Heavy Metal Pollution Problems in the Vicinity of Heap Leaching No. 3 of Sarcheshmeh Porphyry Copper Mine

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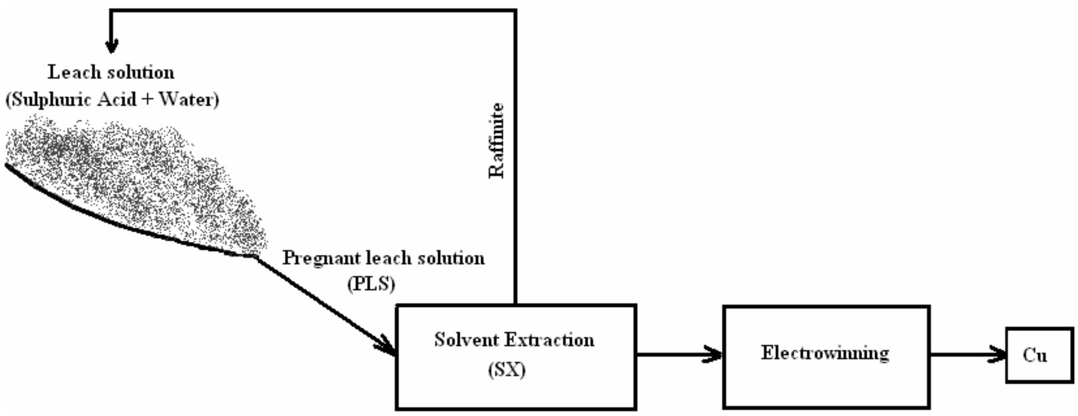
Abstract
Environmental damage resulting from the transport of heap-structure leachate containing elevated concentrations of heavy metals to the environment has occurred due to poor management during the planning, development and operation of the heap leaching process and misunderstanding of the detrimental impacts of heavy metals on human beings, aquatic flora and other creatures. In this paper, the effects of heavy metals discharged from the heap-leaching structure No. 3 of Sarcheshmeh copper mine were investigated by sampling and analyzing water from the Shour River. Samples were taken from upstream, from the entry of leachate into the river, and from downstream of it. Chemical analysis of the samples and field observations show that the concentrations of many heavy metals downstream in the Shour River are very high, which is harmful to the environment. The pH varies from 2.0 to 4.3, and its variations strongly control the mobility of dissolved heavy metals. Heavy-metal concentrations in the water decrease with distance from the heap facility due to dilution by uncontaminated waters and to an increase in pH. Fe is the most rapidly depleted species from the aqueous phase in the river.

Key words: Sarcheshmeh, copper mine, heap leaching, heavy metals, pollution problems

Introduction

Solvent extraction of metals in a heap leaching facility is a novel but widely used method of processing low grade ore deposits of nonferrous ores such as gold, silver, copper and uranium ores. An appropriate solvent is used depending upon the mineralogical composition of the ore to be extracted using the heap leaching process,. The leachates from heap structures contain elevated concentrations of heavy metals and are transported to the solvent extraction unit to separate the metal under investigation. The solvent is then recycled to the heap to leach low grade ores (Figure 1).

***Figure 1** Leaching process in a heap facility*



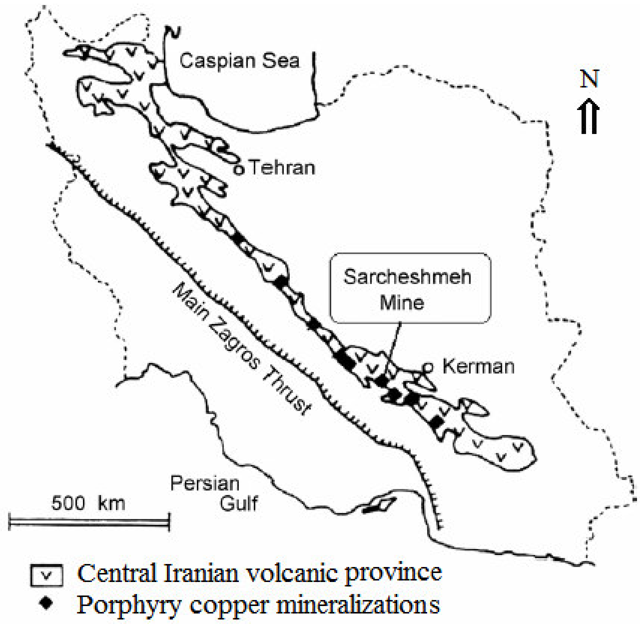
Various aspects of the Sarcheshmeh copper deposit have been previously described by Bazin and Hubner (1969), Ghorashizadeh (1978), Aftabi and Atapour (2000), Banisi and Finch (2001), Doulati Ardejani et al. (2005), Atapour and Aftabi (2007), Shayestehfar et al. (2007), and Majdi et al. (2007).
The environmental problems of heap structures are a major concern. While heap leaching is widely used as part of normal copper recovery operations, the process can produce high volumes of sulphuric acid containing heavy metals and lead to potential environmental damages.To design an appropriate

heap structure, an impermeable base should be constructed in order to prevent heap leachate entering groundwater aquifers and surface water bodies. Although considerable efforts have been made to prevent the acidic leachate containing heavy metals from heap No. 3 of the Sarcheshmeh mine from migrating to downstream environments, most importantly the Shour River.This river is the main stream flowing in the study area, into which the Sarcheshmeh mine drainages are discharged. The hydrogeochemical studies described in this paper show a high concentration of heavy metals and low pH in this River. This should be a warning to mine operators and environmental groups to take appropriate water management steps to control pollution problems arising from the heap. The investigations would facilitate the development of a mine rehabilitation and environmental management plan during the design stage of an open pit mining operation and associated heap leaching structures. The objective of this study was to determine the hydrogeochemical characteristics of the Shour River impacted by heap leaching No. 3 of Sarcheshmeh mine, and to assess the pollution of heavy metals in the river water.

Study area

The Sarcheshmeh copper mine is located in the southern part of Iran, at $29^{\circ} 58'$ N, $53^{\circ} 55'$ E, about 160 km to southwest of Kerman city and about 50 km southwest of Rafsanjan in Kerman province, Iran (Figure 2).

Figure 2 *Schematic diagram showing Sarcheshmeh mine as a part of the central Iranian volcanic province and porphyry copper mineralization associated with the main Zagros thrust [1].*



Materials and methods

A hydrogeochemical analysis was carried out to investigate the impacts of acidic leachate containing heavy metals on the quality of the surface water. Water samples were collected in February 2006 and consist of water from the Shour River coming from Sarcheshmeh mine upstream of the heap facility, acidic leachate from the heap structure, run-off of leachate into the river, and downstream river water impacted by leachates. The water samples were immediately acidified in the field by adding HNO_3 (10 cc acid/ 1000 cc sample).

Equipment used in this study consisted of sample containers, GPS, oven, autoclave, pH meter, atomic adsorption and ICP. The pH of the water was measured using a portable pH meter in the field. Analyses for dissolved metals were performed using an atomic adsorption spectrometer (AA220) in the water laboratory of the National Iranian Copper Industries Co. ICP (model 6000) was also used to analyse the concentrations of heavy metals are detected in the ppb range.

Results and discussion

The results obtained for heavy metals, including Pb, Zn, Cd, Co, Ni, Cr, Mo, Fe, Mn, Cu, and other chemical parameters are shown in Table 1.

***Table 1** The physical and chemical constituents of water samples affected by acidic leachate emanating from heap structure No 3*

Parameter	Sample						
	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Cu (ppm)	410	215	570	100	225	32	83
Mo (ppm)	0.6	0.3	0.1	0.01	0.1	0.01	0.01
Zn (ppm)	475	185	67	10.9	25	1.51	1.13
Cr (ppm)	1.3	0.7	0.2	0.05	0.07	0.05	0.05
Ni (ppm)	130	84.5	2.60	0.72	1.07	0.17	0.15
Pb (ppm)	1.8	1.0	0.4	0.13	0.22	0.18	0.1
Co (ppm)	22.4	12.5	3.9	0.5	1.5	0.17	0.12
Cd (ppm)	3.8	1.7	0.45	0.08	0.17	0.02	0.01
Mn (ppm)	1050	360	215	37.5	62.5	5.5	4.2
Fe (ppm)	4800	1515	38	1.3	2.1	0.5	0.12
Bi (ppm)	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Se (ppm)	<5	<5	<5	<5	<5	<5	<5
As (ppm)	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8
Mg (ppm)	2440	2080	620	92	255	52	48
Ca (ppm)	208	216	208	184	280	176	160
Na (ppm)	48	46	42	34	38	30	30
K (ppm)	9.2	9.0	8.6	6.8	7.0	6.6	6.2
Cl (ppm)	19.6	17.2	16.2	12.8	13.4	14.2	12.4
SO_4 (ppm)	>3000	>3000	>3000	1643	>3000	1023	624
Ec ($\mu s/cm$)	21500	13300	6076	1996	3200	1350	1115
pH	2.0	2.3	3.4	3.8	3.9	4.3	4.3
TDS (ppm)	9110	6536	2574	846	1356	572	472
TSS (mg/L)	23	31	36	17	262	24	6
HCO_3 (ppm)	Tr	Tr	Tr	Tr	Tr	Tr	Tr

S_1= run-off of leaching solution into the River, S_2, S_6, S_7 = River waters impacted by leaching process in the downstream of River

S_3= acidic leachate of heap structure

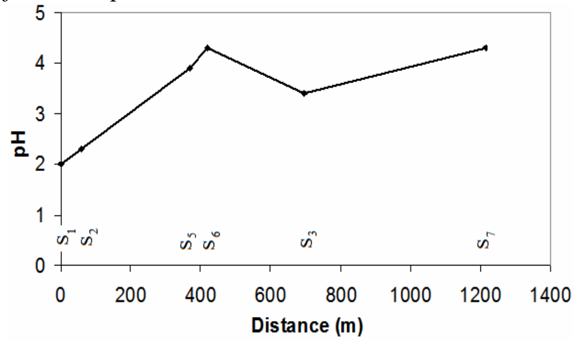
S_4= water from Shour River coming from Sarcheshmeh mine in the upstream of heap facility

S_5= heap leachate mixing with River water

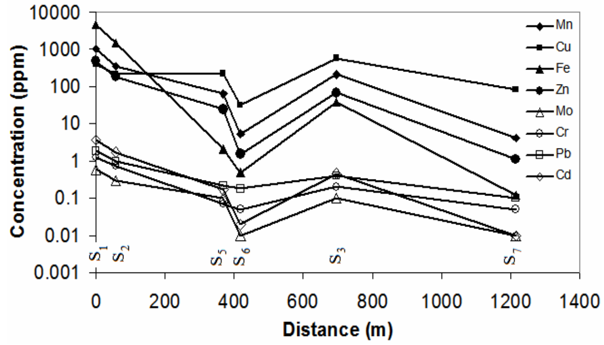
The pH of the aqueous system has an important role in the transport of heavy metals. Figure 3 shows the variations of pH and heavy metals in water samples from different locations in the Shour River. The pH varies from 2.0 (acidic solution run-off) to 4.3 (Shour River impacted by leachate from the heap facility). This range is lower than the acceptable values of pH from any surface mine site (Stiefel and Busch 1983). Due to the low pH, dissolved heavy metals remain in the river water, potentially leading to environmental damage.

Variations in pH strongly control the mobility of dissolved heavy metals, with a typical inverse relationship (Dinelli et al. 2001). As Figure 3b shows, the heavy metals are significantly elevated in water sampled at the points of the river nearest to the heap structure. Concentrations of heavy metals decrease with distance from the heap facility due to dilution by uncontaminated waters and due to an increase in pH. This shows that high concentrations of metals are greatly influenced by leachates from heap structure. The concentrations of most metals are significantly higher than the guideline values specified by US EPA.

Figure 3 *Variations of (a) pH and (b) heavy metals in Shour River water samples versus distance from heap structure No 3*



(a)



(b)

Conclusions

Copper recovery operations using heap leaching can produce high volumes of acid leachates containing heavy metals and potentially lead to environmental damages. In this study, the hydrogeochemical characteristics of the Shour River impacted by heap leaching No 3 of Sarcheshmeh mine were investigated to assess the pollution of heavy metals in the river water. The chemical analysis of the samples show that the concentrations of both sulphates and many heavy metals downstream in the river are very high. The pH changes from 2.0 to 4.3. Concentrations of heavy metals in water decrease with distance from the heap facility due to dilution by uncontaminated waters and to the increase in pH. In the Shour River, Fe is the species most rapidly depleted from the aqueous phase. The heap leaching structure No 3 is the main pollution source at the Sarcheshmeh copper mine, with high acidity and high contents of Fe, SO_4, and toxic heavy metals such as Cu, Mo, Mn, Cr, Ni, Pb and Cd.

Acknowledgments

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