performed at room temperature, standard pressure, coarse carbon was used and the size of particles was between]2, 4[mm (6 · 12 mesh). The pH was adjusted by adding NaOH to get a pH value between 10 and 13.5.

The results in Fig. 4 show that the desorption rate rises when the pH is up. With $\text{pH} = 13$ we got a percentage over 85 %. Under $\text{pH} = 10$ we got 65 %. So, NaOH is required for gold desorption. The chemical reactivity of activated carbon is relatively related to its functional groups when the excessive oxygenating groups like carboxyl might reduce the adsorption

Table 6

Adsorption isotherm parameters

T , $^\circ\text{C}$	24.2	25.8	31.6	35.1
Freundlich				
n	3.57	3.89	2.68	3.50
K_f , l/mg	17.52	18.78	9.87	14.69
R^2	0.9087	0.9113	0.9570	0.9772
Langmuir				
Q_m , mg/g	60.24	58.14	59.17	57.80
K_L , l/mg	0.14	0.17	0.06	0.09
R^2	0.9957	0.9943	0.99	0.9938

Table 7

Desorption isotherm parameters

T , $^\circ\text{C}$	35	31	25
Freundlich			
n	1.33	1.86	2.29
K_f , l/mg	0.06	0.09	0.14
R^2	0.96	0.96	0.96
Langmuir			
Q_m , mg/g	1.07	1.15	0.96
K_L , l/mg	0.04	0.04	0.08
R^2	0.97	0.95	0.97

of aurocyanide and in consequence favored desorption [1]. This result is in accordance with the study of Ubaldini [6], when he confirmed that the absence of NaOH in the solution reduces the rate by 30 %.

Effect of particle size of carbon. The experiment was performed with different carbon particle sizes Intervals [0.100[μm ,] 100,425[μm ,] 425 μm , 1 mm [,] 1, 2[mm]. The results in Fig. 4 show that the desorption rate increases inversely with the size of particles. The best rate is reached with carbon particle size under 100 μm in a very short time, less than 5 min. It is expected that the size of particles will have a high effect because the contact between the eluant solution and the carbon particle increases when the particle size decreases. Ubaldini confirms in his study of the AARL elution process [6] that the desorption rate for powder carbon is much higher than for coarse one.

Effect of carbon concentration in solution. This experiment was carried out with different concentrations of carbon in so-

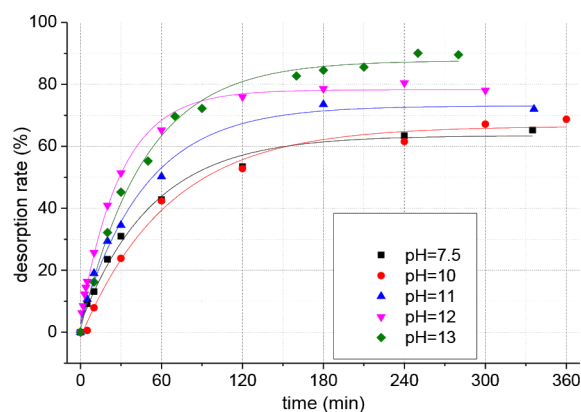


Fig. 4. pH effect:

$T = 26.5\text{--}35\text{ }^\circ\text{C}$; Agitation 300 tr/m; $Q_0\text{AU} = 1\text{ mg/g}$; Acetone 20 %; CC5 g/l

lutions. Four values of concentration were used: 3, 5, 10 and 15 g (g of carbon/l solution). The results in Fig. 6 show that the rate of desorption increases when the concentration decreases. The best rate is with a concentration of 3 g/l. However, it looks like the effect is not significant except for the concentration of 15 g/l. It is obvious that over this concentration the desorption rate will decrease.

Effect of temperature. The effect of temperature was tested in three temperature values: 26, 31 and 34 °C. The results in Fig. 7 show the efficiency of the operation increases when temperature increases. Above 34 °C the percentage of desorption goes up more than 90 %. Espiell, Van Deventer and Snyders [9], all found that the temperature is a significant factor that affects the gold desorption from activated carbon. The adsorption of gold onto activated carbon is an exothermic process; for that reason an increase in temperature will shift the equilibrium toward the desorption.

Effect of agitation. It was studied using coarse carbon under optimal variables of pH, temperature, acetone ..., etc. The stirring speed has been varied three times: 100, 300 and 1,000 tr/min.

Fig. 8 shows that the desorption rate changes slightly when there is little change in agitation. It looks like there is no significant change between 100 and 300 tr/min, but with 1,000 tr/min the rate increases by 5 %.

Effect of initial concentration of gold in carbon. To show the effect of the initial concentration of gold in carbon, the test was performed with four values: $Q_0Au = 0.5, 1, 5$ and 10 mg/g.

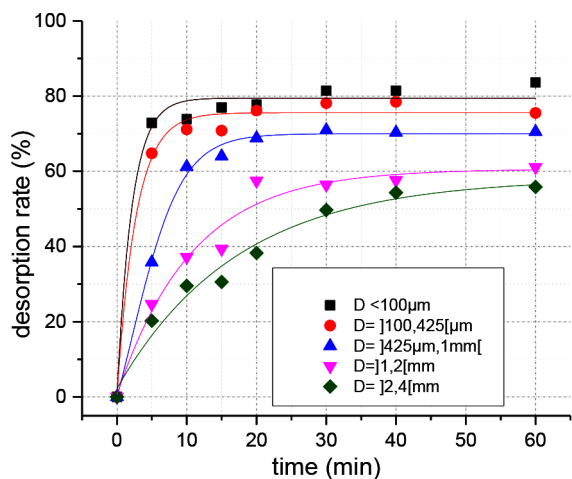


Fig. 5. Effect of particles size:
Acetone 20 %; Agitation 150 tr/min; $Q_0Au = 5$ mg/g; pH = 13;
C Carbon = 5 g/l; Carbon size] 2, 4[mm, $T = 32.3-35.6$ °C

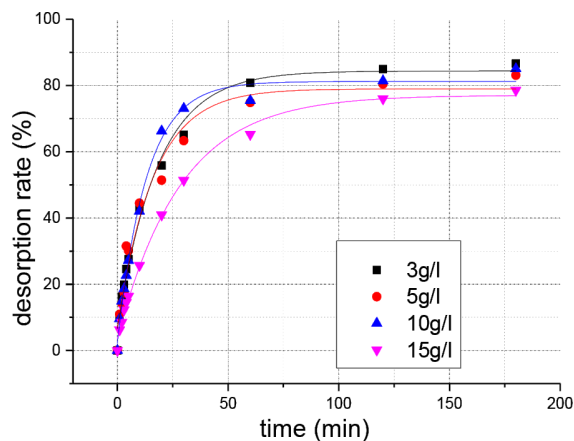


Fig. 6. Effect of carbon concentration in solution:
Acetone 20 %; Agitation 300 tr/min; $Q_0Au = 5$ mg/g; pH = 13;
C Carbon = 5 g/l; Carbon size] 2, 4[mm, $T = 32.3-35.6$ °C

The results are illustrated in Fig. 9. It shows that the desorption rate is more than 80 % with 1 and 5 mg/g, more than 90 % with 10 mg/g, and with 0.5 mg/g the rate is under 70 %. It is obvious that for low values of initial carbon-gold-loading, the desorption rate cannot be high.

Tests performed with authentic sample of waste fine carbon.

Many samples from authentic waste fine carbon of the Ames-messa gold mine were taken and tested using optimal parameters of pH, temperature, agitation ..., etc. Fig. 10 shows that the desorption rate is about 88 % in 30 min resident time. This rate can be increased if the time of operation was extended to one hour, or if the carbon samples are pretreated with hydrochloric acid.

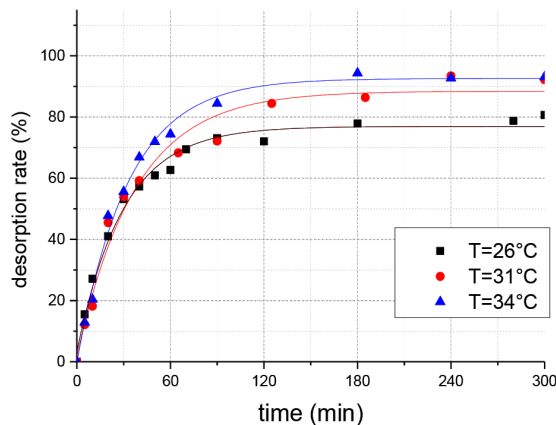


Fig. 7. Effect of temperature:
Acetone 20 %; Agitation 300 tr/min; $Q_0Au = 1$ mg/g; pH = 13;
C Carbon = 5 g/l; Carbon size] 2,4[mm

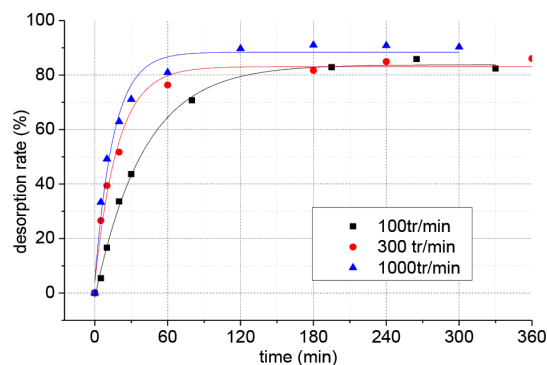


Fig. 8. Effect of agitation:
Acetone 20 %; Temperature $T = 30-35$ °C; $Q_0Au = 5$ mg/g; pH = 13;
C Carbon = 5 g/l; Carbon size] 2,4[mm

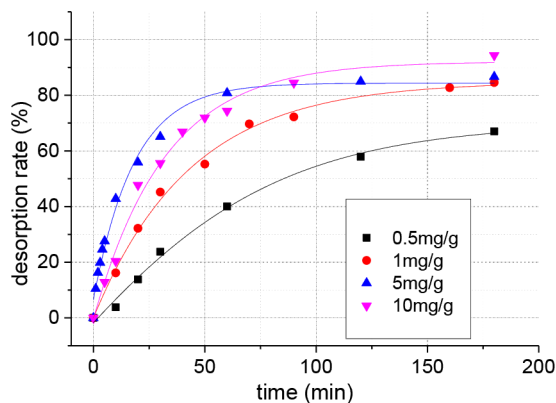


Fig. 9. Effect of initial gold concentration in carbon:
Acetone 20 %; Temperature $T = 33-35$ °C; pH = 13; C Carbon = 5 g/l, Carbon size] 2,4[mm

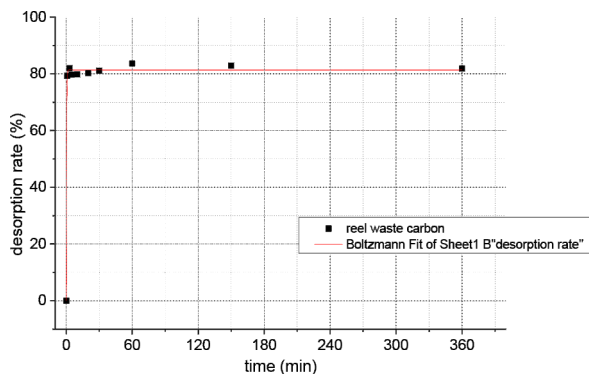


Fig. 10. Reel waste fine carbon:

Acetone 20 %; Temperature $T = 32\text{--}33\text{ }^{\circ}\text{C}$; pH = 13; C Carbon = 5 g/l; Carbon size < 100 μm ; $Q_0\text{AU} = 0.696\text{ g/kg}$

Table 8

Test performed in three stage assays (pH = 13, $T = 38\text{ }^{\circ}\text{C}$, $C_c = 5\text{ g/l}$, agitation 300 tr/min, acetone 20 %)

Q_0 , mg/g	Desorption rate, %		
	1 st cycle	2 nd cycle	3 rd cycle
10	84.02	90	92
2	92.34	95.36	96.7
0.5	84	89	90

Test performed in three stages. To see if we can increase the recovery efficiency, an experiment was carried out with three-stages assays at optimal parameters. For each stage, a new desorbing solution is used. The results presented in Table 8 show that the efficiency can be improved by renewing the solution and the desorption rate can go up to 96 %.

Conclusion. In this study, only 0.2 % caustic soda in an agitated solution was mixed with 20 % organic solvent as acetone to desorb gold from fine and coarse carbon. The main factors that can affect this operation have been studied. The results show that the efficiency of this method is more than 90 % in optimal parameters. This rate can be increased if the resident time is extended more than 3 hours.

In light of these results, this method can be a good process to recover gold entrapped into waste fine-loaded carbon. It can be also a good alternative to the conventional processes used nowadays in the processes of gold stripping for the reasons below:

1. Low energy: the operation runs at room temperature and atmospheric pressure.
2. Short resident time: <3 h for coarse carbon and <5 min for fine carbon.
3. No use of toxic chemicals as cyanide.
4. The desorbed carbon has higher activity than it can be used for other processes.
5. This method can be used for fine carbon as well as coarse one, separately or in a mixture.
6. This method can be used to recover other precious metals such as silver, Platine ..., etc. or even base metals such as copper, Nickel ..., etc.
7. This can be a good alternative to carbon burning used nowadays.

We suggest using this method followed by electrolysis or by zinc or aluminum precipitation to recover gold cyanide from activated carbon used nowadays in gold ore treatment.

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Вилучення золота з відходів дрібнодисперсного вугілля з використанням ацетону як розчинника (золота копальня Амесмесса, Алжир)

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Мета. Метою цієї роботи на першому етапі є розробка нового методу вилучення золота з відходів дрібнодисперсного насиченого активованого вугілля. На другому етапі – розробити новий метод з використанням меншої кількості енергії та менш небезпечних хімічних речовин для вилучення золота з дрібнодисперсного й необробле-

ного активованого вугілля під час усього процесу обробки золотої руди.

Методика. Десорбцію ціаністого золота з відходів дрібнодисперсного насиченого активованого вугілля проводили шляхом перемішування вугілля на лужному водному розчині, що містить 20 % (об./об.) ацетону (рН в межах 10–13), за кімнатної температури.

Результати. Застосування запропонованого способу дало задовільні результати з точки зору ефективності процесу, часу виконання операції й відсутності необхідності використання шкідливих хімічних речовин, таких як ціанід. Ефективність становить понад 96 %, час виконання менше 3 годин. Щодо небезпечних хімічних речовин – ціанід не використовується, на відміну від традиційних процесів.

Наукова новизна. Використання ацетону в якості органічного розчинника сприяє десорбції ціаністого золота з активованого вугілля за кімнатної температури та за короткий час краще, ніж будь-який інший традиційний процес.

Практична значимість. Цей метод дозволяє легко та економічно вилучати золото, що міститься у відходах активованого вугілля, яке знаходиться на гірничодобувній установці за кімнатної температури в резервуарі для перемішування, рН = 10–13 з ефективністю понад 96 %. Цей метод може бути гарною альтернативою для всіх процесів вилучення золота з активованого вугілля, що використовуються сьогодні.

Ключові слова: *активоване вугілля, сорбція та десорбція золота, видобуток золота, елювання органічного золота*

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