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Andrzej Zuber
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Ewa Kmieciak



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title: **Assessment of the arsenic contamination in groundwater in Hired Gold Mine Zone (Northwest of Nehbandan, Iran)**

author(s): **Elham Damshenas**
Department of Environmental Geology, Shahrood University of Technology, Iran,
elhamdamshenas@yahoo.com

Behnaz Dahrazma
Department of Environmental Geology, Shahrood University of Technology, Iran,
behnaz_dahrazma@yahoo.com

Mahmood Sadeghian
Department of Geology, Shahrood University of Technology, Iran,
sadeghianm1386@yahoo.com

Ali Askari
Geological Survey of Iran, Iran, Askari_48@yahoo.com

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INTRODUCTION

Mineralization in mining zones, as one of natural complex deformations in primary rocks, is responsible for the release, concentration and spill of many heavy and toxic elements as well as metalloids into the water and soil bodies. Generally, gold deposits accompany metallic sulfide minerals and their oxidized products such as pyrite, arsenopyrite, chalcopyrite, sphalerite, limonite, and quartz. Arsenic, cadmium, and antimony minerals usually exist in gold deposits and thus, arsenic pollution is always a concern for these areas (Edinger et al., 2007). Distribution of arsenic in aquatic systems is controlled by pH and Eh (Takeno, 2005). By increasing pH, the concentration of As in water is elevated. Anions such as carbonate, phosphate, and sulfate also affect the mobility of arsenic in water (Villaescusa, Bollinger, 2008). Millions of people suffer from arsenic pollutions, usually with geogenic sources, around the world. Reports indicate several arsenic pollution symptoms in human due to exceeding level of arsenic in drinking water in Bangladesh, Argentina, Taiwan, Mexico, India, and the USA (Borgono et al., 1997; Chen et al., 1994; Del Razo et al., 1990; Dhar et al., 1997; Deschamps et al., 2005; Lasate, 2002). There are six areas in Asia where the groundwater is highly polluted with arsenic, namely, Cambodia, Laos, Pakistan, Myanmar, Vietnam, and Nepal (Zeng, 2003). Arsenic pollution can be accounted for diabetes, kidney disease, cardiovascular diseases, skin lesions, and cancer (Katesoyiannis, Katesoyiannis, 2006; Lackovic, Nikolaidis, 2000). Gold mines can change the concentrations of the heavy metals as well. For example Baba and Gungor (2002) reported that gold mines may cause an elevation on the concentration of Pb and Cd in groundwater. The present research aimed to evaluate the effects of gold mineralization on the arsenic pollution in the groundwater resources in the Hired tin-gold exploration zone, north-west of Nehbandan, Iran.

DESCRIPTION OF THE STUDY AREA

Hired is a mining area located between 59°8'00"E and 59°15'00"E and 31°54'00" and 31°59'00" N with the total area of 97 km². Hired Gold intrusion recently has been accepted as a gold mine. Gold mineralization has been identified in four areas, targets 1 to 4, when the biggest and most important one is Target 1. Mineralogical studies confirm the existence of arsenopyrite as a major mineral in the east of Target 1. Also, a high level of arsenic anomaly was observed.

MATERIALS AND METHODS

To determine the effects of gold mineralization in the quality of the groundwater resources, samples were taken from five qanats and four wells throughout the region and the pH was measured in site. Rock samples were taken for microscopic studies. The concentrations of arsenic in water and rock samples were determined by ICP-MS techniques in the lab.

RESULTS AND DISCUSSIONS

Microscopic studies disclosed the abundance of arsenopyrite accompany with pyrotite and chalcopyrite in the rocks (Figs. 1 and 2). Chemical analysis of the rocks showed that the concentration of arsenic in rocks increases toward south (gold mineralization zone) and ranges between 2.6 ppm and 1835 ppm (Fig. 3).

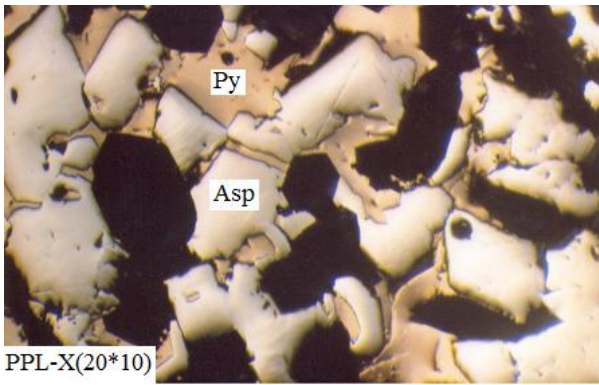


Figure 1. Arsenopyrite (Asp) accompanying pyrotite (Py).

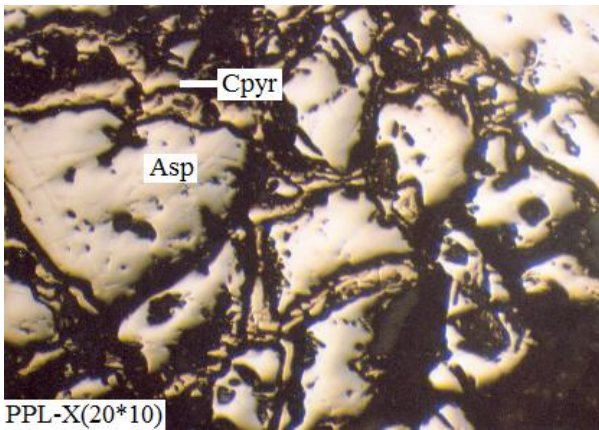


Figure 2. Arsenopyrite (Asp) accompanying chalcopyrite (Cpyr).

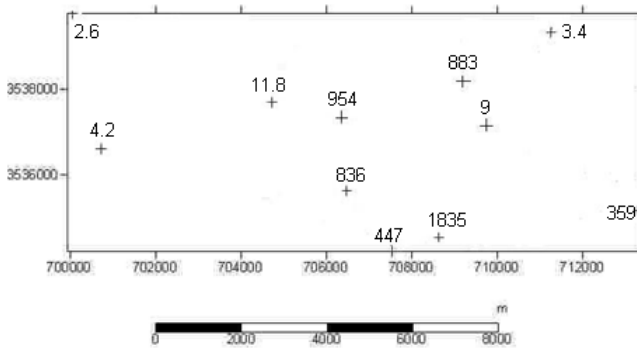


Figure 3. Distribution of the concentration of arsenic in the rocks throughout the region (in ppm).

The pH in wells and qanats of Abrikkeh, Rahimi, Shoorabeh, Alizadeh, Golchin, Lakatoo, Noori, Hematabad, and Hired was recorded at 7.92, 7.80, 7.75, 7.75, 7.33, 8.13, 7.4, 7.45, and 7.57 respectively (Tab. 1).

Table 1. The pH of the groundwater resources in Hired Gold Exploration Zone.

Sample Location	pH
Abrikkeh Well (S6)	7.92
Rahimi Qanat (S5)	7.80
Shorabeh Qanat (S1)	7.75
Alizadeh Well (S10)	7.75
Golchin Well (S2)	7.33
Lakattoo Well (S3)	8.13
Noori Qanat (S9)	7.40
Hematabad Qanat (S8)	7.45
Hired Qanat (S4)	7.57

The concentration of arsenic was as high as 1426.2, 101.8, and 37.3 (in ppb) in Lakattoo, Abrikkeh, and Rahimi respectively as shown in Figs. 4 and 5. The results also indicate a direct correlation between pH and arsenic concentration in water. The highest concentration of arsenic occurs in Lakattoo (1426.2 ppb) which has the highest pH (8.13). Concentrations of arsenic in Hematabad, Hired, Shoorabeh, and Rahimi qanats and Alizadeh, Abrikkeh, and Lakattoo wells are 1.1, 1.3, 1.9, 3.7, 2.2, 10.2, and 142.6 times more than the allowable limit for drinking water.

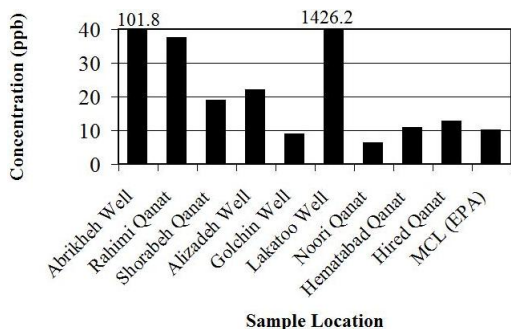


Figure 4. Concentration of arsenic in the groundwater resources in Hired Gold Exploration Zone.

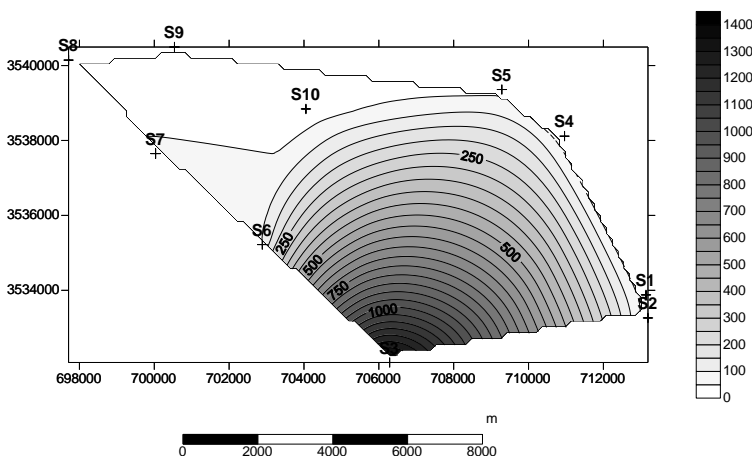


Figure 5. Distribution of the concentration of arsenic in groundwater throughout the region (in ppb).

The high level of EC (ranges from 3800 μS in Abrikhe Well to 13040 μS in Hematabad Qanat) along with the high concentration of arsenic makes the groundwater resources of the region unsuitable for drinking water. In terms of distribution of the concentration of arsenic in groundwater, 4 zones could be identified (Tab. 2). Concentration of arsenic is highest in south-west and north-east of the region.

Table 2. Distribution of As in the mineralization area.

Zone	Sample Location	Position	Avg. As Concentration (ppb)
1	Abrikheh Well and Lakatoo Well	SW	764.00
2	Shorabeh Qanat and Golchin Well	SE	13.70
3	Hired Qanat and Rahimi Qanat	NE	25.00
4	Hematabad Qanat, Noori Qanat and Alizadeh Well	NW	9.96

The highest concentration of arsenic is detected in Zone1, which is charged by groundwater from Targets 1 and 3. The only zone with allowable level of arsenic is Zone 4, located in North West of the region. Arsenopyrite (FeAsS) is the main arsenic mineral in all zones which shows a high anomaly in the gold exploration zone, thus, it can be the main source of arsenic in groundwater.

CONCLUSION

The effect of Hired Gold Mine on the groundwater quality in the whole region was verified through correlation between the arsenic minerals and the concentration of arsenic in groundwater. The highest level of arsenic was detected in Lakatoo Well and Abrikheh (1426.2 and 101.8 ppb respectively). Groundwater in the whole region is highly polluted and it is not suitable for drinking. The concentration of arsenic in rocks showed the same trend and augmented southward. Since the current situation is due to natural geological condition, extreme care should be taken before any attempt for extraction and mining activity in order to prevent more problems in water quality.

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