Environmental Protection by Paste Production and Storage Mechanism for Cyanide Disposal in Gold Processing- A Case Study, Aq Dareh, Takab, Iran

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Abstract

Cyanide is widely used to process low grade ores such as gold and silver economically. However, its high levels of toxicity pose many environmental pollution problems that are major sources of concern for mining engineers and environmental groups. HCN and CN^- are two major cyanide pollutants that threaten aquatic life and constitute health hazards for human beings and other creatures. In gold processing, the pH is kept above 10 in order to prevent the release of dangerous HCN gas. In Aq Dareh mine, the gold processing slurry that contains cyanide is transported to the tailings dam, and damages the aquatic ecosystem in downstream environments. This paper describes the paste production and storage mechanism (PPSM) as an alternative method for cyanide disposal and presents the results of the application of PPSM in Aq Dareh gold processing plant. Using the PPSM system, the solid residue paste containing high concentrations of toxic cyanide is dumped on the ground, but limits cyanide release into the surface and ground water system. The use of PPSM in Aq Dareh gold processing plant can considerably reduce pollution problems caused by the release of cyanide into the environment.

Key words: Cyanide, gold processing, environmental impacts, effluents, Aq Dareh mine, PPSM

Introduction

Aq Dareh mine and gold processing plant is located 32 km from Takab city in western Azerbaijan province, Iran, at 46° 58' 30" N and 36° 39' 29" E. The elevation of the site is about 1926 m above sea level. Figure 1 shows the geographical location of the mine site, which is owned by the Iranian Government. The area consists of limestones of the Qom formation. Gold mineralization occurred in the lower Miocene micritic limestone (Maghsodi 2005). Geological and geochemical studies show that there are similarities between Aq Dareh gold mine and Carlin-type gold ores (Evans 1997). The similarities can be seen in the kind of host rock, the presence of gold within arsenopyrite ($FeS_2 \cdot FeAs_2$), gold mineralization with As, Hg and Sb and type of alteration including silicification, solution in carbonate rocks and argillite formation (Nekovaght Tak 1997). The grade of the gold in ore is 3 ppm.

Cyanide is used to process gold in Aq Dareh mine. Because conventional slurry disposal of the tailings produces many environmental problems due to cyanide, it was decided to use paste tailings rather than slurry disposal in order to limit cyanide leaching problems.

Many benefits have been reported by using paste technology including design, operation, reclamation, environmental and, most importantly, public perception (Verburg 2001). With paste, water recovery is maximised at the paste plant and recycled to the mill. This method of tailings disposal simplifies water management, eliminates the requirement to maintain a pond of water on the top of tailings, inhibits the oxidation process and reduces long term pollution problems.

This paper highlights the environmental benefit related to the disposal of tailings in Aq Dareh gold mine in paste form instead of by conventional disposal as slurry. Figure 2 shows the mechanism of tailings disposal as paste.

Paste characteristics

Tailings paste is defined as a dense, viscous mixture of tailings and water which, unlike slurries, does not segregate when deposited. It is defined practically as well-dewatered tailings which do not have a critical flow velocity when pumped and which produce minimal water bleed when discharged from the end of a pipe, as shown in Figure 2. One of the most distinguishing properties of paste is the grain size distribution of the solids. Based on a large volume of empirical data and operational experience, it has been suggested that a paste must contain at least 15 % by weight passing 20 microns to exhibit the typical paste flow properties and retain sufficient colloidal water to create a non-segregating mixture.

When being transported either by gravity or through pumping, paste produces a plug flow, with the fine particles creating an outer annulus, thereby reducing friction. The coarse particles are forced into the centre of the conduit with the finer fraction acting as the carrier (Verburg 2001). Positive displacement pumps are required to transport the paste through a pipeline.

Figure 1 *Geographical position of Aq Dareh gold mine*

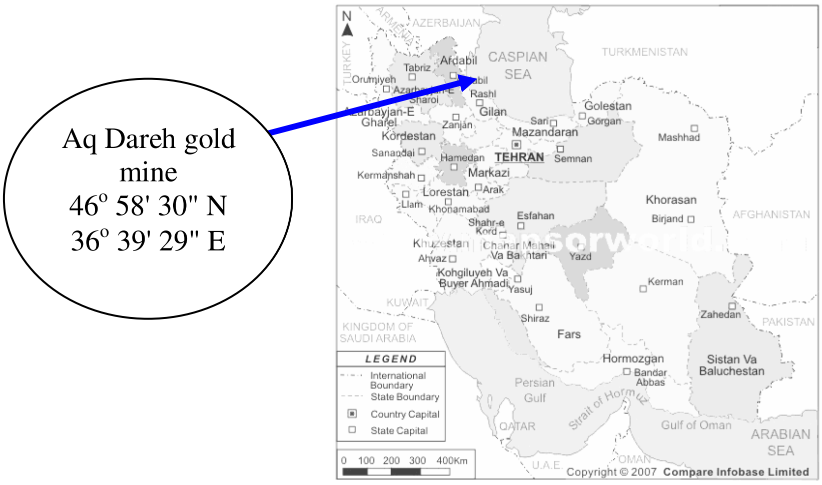


Figure 2 *Paste placement of tailings materials* (Verburg 2001)

Environmental problems of cyanide

One of the most important applications of the cyanide (as CN^-) in mining industry is to economically extract valuable metals such as gold and silver from their ores. However, cyanide is the most toxic material used to process low grade ores, particularly gold. Only 200 mg of cyanide can cause the death of human. The amount of free cyanide is controlled by the pH of the solution. HCN is the most common free cyanide in water with a pH range of 6 to 8.5; its solution in water produces a weak acid. CN^- is stable at pH above 9.2 but changes to HCN when the pH drops. Thus, a decrease in pH increases the percentage of HCN. At pH 7, about 99.5 % of cyanide type is HCN, which can be easily changed to gas and released to air. This is a dangerous gas that can be used as an insecticide (Manahan 2004). Cyanide spills to water bodies and soil create many environmental problems and are recognised as a threat to human life. Some cyanide complexes are degraded by water temperature, pH, and suspended solids; many other factors such as sunlight, microorganisms, CO_2 and oxygen may enhance the degradation process.

It is a crucial task to remove cyanide from the environment. Many attempts have been made in this regard. Some of them change cyanide to cyanate or other less toxic or nontoxic components (Ritcey 2005). Bacterial degradation is another method for cyanide removal.

Environmental problems of cyanide in Aq Dareh mine
In spite of the many economic benefits of using cyanide for processing low grade ores and in other industries, its environmental problems related to its toxicity, seepages and dam failures, are a major concern for mining operators and environmental groups.

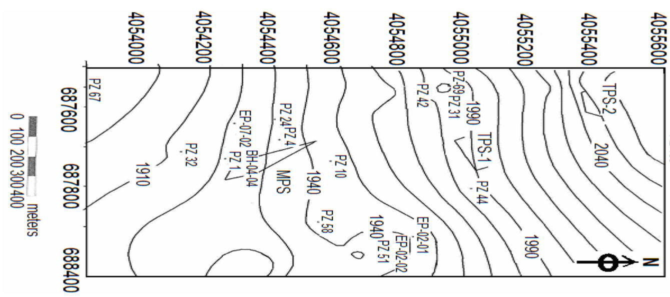
Effluents from the Aq Dareh processing plant contain considerable amounts of cyanide and sulphides. Previously, the tailings at Aq Dareh were disposed as slurry via a tailings dam system without any appropriate water management consideration. The toxic solution containing cyanide and other hazardous materials has spilled through the tailings dam and polluted ground water resources, nearby lands and the Aq Dareh River. For example, an accident killed many types of fish and frogs in the river and the toxic solution reached Takab city and contaminated potable water bodies in the region.

Paste production and storage mechanism in Aq Dareh gold processing plant
In order to reduce environmental problems of tailings disposal in Aq Dareh, a new system called paste production storage mechanism (PPSM) is being used. PPSM involves a kind of thickener with some modifications whereby the pulp loses more water and the solids content reaches about 60 to 70 %; the final product of the thickener has 55 % solids. The PPSM unit is located about 1300 m from the processing plant. The tailings are transported to the PPSM unit by a pump and pipeline. The paste is finally transported to the tailings dam using a displacement pump.

Cyanide recovery in Aq Dareh
About 52.3 % of the water in the processing plant effluent at Aq Dareh is reclaimed and reused in the plant. The output pulp contains 120 ppm sodium cyanide of which about 80 ppm (67 %) is recycled.

Environmental studies on cyanide spill in Aq Dareh mine
In order to control the quantity of cyanide in water around the gold processing plant at Aq Dareh, about 50 samples are taken weekly. The samples are taken from 45 piezometric wells and two springs which are located downstream of the dams. Water is also sampled from a few locations in Aq Dareh River. Figure 3 shows a location map for sampling points.

Figure 3 *Sampling locations in Aq Dareh gold mine*



Even with very low concentrations, cyanide can easily be detected in the samples, which are normally analysed by two methods, titration and photometry. In the photometry analysis method, a full automatic UV device is used which can detect cyanide concentrations below 0.22 ppm. In the titration method, $AgNO_3$ is used as a detector, and can detect cyanide concentrations above 0.22 ppm. Table 1 shows cyanide concentrations in water sampled around the Aq Dareh gold processing plant. In addition to the above methods for analysing water, the cyanide spill is also investigated using a bio-monitoring method, in which the effects of cyanide on aquatic organisms such as fishes are monitored in the springs near to the tailings dams. As Table 1 shows, the use of paste disposal of the tailings in Aq Dareh gold processing plant minimised the cyanide spill problems.

Conclusions
Disposal of tailings of gold processing operations as slurry form poses many environmental and safety problems such as dust generation, dam failure and leaching problems. The use of paste production and storage mechanism (PPSM) limits the pollution problems due to the leaching of cyanide into groundwater aquifers and surface water bodies. The applicability of paste disposal of tailings in Aq

Dareh gold processing plant was examined. The results show that the use of PPSM in the Aq Dareh gold processing plant decreased the pollution problems of cyanide release to the environment. Furthermore, the recovery of a considerable amount of water and dissolved cyanide in PPSM system reduces fresh water and cyanide consumption by about 50 %. In addition, the toxic materials in paste, in particular cyanide, were degraded into non- and/or low-hazardous compounds by biological processes in the soil and by solar UV radiation.

***Table 1** Cyanide concentration in water samples collected around the Aq Dareh gold processing plant (February 2006)(Nick 2006)*

No.	Sampling point	Concentration (ppm)	Analysis method	Water sample	Description
1	P.Z.10	0	Titration	piezometer	north of dam MPS
2	P.Z.22	0.002	Photometry	piezometer	downstream of dam MPS
4	P.Z.24	0	Titration	piezometer	downstream of dam MPS
5	P.Z.25	0	Titration	piezometer	west of dam TPS-2
6	P.Z.28	0.004	Photometry	piezometer	between dams TPS-1 and TPS-2 close to asphalt road
9	P.Z.31	0	Titration	piezometer	west of dam TPS-1
10	P.Z.32	0.05	Titration	piezometer	downstream of dam MPS
13	P.Z.42	0	Titration	piezometer	southeast of dam TPS-1
14	P.Z.44	0	Titration	piezometer	north of PPSM
16	P.Z.51	0	Titration	piezometer	southeast of PPSM, close to road
20	P.Z.55	0	Titration	piezometer	southeast of Agho hill
21	P.Z.58	0	Titration	piezometer	east of storage MPS
23	P.Z.66	0	Photometry	piezometer	southwest of dam MPS, close to asphalt road
25	P.Z.70	0.001	Photometry	piezometer	West of dam TPS-1, close to asphalt road
26	P.Z.91	0.006	Photometry	piezometer	downstream of dam MPS
27	P.Z.97	0	Titration	piezometer	Inside the plant site
28	P.Z.100	0	Titration	piezometer	southeast of plant
29	E.P-01	0	Titration	piezometer	east of PPSM
31	E.P-02(1)	0	Titration	piezometer	southeast of PPSM
33	E.P-04	0	Titration	piezometer	south of dam TPS-2
36	E.P-06	0.001	Photometry	piezometer	southwest of dam TPS-1
38	E.P-07(2)	0	Titration	piezometer	downstream of dam MPS
39	RX	0	Photometry	River	Aq Dareh river, under bridge of Takht Soleiman road
40	RBU	0.015	Photometry	River	Sarough river, under bridge of Shir mard country
41	P1	0	Photometry	piezometer	south part of MPS hill
44	OS-1	0.052	Photometry	Spring	Aq Dareh river bank, under bridge

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