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APPLICATION OF LEACHING KINETICS MODELLING TO A GOLD CYANIDE LEACH PLANT BY USING REAL PLANT DATA

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Abstract: Gold cyanide leach kinetics modeling was applied to the Bergama Ovacik gold cyanide leach plant in Turkey by processing the real plant data without need of any laboratory work. For this aim, solid ore samples were taken from each leaching tanks and analysed for gold contents as Au ppm while plant variables such as solid % concentrations in each tank, feed rate of plant as megagrams per hour (Mg/h), slurry flow rate as m^3/h and the slurry residence times in each tank calculated and noted for modelling study. Five sampling work performed at plant at different times. Each sampling data were modelled seperately by the Anglo-American Research Laboratories (AARL) leach kinetics model to obtain five seperate model parameters and regression coefficient (R^2) values. Then, total five sampling data were all together modelled to obtain just one model equation and R^2 value to represent the plant generally. All R^2 values were above 0.90 indicating that the AARL gold leaching kinetics model fits well on real plant leaching conditions. By using the model parameters, the residual gold contents in each tank were predicted for different possible ore feed rate tonnages such as 80, 90, 100, 110 and 120 megagrams per hour. Thus, leaching recoveries for any ore feed rate would be estimated for possible tonnage increases in the future.

Keywords: *gold, cyanide, leach, kinetics, model*

Introduction

Gold is produced from its ores by cyanide leaching. The cyanide leaching process is applied by, first, grinding the ore below 75 micrometers and dissolving gold as $Au(CN)_2^-$ by mixing the ground ore with dilute cyanide solution to obtain slurry above pH 10 and by providing oxygen to the leaching tanks. Dissolution of gold-cyanide completes in about 24 hours. The hydrometallurgical reaction for extracting gold from its ores can be shown as:

$$Au^0 + 2CN^- + \frac{1}{2} H_2O + \frac{1}{4} O_2 \rightarrow Au(CN)_2^- + OH^- . \quad (1)$$

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Following dissolution of gold in leaching tanks, the slurry passes through the carbon adsorption tanks. In those tanks, granulated activated coconut carbon is mixed with the slurry and the dissolved gold is adsorbed by carbon. Thus, gold loaded carbon is seperated from the barren slurry and gold is stripped from the carbon. (Cerovic et al., 2005; Davidson and Sole, 2007; Pleysier, et al. 2008).

The slurry passes from the leaching tanks to the first adsorption tank through the last tank, while the activated carbon follows the reverse direction from the last tank to the first one. By this counter current flow of the slurry and carbon. The $Au(CN)_2^-$ complex is loaded onto the carbon. At the first adsorption tank the most Au loaded final activated carbon is obtained and the loaded gold is gained by stripping it from carbon by the column elution method. To prevent the granulated carbon to move the slurry, there are special sieves at the tanks discharge openings, so carbon is driven in a reverse direction by special carbon pumps.

The research study was performed by using plant data of the gold cyanide leaching plant in Ovacik Gold Mine in Turkey. The Ovacik gold cyanide leach plant includes initial two leaching tanks and following eight adsorption tanks. In both leaching and adsorption tanks, gold dissolution from the ore continues. Leaching time of the ore depends on the feed tonnage rate, solid concentration and the amount of the leach and adsorption tanks. Thus, the gold contents of the solid residue samples from each tank provides an opportunity to model the leach kinetics of the plant. By modeling the plant, the residual gold contents in each tank, thus the final gold % recovery was predicted for any planned ore feed rates and for any gold contents of the feed ore.

In the literature, several gold ore cyanide leach kinetics modelling laboratory investigations were conducted (Bellec et al., 2009; de Andrade Lima, 2007; Guo et al., 2004; Jeffrey, et al., 2001; Rubisova et al., 1996; Srithammavut et al., 2011; Woollacott et al., 1990). There, the plant data were used for the modelling of the cyanide leach kinetics of gold.

Gold cyanide leach kinetics model

Modelling study was performed by using AARL (Anglo American Research Laboratories) gold cyanide leach kinetics model (Woollacott, L.C. et. al., 1990). The model is described by Eqs. 2 and 3:

$$R = -\frac{dS(t)}{dt} \tag{2}$$

$$R = a\frac{So}{(a+bt)^2} \tag{3}$$

Thus, integration of Eqs. 2 and 3 gives Eq. 4:

$$S(t) = So\left(1 - \frac{t}{a + bt}\right). \tag{4}$$

In the equations, *R* is decreasing of the ore gold content, depending on leaching time, *t*. Parameter S_o is the initial gold content of the ore (ppm), *S*(*t*) is the ore content at time *t*, while *a* and *b* are parameters that are determined by a non linear regression analysis. Once the *a* and *b* parameters are determined modelling of the plant can be performed for any ore feed rate, solid concentration and tank volume.

Materials and methods

Plant data were used for the gold leach kinetics modelling. The Ovacik plant has two leaching tanks and eight adsorption tanks. At five different times, the residual solid from each tank were taken and analysed for gold while the ore feed rate and solid concentration values, occured at the time of sampling, were noted. For a feed rate (Mg per hour), solid concentration (%) and tank volumes (m^3), residence time (h) and flow rate (m^3/h), of the slurry in each tank were calculated. The plant data for the five seperated sampling conditions were shown in Tables 1 and 2.

Table 1. Plant data for the five different samplings

		Leaching time (slurry residence time in tank) *t*, hours				
	Tank volume m^3	A	B	C	D	E
Leach tank 1	749	4.42	5.14	5.58	5.19	4.44
Leach tank 2	743	8.80	10.23	11.11	10.35	8.84
Ads. tank 1	256	10.31	11.99	13.02	12.12	10.36
Ads. tank 2	252	11.79	13.71	14.90	13.87	11.85
Ads. tank 3	249	13.26	15.42	16.75	15.60	13.33
Ads. tank 4	246	14.71	17.11	18.59	17.30	14.79
Ads. tank 5	242	16.14	18.77	20.39	18.98	16.22
Ads. tank 6	239	17.55	20.41	22.17	20.64	17.64
Ads. tank 7	236	18.94	22.02	23.93	22.28	19.04
Ads. tank 8	232	20.30	23.61	25.65	23.89	20.41
slurry flow rate, m^3/h		169.62	145.85	134.24	144.19	168.72
feed tonnage, Mg/h		90	88	81	87	105
solid concentration, %		40	44	44	44	45

Gold contents in each solid residue in the tanks are given in Table 2. By using plant data noted in Tables 1 and 2, modelling was performed by considering the five plant conditions both seperately (A, B, C, D, E) and together to determine one *a* and *b* parameter which would be applicable for all plant sampling conditions.

Table 2. Gold contents of the residue in each tanks for the five sampling periods

	Au content in residue solid, ppm				
	A	B	C	D	E
Leach tank 1	1.70	4.55	1.25	1.37	1.28
Leach tank 2	1.44	3.49	0.81	0.97	1.01
Ads. tank 1	0.98	2.16	0.52	0.51	0.59
Ads. tank 2	0.68	1.56	0.40	0.43	0.33
Ads. tank 3	0.63	1.36	0.29	0.41	0.32
Ads. tank 4	0.54	1.07	0.23	0.38	0.27
Ads. tank 5	0.47	0.86	0.22	0.33	0.24
Ads. tank 6	0.44	0.77	0.20	0.31	0.20
Ads. tank 7	0.32	0.69	0.17	0.28	0.18
Ads. tank 8	0.25	0.61	0.16	0.26	0.16

Results and discussion

First, by sing the AARL (Anglo-American Research Laboratories) model equation (4), the five conditions were modelled to find *a*, *b* and *So* model parameters by non linear regression analysis. Besides, regression coefficients (R^2) were found for the five conditions. The modelling results for five conditions are shown in Table 3.

Table 3. Model parameters determined for five plant periods

	A	B	C	*D*	E
a	10.67	7.84	4.69	3.19	5.72
b	0.56	0.72	0.85	0.92	0.76
S_o	2.65	8.46	3.10	3.97	2.59
R^2	0.9406	0.9470	0.9675	0.9333	0.9122

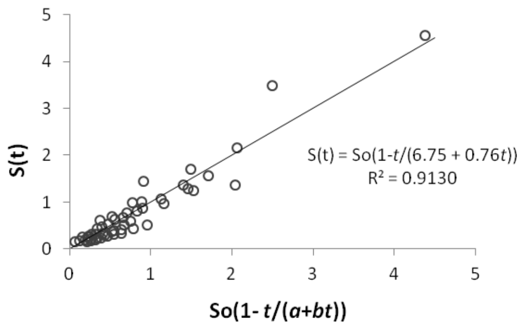

Fig. 1. The plants characteristic leach kinetics model graph

Thus, for the first modelling study model parameters *a*, *b* and S_o were calculated for the five conditions seperately. As shown in Table 3, all R^2 values are above 0.90

indicating the AARL model is appropriate for the plant gold leaching modelling. Secondly, all five plant data were modelled together to obtain one *a* and *b* parameters. The model graph is shown in Fig. 1. In Figure 1, the model graph and equation indicating the general leach kinetics characteristic of the plant are shown. The R^2 value is 0.9130 indicating that the model fits well to the plant leaching kinetics. The *a* and *b* values are determined as 6.75 and 0.76, respectively. Besides, S_o is determined as 4.15 ppm, which is the average ore feed gold content of the plant.

Consequently, the plant was modelled according to the model parameters *a* and *b*, 6.75 and 0.76 respectively for different feed rates as 80, 90, 100, 110 and 120 Mg/h. For those feed rates, the final gold recovery and residual gold contents in each tank were predicted. The prediction results are shown in Table 4.

Table 4. The predicted values of residual gold contents and final gold recoveries for different feed rates

	Predicted Au content in residue, ppm				
Leach tank 1	2.03	2.18	2.31	2.42	2.52
Leach tank 2	1.10	1.26	1.40	1.53	1.65
Ads. tank 1	0.89	1.04	1.19	1.32	1.43
Ads. tank 2	0.71	0.87	1.00	1.13	1.25
Ads. tank 3	0.57	0.71	0.85	0.98	1.09
Ads. tank 4	0.44	0.58	0.72	0.84	0.95
Ads. tank 5	0.33	0.47	0.60	0.72	0.83
Ads. tank 6	0.24	0.37	0.50	0.61	0.72
Ads. tank 7	0.15	0.28	0.41	0.52	0.63
Ads. tank 8	0.08	0.21	0.32	0.44	0.54
Total leach time, h	25.98	23.09	20.78	18.89	17.32
feed tonnage, Mg/h	80	90	100	110	120
Solid concentration %	44	44	44	44	44
Feed Au content g/Mg	4.15	4.15	4.15	4.15	4.15
Final Au recovery, %	98.05	95.03	92.18	89.50	86.97

According to Table 4, the final gold recoveries and residual gold contents in each tank were predicted for 80, 90, 100, 110 and 120 Mg/h. The final gold recovery is decreased down to 86.97% in case of 120 Mg/h. Thus, as the planned tonnage increases, additional leaching and adsorption tanks may be considered to maintain the higher gold recoveries. The amount of additional tanks may be determined by this modelling work as well.

Conclusions

Gold cyanide leaching kinetics modelling of the Ovacik Plant were performed by using plant data, first by five different plant periods, secondly by all five periods together to determine the characteristic leach kinetics model parameters of the plant. Consequently, according to the model parameters *a*, and *b*, the expected gold recoveries and expected residual gold contents in each tank were predicted for feed rates of 80, 90, 100, 110 and 120 megagrams per hour.

The AARL model was used to model the leach kinetics of the plant. All modelling regression coefficients (R^2) values were above 0.90, indicating that the AARL model fits well to the Ovacik plant and the predictions performed depending on this model were reasonable.

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