Measurement of Heavy Metals (Zn, Cu, Fe, Ni, Cd, Co) in Chadormalu Underground Water Resources and Presentation of an Environmental Management Plan

Mohsen Dehghani
Assistant Professor
Islamic Azad University, Department of Environment
Bandar Abbas Branch, Iran
E-mail: dehghani933@gmail.com, Phone: 00989171613922

Alireza Kashefi Ghasem Abadi (Corresponding Author)
Department of Environment
Islamic Azad University
Bandar Abbas Branch, Iran,
E-mail: a_kashefi_90@yahoo.com Phone: 00989131913324

Abstract

Iranian Chadormalu ore mine is located within 180 km northeast of Yazd, 65 km north of Bafgh. Under the present circumstances, this mine enjoys four production lines which produce almost 8.5 million ton/year iron concentrate via direct reduction process for the use of steel manufacturers. The Iron concentrate is shipped by freight trains and trucks to Esfahan's Mobarakeh Steel Company and Khouzestan Steel Company. The area has no resident (other than miners) while closest village is located within 60 km away from the mine. With respect to the mining business running in the respective region, and also given the establishment of this industrial complex close to the wildlife refuge of Anjir-Neybaz Valley, density of heavy metals (including Zn, Cu, Fe, Ni, Cd, Co) existing in the underground water resources of Chadomalu region was measured. The results then were matched to the standards declared by Institute of Standard and Industrial Research of Iran (ISIRI) and World Health Organization (WHO). The current survey indicates that mining operations in Chadormalu do not pollute the underground resources as far as heavy metals are concerned, and density of these metals is lower than the authorized standard maximum. Considering the significance of mining business in the area, an environmental management plan consisting of three elements of Training, Restrictions, and Monitoring was also provided in order to improve the environmental circumstances.

Key words: Chadormalu, heavy metals, underground water resources, water pollution

1. Introduction

The Chadormalu area of Iran has the following geographic coordinates: 32° & 17 minutes of north latitude and 55° & 30 min of east longitude. It is located within 180 km northeast Yazd, 300 km south Tabas, in hillside of Chah Mohammad grey mountains at an altitude of 1410 meter(Darvishzade, 1996). Chadormalu mine with its 400 million ton ore reservoir is located in this area. The mine's annual amount of extracted raw stone is approximately 12.5 million ton which lead to production of 8.5 iron concentrate of 67.5 carat while the Fe & P alloy is almost 0.07 percent(*www.desertiran.co*). This concentrate is shipped by trucks and train wagons to steel manufacturing companies (Mobarakeh & Khouzestan) using direct reduction. The area has no resident (other than miners) while closest village is located within 60 km away from the mine (*www.chadormalu.com*). From a geological point of view, Chadormalu is biggest ever mine in the central Iran which is located in a big geyser zone.

Andezits and Infercamberian riolits has established a relationship between this mine and Pan African mountain-making (*www.ngdir.net*). This area has no permanently running river(Ahmadi, 2008); however, Sepidan seasonal river is the only river running there which flows out from high parts of Anjir Valley desert(Alijani, 1995), moves from southeast toward northwest, and flows into Saghand desert(eghtesad keshavarzy, 2002). This running river, as a natural drainpipe, collects all the rains during the cold quarter of the year and carries it into the Saghand desert. Chadomalu underground water resources are located in the hydrologic part of Saghand (this part is located in the north Anjir Valley's water-flowing area) which is a part of Central Iran zone (Majnoonyan, 2001). The following four water sampling stations were the targets of the current survey: Neyzar well (station 1), Bafgh road well (station 2), well No. 48 (station 3), and well No. 31 (station 4). With respect to the mining business of Chadormalu ore mine, the underground water samples of the respective area were addressed and tested to find if they are polluted with heavy metals such as Zn, Cu, Fe, Ni, Cd, and Co.

Once the samples were taken from the four aforesaid stations (the area's wells) in two seasons of the year (winter & spring), the related analyses were done by the use atomic device and spectroscopy method. The results were finally matched to relevant tables provided by WHO (Geneva, 1993)(B.E. 2528 ,1985), and also to standards defined by ISIRI (1053))(Organization of Hefazate mohyte zyst, 2004)to see if and how much the water samples are polluted as far as heavy metals are concerned. Then, according to the measurements, an environmental management plan was proposed for Chadormalu ore mine.

2. The Under-Survey Location

The Iran's Chadomalu ore mine is located at an altitude of 1450 with the following geographical coordinates: 55° & 30 min of longitude and 32° & 17 min of latitude It is confined by relatively high valleys in south while surrounded by a flat and sandy valley in north(Jamzad, 2002). Access to this area is possible through Yazd-Tabas road. The mine's own road is as long as 57 km which swerves from Yazd-Tabas road around Saghand village, and the mine is located at kilometer 47 of this road. A 197 km railway also links the complex to the country's national railway system around Ardakan city (Geology organization 2000).

3. Methodology

The following four stations were used for the purpose of underground water sampling: Neyzar, station 1; Bafgh road well, station 2; well No. 48, station 3; and well No. 31, station 4). Two samples were separately taken per station during winter and spring. A chemical analysis was performed per sample to measure the heavy metals (Zn, Cu, Fe, Ni, Cd, Co) density. TDS, darkness, TSS, EC, and ph were also measured. The heavy metals density was measured by atomic absorption Shimadzu device, model AA680. The samples absorption then was read by atomic device using density determination method. Considering the fact that Cadmium proportion was low, the related analysis was done by ICP device and the measures were achieved in terms of PBB then turned into milligram/liter (these measure are significantly low). The measurements were finally compared to standards established by WHO (Geneva, 1993)(B.E. 2528, 1985) and ISIRI (1053)(Organization of Hefazate mohyte zyst, 2004). Then, an environmental management plan was proposed based on the field study and investigation done in Chadormalu area (Lee, 1998).

4. Data Analysis

The achieved results are provided as follows for the purpose of data analysis:

The figures indicative of heavy metals (Zn, Cu, Fe, Ni, Cd, Co) density in Chadormalu underground water resources during winter and spring have been respectively provided in Tables 2 & 5b; the other parameters to measure the water level in the under-study wells including the remaining Cl amount, the remaining dry …., the suspense particles,..., electric conduct, and darkness during winter and spring have been respectively presented in Tables …; the full analysis of underground water resources of the area including cations' density, anions, general solidity, temporary solidity, etc. during winter and spring respectively in Tables 7, 8, …; and also the geographical coordinates of Chadormalu area's wells along with their details including the wells' depth, static level, geographical direction, altitude, and geographical coordinates gathered through … device and information available in the mine's archive have been provided in Tables 3 & 6. The locations of these wells (which are active in the mine) indicate that station 1 & 2 including Neyzar spring and Bafgh road well are of the approximately same altitudes and geographical longitudes & latitudes. The chemical analysis done upon the samples resulted in the same measured amounts of chemicals.

The same applies to stations 3 & 4 (well No. 48.31) mainly because of the regions' geology and similar soil. Chemical analysis of the wells' other parameters leads us to this conclusion that well No. 31, well No. 48, Bafgh road well, and Neyzar spring are in the ranks 1-4 respectively as far as Cl amount, dry remaining stuff, suspense particles, and conduction are concerned. The above-said high amounts are rooted in the geographical locations of these well since wells No. 31 & 48 are located in the bed of Sepidan seasonal river which welcomes all the year's rains (considering the respective slope) which, in turn, paves the way for movement of the seasonal river in deserted area, and is of the most effective reasons of increase in the said parameters (Majnoonyan, 2001). To address the density of heavy metals in Chadormalu underground water resources, the achieved results were compared to the so-called "1053 standard" of ISIRI (5th edition). As far as the Table 9 in the said edition is concerned, Cd, Co, Ni in winter and spring are not higher than the maximum authorized standard level. According to Table 10 in the 4th edition of ISIRI's "1053 standard", which was used because standard density of Zn & Fe is not mentioned in the 5th edition,

density of the said chemicals is not higher than the maximum authorized standard level. Standard density of Co is mentioned in none of the said editions. However, with respect to low level of this metal in the two measurement steps, the Co density cannot be problematic. The measured amounts were matched to the maximum authorized standard since the favorite maximum levels have been determined with regard to drinking water quality while the said wells' water is not used for dinking in Chadormalu ore mine (drinking & industrial water of this mine is provided by pumping water from 18 wells in Bahabad located within 80 km of the mine). Taking this fact into consideration that mining operations do not affect the water of these wells, they were not addressed in the current survey. The WHO standards (Geneva, 1993) were also referred to match the measured amounts with the standard levels(B.E. 2528, 1985). The comparison indicated that density of heavy metals including Cu, Co, Fe, Ni, and Zn is lower than the respective standard level. Thus, none of the said heavy metals' density in Chadormalu underground water resources was higher than the authorized maximum standard (Table 11). There is no reference line, table, or description regarding Co.

Table1:Result of measurement of other parameters for Chador Malu underground water

Station number	Station name	CL- mg/li	TDS mg/li	TSS mg/li	pH	Conductivity µs/cm	NTU
1	Nayzar fountion	470.0	2103	16.0	8.42	3270	0.131
2	Bafgh road well	715.0	3442	26.0	8.25	4960	0.262
3	48 well	1778.0	5475	34.0	8.04	8250	0.480
4	31 well	6382.0	15820	52.0	7.55	22000	0.611

Table 2: Result of heavy metal measurement in Chador Malu underground water

Station number	**Station name**	**Cd cadmium mg/li**	**CO cobalt mg/li**	**Cu copper mg/li**	**Fe iron mg/li**	**Ni nickle mg/li**	**Zn zinc mg/li**
1	**Nayzar fountion**	0.0010	0.345	0.328	0.714	0.059	0.010
2	**Bafgh road well**	0.0012	0.256	0.297	0.695	0.055	0.008
3	**48 well**	0.0025	0.413	0.294	0.891	0.061	0.011
4	**31 well**	0.0029	0.647	0.524	0.972	0.063	0.013

Table 3: Coordination of water wells in Chador Malu Area

Explaination	**Static level m**	**Depth well m**	**Station number**	**Station name**
Access depth to water in Nayzar spring : 6 m	-	-	1	**Nayzar fountion**
-	9	59	2	**Bafgh road well**
-	101	138	3	**48 well**
-	136	210	4	**31 well**

Table 4: Result of measurement of other parameters for Chador Malu underground water

Station number	**Station name**	**CL- mg/li**	**TDS mg/li**	**TSS mg/li**	**pH**	**Conductivity µs/cm**	**NTU**
1	**Nayzar fountion**	481.0	2110	14.0	8.44	3430	0.118
2	**Bafgh road well**	700.0	3451	29.0	8.30	4992	0.292
3	**48 well**	1780.0	5521	35.0	8.00	8300	0.525
4	**31 well**	6302.0	16002	54.0	7.49	22021	0.629

Table 5: Result of heavy metal measurement in Chador Malu underground water

Station number	**Station name**	**Cd cadmium mg/li**	**CO cobalt mg/li**	**Cu copper mg/li**	**Fe iron mg/li**	**Ni nickle mg/li**	**Zn zinc mg/li**
1	**Nayzar fountion**	0.0011	0.351	0.319	0.739	0.054	0.011
2	**Bafgh road well**	0.0017	0.249	0.299	0.689	0.052	0.006
3	**48 well**	0.0026	0.400	0.292	0.884	0.059	0.012
4	**31 well**	0.0028	0.655	0.541	0.979	0.066	0.015

Table 6: Description of Chador Malu area wells

1 (Nayzar fountion
Latitude (N) 320/17'/10.9"
Longitude (E) 550/30'/01.2"
Altitude:1601 m
Direction: North

2 (Bafgh road well
Latitude(N) 320/16'/58.0"
Longitude(E) 550/30'/33.8"
Altitude:1604 m
Direction:Souwester

3 (48 well
latitude(N) 320/19'/47.7"
Longitude(E) 550/31'/59.8"
Altitude : 1292 m
Direction: North

4 (31 well
Latitude(N) 320/20'/38.6"
Longitude(E) 550/32'/55.9"
Altitude :1202 m
Direction: Northeast

Table 7: Water Analysis Results for Chador Malu Wells

Sample No	Sample Specifications	Unit	Anions					Cations				
			Co3--	HCO3	SO4--	CL-	∑	Ca++	Mg++	Na+	K+	∑
1	Nayzar Fountain	mg/l	53	200.00	669.00	470.00		28.00	48.00	612.00	13.00	
		mg/eq	1.77	3.28	13.94	13.26	32.25	1.40	3.95	26.61	0.33	
2	Bafgh Rood Well	mg/l	8	154.00	1361.00	715.00		48.00	81.00	964.00	16.00	
		mg/eq	0.27	2.52	28.35	20.17	51.31	2.40	6.66	41.91	0.41	
3	48 Well	mg/l		148.00	1037.00	1778.00		140.00	30.00	1478.00	20.00	
		mg/eq		2.43	21.60	50.15	74.18	6.99	2.47	64.26	0.51	74.23
4	31 Well	mg/l		91.00	2229.00	6382.00		541.00	302.00	4014.00	63.00	
		mg/eq		1.49	46.44	180.01	227.94	27.00	24.85	174.52	1.62	227.99

Continue of Table 7

Sample No	Sample Specifications	Unit	(T D S)	PH	Hardness			Conductivity $\mu s/cm$
					T.H.	C.H.	N.C.H.	
1	Nayzar Fountain	mg/l	2103	8.42	267.50	252.50	15.00	3270
		mg/eq			5.35	5.05	0.30	
2	Bafgh Rood Well	mg/l	3442	8.25	453.00	139.50	313.50	4960
		mg/eq			9.06	2.79	6.27	
3	48 Well	mg/l	5475	8.04	473.00	121.50	351.50	8250
		mg/eq			9.46	2.43	7.03	
4	31 Well	mg/l	15820	7.55	2592.50	74.50	2518.00	22000
		mg/eq			51.85	1.49	50.36	

Table 8: Water Analysis Results for Chador Malu Wells

Sample No	Sample Specifications	Unit	Anions					Cations				
			Co_3^{--}	HCO_3	SO_4^{--}	CL^-	$\sum$	Ca^{++}	Mg^{++}	Na^+	K^+	$\sum$
1	Nayzar Fountain	mg/l	55	195.00	704.00	481.00		25.00	51.00	608.00	12.00	
		mg/eq	1.84	3.20	14.67	13.57	33.28	1.25	4.20	26.44	0.30	32.19
2	Bafgh Rood Well	mg/l	9	160.00	1340.00	700.00		49.00	84.00	950.00	18.00	
		mg/eq	0.30	2.62	27.91	19.75	50.58	2.45	6.91	41.30	0.46	51.12
3	48 Well	mg/l	___	142.00	1042.00	1780.00		138.00	29.00	1481.00	21.00	
		mg/eq	___	2.33	21.70	50.21	74.24	6.89	2.39	64.39	0.54	74.21
4	31 Well	mg/l	___	92.00	2239.00	6302.00		550.00	304.00	4028.00	65.00	

Continue of Table 8

Continue of Table 8

Sample No	Sample Specifications	Unit	(T D S)	PH	Hardness			Conductivity $\mu s/cm$
					T.H.	C.H.	N.C.H.	
1	Nayzar Fountain	mg/l	2110	8.44	272.50	252.00	20.50	3430
		mg/eq			5.45	5.04	0.41	
2	Bafgh Rood Well	mg/l	3451	8.30	468.00	146.00	322.00	4992
		mg/eq			9.36	2.92	6.44	
3	48 Well	mg/l	5521	8.00	464.00	116.50	347.50	8300
		mg/eq			9.28	2.33	6.95	
4	31 Well	mg/l	16002	7.49	2623.00	75.50	2547.50	22021

Table 9: Maximum permissible of heavy metal consistency in potable water. 1053 standard. Institute of standard and industrial research of Iran. (5th revision)

Permissible maximum mg/l	Formula	Havey metal	Row
0.005	Cd	cadmium	1
-	Co	cobalt	2
1	Cu	copper	3
3	Fe	iron	4
-	Ni	nickle	5
3	Zn	zinc	6

Table 10:Maximum permissible of heavy metal consistency in potable water. 1053 standard. Institute of standard and industrial research of Iran. (4th revision)

Permissible maximum mg/l	Formula	Havey metal	Row
0.003	Cd	cadmium	1
-	Co	cobalt	2
2	Cu	copper	3
-	Fe	iron	4
0.07	Ni	nickle	5
-	Zn	zinc	6

Permissible maximum mg/l	Formula	Havey metal	Row
0.003	**Cd**	**cadmium**	1
-	**Co**	**cobalt**	2
2	**Cu**	**copper**	3
5	**Fe**	**iron**	4
0.07	**Ni**	**nickle**	5
3	**Zn**	**zinc**	6

Table 11: Maximum permissible of heavy metal consistency in potable water standard. World Health Organization. (Geneva 1993)

5. Conclusion

With respect to laboratory tests and field studies in Chadormalu mine and Table 3 regarding the region's wells depth, the match of achieved results with ISIRI & WHO's standard tables indicated that mining operations in the Chadormalu ore mine do not pollute the underground water resources as far as heavy metals are concerned, and these metals' density compared to the standard levels is lower than the authorized maximum levels.

Therefore, considering the significance of mining business in the area, an environmental management plan consisting of three elements of Training, Restrictions, and Monitoring was also provided in order to improve the environmental circumstances.

References

Lee, H. L. & Ng, S. M., (1998), "Preface to global supply chain and technology management", *POMS series in technology and operations management*, Vol. 1, Miami, Florida, pp: 1-3.

Alijani, B., (1995), "Iran's weather", *Payamnoor Uni. Publication*.

Edare kolle sazmane havashenasye ostane Yazd, "Amare eistgahhaye havashenasye Chadormaloo & Saghand".

Moasseseye pazhooheshhaye barnameryzy & eghtesad keshavarzy., (Winter 2002), "samandehy naghshehaye santeze ostany jahate santeze melli", *arzyabye manabe va tabaghebandye arazy*, Vol. 1.

Darvishzade, A., (1996), "Iran geology", *Neda publication*.

Geology organization keshvar, (2000)"Naghshe zaminshenasye Chadormaloo ba meghyase 1:100000".

Ahmadi, H,. (2008), "Zheormofologye karbordy (farsayeshe abi)", *Tehran Uni. Publication*.

Perozhe motale'e jame'e mohite zyste keshvar., (March 1994), "vazeiiate mohit zyste ostane Yazd", *edare kolle hefazate mohite zyste ostane Yazd*, Vol. 23.

Majnoonyan, H., (2001), "Manateghe hefazat shodeye Iran (mabany & tadabyre hefazat az parkha & manategh)", *Sazmane hefazate mohyte zyst Publication*.

Edare kolle hefazate mohite ziste ostane Yazd., (2002), "Gozareshy az mohite ziste ostane Yazd".

Organization of Hefazate mohyte zyst., (2004), "Zavabet & Standardhaye zyst mohity".

Notification of the Ministry of Industry No. 12 B.E. Notification of the Ministry of Science, Technology and Energy, B.E. 2528 (1985).

Jalili, A. & Jamzad, Z., (2002)"Red data book of Iran", *Research institute of forests and Rangelands*.

Site ma'adane Chadormaloo: *www.chadormalu.com*

Site mellie dadehaye Oloome zamin: *www.ngdir.net*