STUDY OF IN SITU CYANIDE DETOXIFICATION ON GOLD PROCESSING TAILING AT PONGKOR GOLD MINE

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Received : 09 November 2007, first revision : 04 February 2008, second revision : 13 February 2008, accepted : 24 February 2008

ABSTRACT

Currently, gold processing unit at Pongkor mine processes cyanide-containing waste at the end pipe or known as final process. Due to the increase of environmental awareness from the community, such a process needs to be re-evaluated. This relates to tight regulation regarding safe waste prior to releasing to the nature. Conflicts will arouse when population at surrounding area increases fast. To anticipate such conflicts, the gold processing unit of Pongkor mine proposes a scenario dealing with waste processing improvement from the end pipe process to the whole one. It includes reagent use optimization and waste minimization including its recycle.

In situ cyanide detoxification is one of waste minimization processes conducted at Pongkor mine. In terms of comparing which one of the methods is the best in reducing cyanide within wastes, a series of cyanide reduction tests employed Inco's and Degussa methods at a laboratory scale. To reduce high cyanide concentration of the wastes, the used reagents in Inco's method include $Na_2 S_2O_5$, $CuSO_4.5H_2O$ and pressured by the air while Degussa method applied H_2O_2 and $CuSO_4.5H_2O$. The results from this experiment suggest that Inco's technology is able to detoxify cyanidation effluents better than that of Degussa technology.

Keywords : in situ cyanide, waste, inco's method, Degussa method

1. INTRODUCTION

Gold extraction operations generate a variety of waste products, which must be responsibly disposed of, in compliance with environmental regulations. During the last decades, increased emphasis has been placed on effluent control and treatment, being most immediate concern the threat to the environment presented by toxic constituents, such as certain cyanide species. Almost all the modern technologies developed for cyanide detoxification from solution require further treatment in order to reach cyanide statutory limits for direct discharge. Taking this into account, Inco's and Degussa technologies can be considered as a viable technology for cyanide removal from mining effluents (Álvarez et.al., 2004).

The precious metals mining industry's use of cyanide to extract precious metals from low grade ores is widespread. Cyanidation is the predominant method for precious metals beneficiation and is used on heap leaches or in *tank* operations to liberate precious metal values from remaining gangue in the ore. The International Nickel Company's (INCO) sulfur dioxide/air process is one of two patented sulfur dioxide processes (Devuyst et al., 1992). Another process is patented by Noranda Inc. Both processes are similar with some limited differences in operating procedures. (McGill and Comba, 1990)

The INCO process has been commissioned at more than 36 sites in North America. Ten sites are located in the U.S. Six of these 10 sites, use the

INCO process to treat tailings prior to disposal. After treatment, tailings are typically disposed of in a tailings impoundment subject to zero discharge requirements under the Clean Water Act. In addition to Federal Clean Water Act standards, many states have solid waste-related discharge standards for the tailings prior to discharge to the tailings impoundment and the INCO treatment process is used to meet these State requirements (U.S. Environmental Protection Agency, 1993; U.S. Environmental Protection Agency, 2000).

Located near Bogor, in the province of West Java, Pongkor mine is approximately 90 km from Jakarta. Figure 1 shows the processing plant at the mine. The mine which is commenced in May 1994 retains the area of approximately 4,058 ha and has three primary veins, namely Ciguha Utama, Kubang Cicau and Ciurug. A conventional cut and fill stoping mining method with hydraulic replacement of tailing is used for the first two of these veins with hydraulic placement of tailings as fill.

Figure 1. Gold processing plant at Pongkor mine (www.antam.com)

Pongkor mine has a problem deals with its cyanide-containing waste. Previously, the mine applied end pipe process to minimize cyanide content prior to release it to the nature. However, such a process needs to be re-evaluated to avoid a conflict with the inhabitants surrounding the mine as normally; the area to process cyanide includes the community area. The increase of resident environmental awareness results in tight regulation dealing with waste disposal. When minimizing cyanide content, the plant sends cyanide-containing slurry directly to tailing dam without chemically detoxifying the cyanide. Natural degradation within the dam process will decrease the cyanide. The overflow from the dam retains relatively low cyanide content and processes at cyanide detoxification area prior to releasing to the nature. Figure 2 exhibits a flow chart of indirect cyanide detoxification.

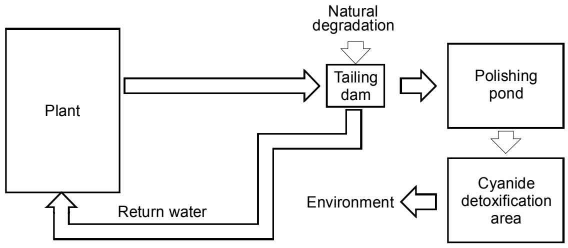

Figure 2. A flow chart for indirect cyanide detoxification used at Pongkor gold mine

The advantage of indirect cyanide detoxification is economic use of chemical reagent for detoxifying cyanide. Such a reagent can be employed in low concentration as the entered cyanide concentration through the decant pond is relatively small (www.engg.ksu.edu /hsrc/95Proceed/young.pdf). However, indirect cyanide concentration retains several disadvantages. Those are:

- needs wide area of tailing dam;
- difficult to handle arisen impacts if slurry leaking occurs during transported to the dam;
- after dilution process in tailing dam, the flow rate volume entering detoxification area is bigger than that of feed from plant. As a result, cyanide reduction process will relatively be difficult;
- needs a tight control for tailing-released waste to get safe cyanide concentration.

Such disadvantages result in arousing internal and external conditions. The former includes disruption of material balance at either the plant or backfill silo, fluctuation of ore grades at the plant and need bigger cost due to twice cyanide detoxification, namely at Cikaret and mine site waste processing unit. The later involves a large amount of puddle entering the tailing dam, dense inhabitant surrounding the plants, limited lifetime of slurry pumping pipe and high rainfall density.

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Referring to such conditions, Pongkor mine considers seeking an alternative to processing cyanide waste that is relatively safe and sound. The proposed alternative is decreasing cyanide wastes immediately prior to releasing them into tailing dam or known as direct method. The substance is detoxified in the plant area using a series chemical methods such as Inco, Carro Acid and Ferro sulfate methods. A flowchart regarding the proposed alternative is presented in Figure 3. Similar to indirect method, the direct method retains advantage and disadvantage. The advantage includes relatively safe condition during waste transportation notably when the distance between the plant and tailing dam is relatively removed.

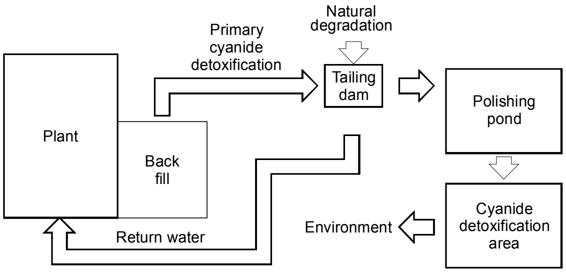

Figure 3. A flow chart for direct cyanide detoxification proposed as alternative for processing cyanide-containing waste at Pongkor gold mine

This paper discusses a series of tests to minimize cyanide concentration within wastes prior to releasing it to the environment.

2. MATERIALS AND METHODS

In terms of detoxifying cyanide within wastes and as a comparison, gold processing unit at Pongkor mine used two technologies, namely Inco and Degussa methods. The former is a method to reduce cyanide content by employing sodium metabisulfate ($Na_2 S_2O_5$), copper sulfate pentahydrate ($CuSO_4.5H_2O$) and pressured by the air during the process, while the later applies hydrogen peroxide (H_2O_2) and $CuSO_4.5H_2O$. When conducting indirect detoxification, Pongkor mine currently applies Degussa method to detoxify cyanide matters followed by alkaline chlorination. The employed reagents are H_2O_2 and $CuSO_4$. $5H_2O$. The later serves as a catalyst. Degussa method is preferred due to its fast kinetics and effectiveness to minimize low cyanide concentration. However, such a method has a disadvantage, namely high consumption of reagent.

3. EXPERIMENTAL DESIGN

The experimental design for laboratory-scale tests is shown in Figure 4. Three tanks above served as reagent mixings and the rests performed as reagent holdings. When mixing done, all reagents

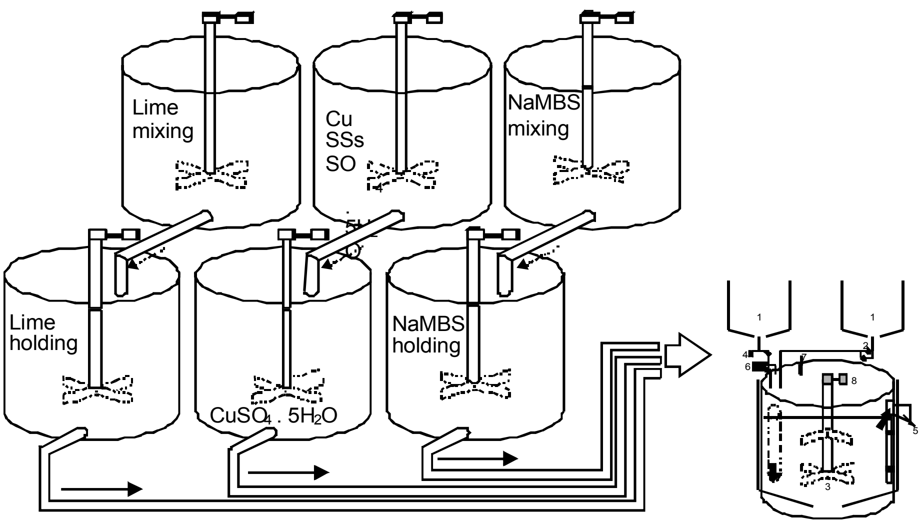

Figure 3. An experimental design for laboratory-scale direct cyanide detoxification as alternative for processing cyanide-containing waste at Pongkor gold mine

go to its holding tanks and then released to the operation tank. The tests to detoxify cyanide includes observation time (3, 4, 4.5 and 6 hours) and reagents used ($Na_2 S_2O_5$) for Inco and H_2O_2 for Degussa methods and catalyst $CuSO_4$. 5 H_2O as well. Samples for these tests were derived from thickener Plant 1 and 2.

nide includes those cyanide species liberated at moderate pH of 4.5 such as HCN (aq) and CN^-, the majority of Cu, Cd, Ni, Zn, Ag complexes and others with similar low dissociation constants. Methods used to measure WAD should be free from interferences due to the presence of high concentrations of more stable cyanide complexes

Table 1. Experiment results for various contact times

Contact time: 3 hours										
Reagents		Cu^{2+}	Initial solution (ppm)				Solution assay (ppm)			
Type	% sto.	added (ppm)	CN^-_{tit}	CN^-_{WAD}	SCN^-	Cu^{2+}	CN_{tit}	CN^-_{WAD}	SCN^-	Cu^{2+}
$Na_2S_2O_5$	100	20	265	280	34	9	60	34	34	20.1
H_2O_2	250	10	265	280	34	9	200	211	8.5	10.6
H_2O_2	250	25	244	270	31	8	105	180	15.6	40
Contact time: 4 hours										
Reagents		Cu^{2+}	Initial solution (ppm)				Solution assay (ppm)			
Type	% sto.	added (ppm)	CN^-_{tit}	CN^-_{WAD}	SCN^-	Cu^{2+}	CN_{tit}	CN^-_{WAD}	SCN^-	Cu^{2+}
$Na_2S_2O_5$	125	25	265	280	34	9	25	27	36	19
H_2O_2	275	5	265	280	34	9	190	200	6.8	10.2
H_2O_2	275	37	244	270	31	8	115	150	12.5	45
Contact time: 4.5 hours										
Reagents		Cu^{2+}	Initial solution (ppm)				Solution assay (ppm)			
Type	% sto.	added (ppm)	CN^-_{tit}	CN^-_{WAD}	SCN^-	Cu^{2+}	CN_{tit}	CN^-_{WAD}	SCN^-	Cu^{2+}
$Na_2S_2O_5$	150	35	265	280	34	9	5	25	35	19
H_2O_2	300	3	265	280	34	9	180	190	3.6	10
H_2O_2	300	10	244	270	31	8	116	130	10	50
Contact time: 6 hours										
Reagents		Cu^{2+}	Initial solution (ppm)				Solution assay (ppm)			
Type	% sto.	added (ppm)	CN^-_{tit}	CN^-_{WAD}	SCN^-	Cu^{2+}	CN_{tit}	CN^-_{WAD}	SCN^-	Cu^{2+}
$Na_2S_2O_5$	200	41	265	280	34	9	0	19	34	18.8
H_2O_2	400	0	265	280	34	9	170	180	2.2	9
H_2O_2	400	42	244	270	31	8	74	120	8.3	58

Note :
sto. : stoichiometry CN_{tit} : CN titatrion

4. RESULTS AND DISCUSSION

In the INCO process, free cyanide and weakly or moderately bound metal-cyanide complexes or known as WAD CN present in the waste stream are oxidized to cyanate (CNO^-). The WAD cyanide includes those cyanide species liberated at

or other cyanide forms. If not, the interference must be quantified and allowed for in the result. Table 1 summarizes WAD cyanide results from the study, and Figure 4 graphically depicts process efficiency during the performance assessment period as measured by WAD cyanide.

Results from the study demonstrate that, once optimized, the laboratory-scale tests of Inco method was able to consistently reduce cyanide WAD by approximately 90.62%, based on an average influent value of 280 ppm and an average effluent value of 26.26 ppm. The table also shows that at six hours contact time for Inco method, the SMBS and copper sulfate pentahydrate additions at 200% stoichiometry – a term for calculation of quantitative (measurable) relationships of the reactants and products in chemical reactions - and 41 ppm respectively seems effectively decreasing the amount of titration cyanide from 265 to 0 ppm while the CN^- WAD declines from 280 to 19 ppm. It looks like that such a method is effective to reduce high cyanide concentration. The bigger the stoichiometry percentage means the bigger the reduced cyanide. Furthermore, it is clear that the longer the contact time the lesser the cyanide content within effluent (Figure 4). Figure 4 also illustrates that the decrease of CN^- WAD runs smoothly. No abrupt fluctuation occurs.

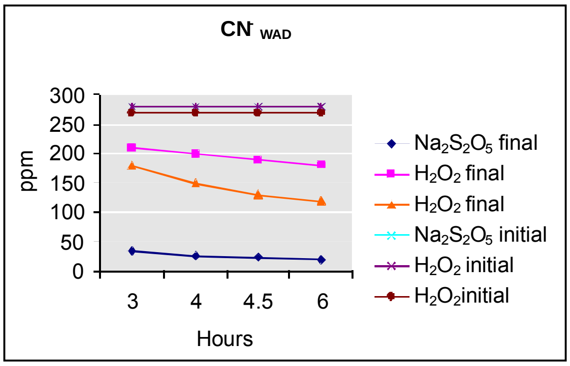

Figure 4. CN^- WAD concentrations over time

Referring to Degussa method, minimizing cyanide concentration at 6 hour contact time which uses hydrogen peroxide without $CuSO_4.5H_2O$ addition seems ineffective. The CN^- WAD, titration cyanide and SCN^- is still high. The CN^- WAD of Degussa method shows that cyanide decrease are relatively low; even by adding $CuSO_4.5H_2O$ catalyst, it only minimizes the CN^- WAD to 120 ppm. This means that compared to the Inco method, the Degussa method can not destruct high cyanide concentration. In addition, the method requires higher reagents.

Discussing the CN^-_{tit}, SCN^- and Cu contents from 3 to 6 hour contact times (Figure 5); the CN^-_{tit} of

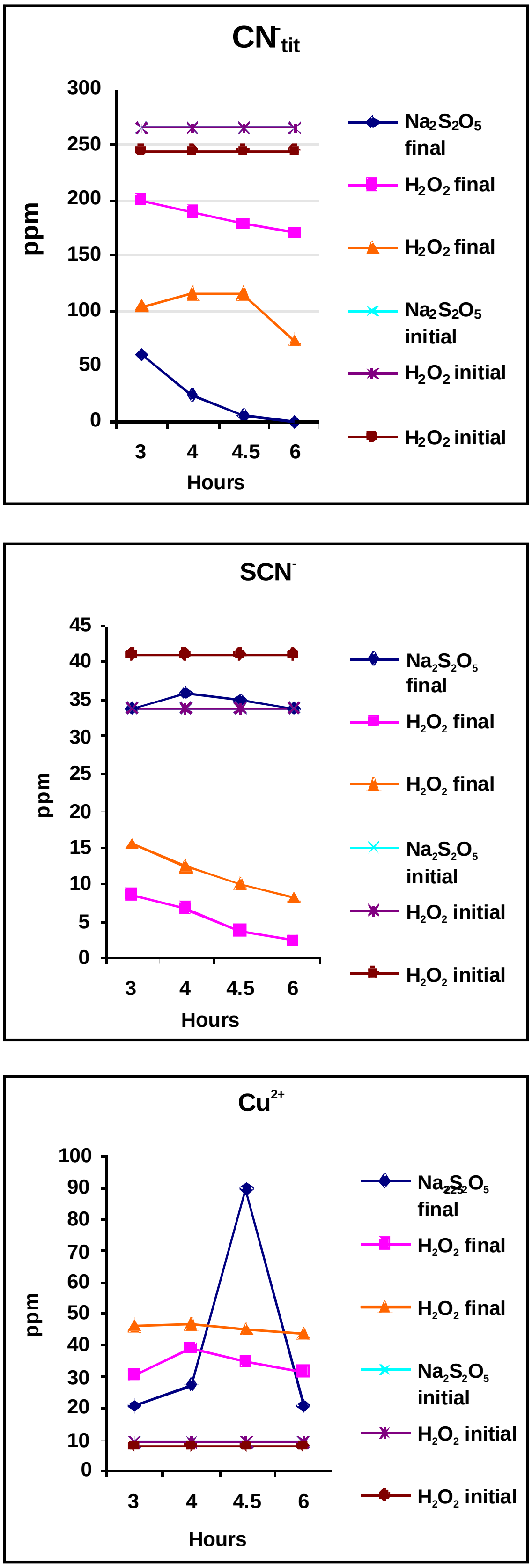

Figure 5. CN^- tit, SCN^- and Cu^{2+} concentrations over time

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Inco method sharply decreased at 3 to 4.5 hour contact times and decreased gradually from 4.5 to 6 hour contact times. Similar to the CN^{-}_{tit} of Inco method for 3 to 4.5 hour contact times, the same substance of Degussa method displays sharp decrease till the end of contact time (6 hours) but the CN^{-}_{tit} of Degussa method without H_2O_2 addition increases sharp at 3 to 4.5 hour contact times and suddenly drops at 6 hour contact time. This condition also occurs for copper ion (Cu^{2+}), the curve of Inco method goes up sharply and is dropped drastically at 6-hour contact time. It seems that 4 and 4.5 contact times are a critical one to destruct cyanide. The reason is not really understood and it takes time to study such a condition.

In addition to test the cyanide destruction capabilities, the system is secondarily evaluated for its ability to remove metal species from the pregnant feed solution of Plant 1 and 2. Table 2 presents a review of the metals data during the performance assessment period of the project.

Gold is mostly undetectable from four samples. Its existence is only a trace while silver (Ag) is still detectable. It is supposed that the grade of the silver within the ore is higher than that of the gold. The metals zinc, copper and iron exhibited apparent increases in the effluent as compared to the feed. The apparent increase is probably due to inputs from process amendments.

The laboratory-scale experiments were conducted for direct cyanidation as shown in Figure 3. Theoretically, it can be applied to reduce cyanide in a plant. However, it needs several tests at a bench and plant scale prior to applying it. Brief economic evaluation shows that total insitu installation requires cost at Rp. 1,843,750,000.00 (Table 3) while the required reagents are shown in Table 4.

Table 2. Gold and silver contents, including its impurities, within underflow thickener II solutions,

		Concentrations (ppm)				
		Au^{+}	Ag^{+}	Zn^{+}	Cu^{2+}	Fe^{2+}
Plant 1	- thickener 1	trace	1.7056	8.6590	10.4200	18.6900
	- thickener 2	trace	1.5975	7.3040	10.4200	20.5600
Plant 2	- thickener 1	trace	5.5145	7.3600	11.4000	11.2375
	- thickener 2	trace	4.2695	5.9790	9.5600	13.2400

Table 3. Cost estimation for installing insitu cyanide detoxification unit

Material	Cost (Rp)	Summary
Destruction tank	850,000,000.00	1 tank + 1 agitator
Reagent mixing unit	218,500,000.00	3 tanks + 3 agitators
Reagent holding unit	108,000,000.00	3 tanks + 1 agitator
Pump including dosing pump	187,000,000.00	6 transferred pumps + 6 dosing pumps
Air sparking unit	127,500,000.00	1 unit compressor
Additional instruments	352,750,000.00	2 units dosing flowmeter, pH meter and milivolt, Keygold analyzer
Total	1,842,750,000.00	

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Table 4. Average reagents consumption for processing the wastes at Cikaret and mine area

Material	Av. dosage		Unit price (Rp/kg)	Cost estimation/ day (Rp)
	kg/hour	kg/day		
Ores: 1,200.00 tpd				
SMBS for 67% SO_2	73.30	1,758.00	3,000.00	5,274,000.00
$CuSO_4.5H_20$	20.00	480.00	3,250.00	1,560,000.00
Lime	-	1,000.00	200.00	200.000.00
Total				8,034,000.00

5. CONCLUSIONS AND SUGGESTIONS

Insitu cyanide detoxification or direct cyanide destruction provides relatively safe performance compared to indirect one. Both Inco and Degussa methods can be used lessen cyanide concentration. The Inco method can destruct high cyanide concentration and contrives relatively stable ligands. It can also be eliminated the extra base metal within waste. The Degussa method is only capable to decrease low cyanide concentration.

The experiments demonstrate that the use of $Na_2S_2O_5$ and copper sulfate pentahydrate are in proportion to the amount of cyanide within effluent and the base metal contents. The optimum condition refers to 200% stoichiometry of $Na_2S_2O_5$ and 41 ppm Cu^+. To optimize minimization of chemical reagents used, the % solid of the samples (from underflow thickener) should be thickened. This will result in increasing cyanide, calcium hydroxide, gold and silver recoveries within the thickener.

If the Inco method will be applied at Pongkor mine, the available waste processing units at Cikaret and mine site can be used as standby units. However, it needs several studies prior to applying the method at a plant scale.

ACKNOWLEDGEMENT

The authors wish to thank Ir. Achmad Dohar Siregar of PT Aneka Tambang for providing facilities during the experiments, several technicians at Research Development Center for Mineral and Coal Technology (RDCMCT) for conducting some required analyses and experiments.

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