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Natural Degradation Behaviour of a Cyanide Leach Solution Under Laboratory Conditions

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Cyanidation has been employed in the recovery of gold and silver for more than a century. Forms of cyanide in mineral processing tailings include free cyanide (HCN and CN ion) and combined or complex cyanides depending on the mineralogy of the ore. Any cyanide containing effluent can be degraded and detoxified by natural degradation or chemically based destruction methods to prevent environmental contamination. In natural degradation certain chemical, physical and biological mechanisms are known to reduce the cyanide content by 99.9%. In this study, the natural degradation behaviour of free cyanide in the leach solution of Gümüşhane Mastra gold ore has been investigated under laboratory conditions. It was determined that the concentration of free cyanide in leach solution was reduced about 20 times after 70 days of retention time.

Key Words: Cyanidation, Natural degradation.

INTRODUCTION

The cyanidation process is the most widely used method for the recovery of gold and silver from its ores. In particular, it made possible the exploitation of low grade, fine grained, so called "invisible" gold beyond the reach of gravity separation. Although the process has been used in the mining industry for over a hundered years with success, various myths, misconceptions and fears still exist regarding this chemical. With the development of first gold project of what is potentially a large new mining industry in Turkey, there are claims and speculations made by some pressure groups that gold operations utilizing cyanide tailings impoundments are intrinsically dangerous to the enviroment and to the workers and residents working and living near these gold operations.

In gold and silver recovery a working solution is usually made from NaCN at a concentration of 500 ppm but sometimes due to cyanacides in the ore itself the working strength of the solution may be over 1000 ppm. Such offenders are copper, zinc minerals and ferrous sulphate. When applied to the ore, the concentration of the cyanide solution rapidly decreases forming complexes with gold, silver and other metals in the ore. Environmental factors such as physical, chemical and bacterial action further reduce the free cyanide levels about ten- fold[1–4].

Seven basic mechanisms are recognized to destroy free cyanide. These are:

(i) photodecomposition by sunlight, (ii) acidification by CO_2 in air, (iii) oxidation of O_2 in air, (iv) dilution, (v) complex formation, (vi) adsorption on solids, and (vii) biological action.

These natural degradation mechanisms were found to reduce the cyanide content[4] by 99.9%. A study carried out by WTC (Wastewater Technology Center) at the waste disposal of Dome Mine, Ontario, showed that cyanide concentration decreased from 63.5 to 0.008 mg/L over a 15 week period[5].

Perhaps the most important mechanisms are those that produce volatilization. These are the first three items resulting in the release of HCN to the atmosphere. Being highly volatile and lighter than air, the small amounts of HCN produced by mining processes are quickly dissipated and diluted by the atmosphere where it is destroyed[1, 2, 6]. The adsorption of cyanide on solids and the effect of biological action are often combined. The percolation of cyanide solution through soil columns is known to remove 90–95% of cyanide[4].

In Turkey, since 1986 various foreign companies have initiated large exploration projects for gold and silver mines and as a result of these efforts some epithermal based gold deposits were discovered. Gümüşhane deposit is one of these new gold mines in Turkey which will employ cyanidation process for the recovery of gold.

This study involves the natural degradation tests of Gümüşhane Mastra ore following the laboratory leach tests where high cyanide consumption was recorded due to significant amounts of cyanacides.

EXPERIMENTAL

Cyanide leaching was performed under optimal conditions which are given in Table-1. The pulp solution obtained has been used at natural degradation experiments. The experiments have been conducted in two stages. These are: (1) Natural degradation experiments carried out in an impervious media; (2) Natural degradation experiments carried out by using the solution obtained from the seepage.

TABLE-1
OPTIMAL LEACH CONDITIONS

Particle size (μm)	(–80%)	–75
Solid-water Ratio	(%)	30
pH		10.5
NaCN	(g/L)	1, 2
	(kg/ton ore)	3
O_2	(mg/L)	6
Rotation speed	(rpm)	300

48 h leach test was performed under these conditions and the following Au and Ag recoveries were achieved: Au recovery 93.62%; Ag recovery 60.27%.

Free cyanide concentration and pH value were measured as: free cyanide (g/L): 1.81*, pH 10.51.

Natural degradation carried out in impervious media: The pulp was taken into a jar and left for degradation in a non-seeping media for 2 months. By taking sample every 10 days, free cyanide, volatilization amount and pH measurements were carried out under normal ambient conditions (in a closed room and no sunshine) which was unfavourable for natural degradation.

Natural degradation carried out using seeped solution: These tests were performed by taking the pulp material into a 20 L container. Ilmenite type clay was used to provide a bed within the container. The thickness of this layer was about 15 cm.

The leach pulp, whose initial free cyanide and pH values had been determined, was poured on this layer and was left for about 10 days to seep through. The seepage was then tested every 10 days with regard to free cyanide, pH and volatilization values for about 2 months.

RESULTS AND DISCUSSION

Natural degradation carried out on a non-seeping medium: The solution, which was leached under optimal conditions, was left for about 70 days (between 1st June–9th August) for natural degradation on an impervious medium. Free cyanide, pH and temperature variations and volatilization rate of the leach solution were measured every ten days.

Fig. 1 shows the variation of free cyanide and temperature by days. As can be seen from the graph, free cyanide concentration shows a rapid decrease within 30 days and continues to decay slowly after about a month. Considerable drops were observed at points of increased temperature.

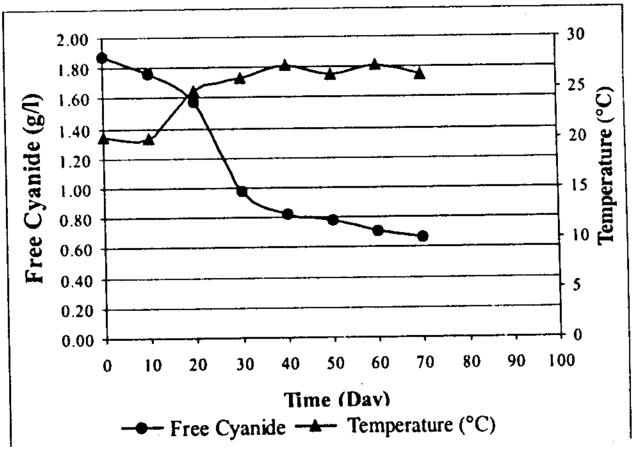

Fig. 1. The variation of free cyanide and temperature by time

*In actual plant operations the free cyanide concentration is reduced as the removal of gold and silver from the ore proceeds. In batch tests the free cyanide concentration is kept constant by the addition of fresh NaCN; therefore working solution concentration is much higher compared to actual conditions.

In Fig. 2, temperature and volatilization rate of free cyanide with time are evaluated. Volatilization increases with increasing temperature. Cumulative volatilization amount *vs*. time is shown in Fig. 3. It can be noted that 50% of the solution is volatilized after a period of 60 days in a closed room with no sunlight.

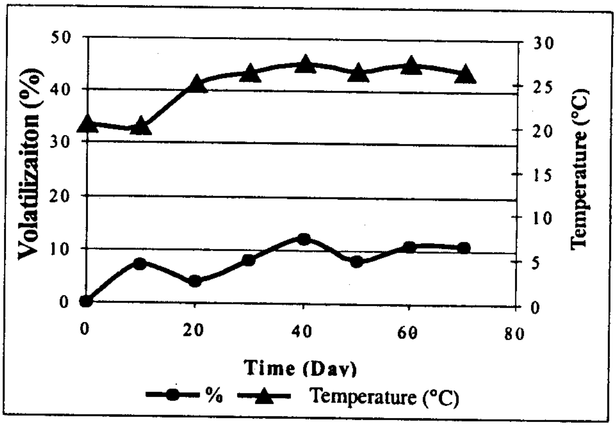

Fig. 2. Relationship between temperature and volatilization with time

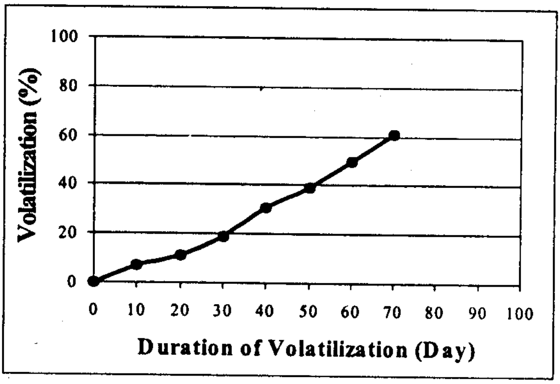

Fig. 3. Cumulative volatilization by time

If the experiment would have been carried out in the open atmosphere in the presence of sunlight, volatilization and eventual degradation of free cyanide would be expected to be quicker. pH of the leach solution is lowered from 10.51 to 9.13 within a period of 70 days.

Natural Degradation carried out using the seepage solution: In the second stage of the natural degradation experiments, leach solution which was passed through a clay layer was used. Experiments were carried out between 1st June–9th August.

Free cyanide concentration, temperature and pH variations and volatilization rate of the seepage solution were tested and shown in Figures 4–7.

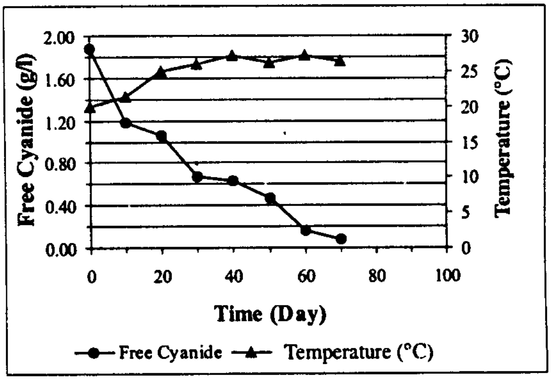

Fig. 4. The variation of free cyanide and temperature by time

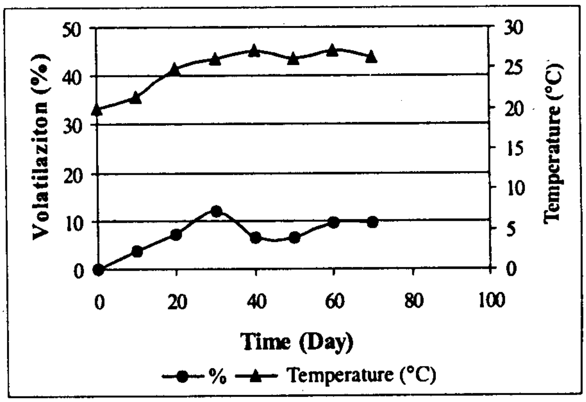

Fig. 5. Relationship between temperature and volatilization with time

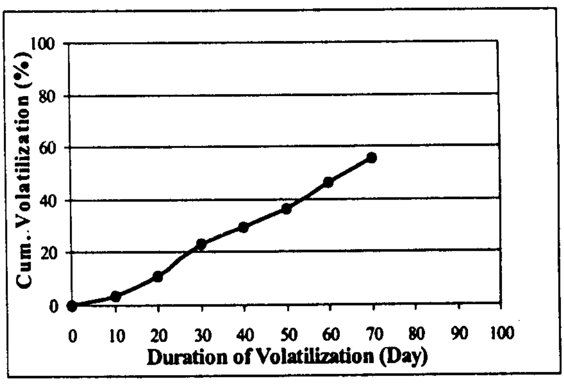

Fig. 6. Cumulative volatilization by time

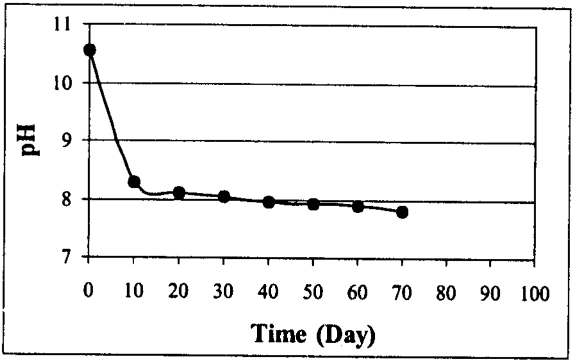

Fig. 7. Change of pH by time

As can be seen from the related figures free cyanide and pH values of the seepage from clay layer showed a noticeable drop compared to previous non-seeping tests. Concentration of free cyanide decreased from 1.88 to 1.18 g/L in a period of 10 days while seepage took place. Free cyanide concentration continued to decrease sharply at the end of 70 days; it reached a value of 0.2 g/L.

It is worth emphasizing that 50% of the solution volatilized within 60 days of the degradation period. pH value of the seepage solution was measured as 8.27 compared to 10.54 at the beginning of the test.

Conclusion

Natural degradation experiments carried out have been performed in two stages. Free cyanide concentrations of both solutions were 1.81 g/L CN^- and the pH = 10.51. After 70 days of retention time, cyanide concentration decreased to 0.63 g/L and the pH of the solution was recorded as 9.13. Free cyanide degradation was enhanced at periods of increasing temperature. Below pH 9.5 free cyanide concentration showed a significant attenuation due to volatilization of HCN gas.

In the second set of natural degradation experiments, CN^- concentration and pH value were measured immediately after the leach solution was passed through a clay liner. Cyanide concentration decreased to 1.18 g/L and pH value was recorded as 8.27. It is believed that clay layers have a natural cyanide degradation capacity. Measurements carried out at later periods indicated that both CN^- and pH values dropped more rapidly compared to previous solution. Eventual CN concentration and pH were measured as 0.08 g/L and 7.80 at the end of the test period.

50% of the solution volatilized within 60 days of degradation period. If the experiment would have been carried out in the open atmosphere in the presence of sunlight, volatilization and eventual degradation of free cyanide would be quicker.

Under the least favourable atmospheric conditions, the CN^- concentration degraded from 1800 to 80 ppm within 70 days of retention time. Natural degradation capacity of the clay layer could also be deduced from the experiments.

For the attenuation and degradation of cyanide down to acceptable limits for the environment a 2 stage pond system is recommended. Each pond will receive mill discharge for 12 months; the first pond is continuously filled except when being emptied into the second pond. Another alternative is to utilize a tailing pond for natural degradation and to treat the pond decant by chemical treatment systems.

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