N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 5, Number 443 (2020), 21 – 29 **https://doi.org/10.32014/2020.2518-170X.100**

Alireza Ashofteh[1], Ali Abedini[1], Dariush Esmaeily[2]

[1]Urmia University, Urmia, Iran;
[2]University of Tehran, Tehran, Iran.
E-mail: sa.ashofteh@urmia.ac.ir, a.abedini@urmia.ac.ir, dsmaeili@ut.ac.ir

ENVIRONMENTAL IMPACTS ASSESSMENT OF TASH BAUXITE MINE IN SEMNAN PROVINCE, NORTHERN IRAN

Abstract. Mineral resources and mining are the pillars of development in any country. Mining development must be performed based on the pillars of sustainable development to prevent the damage to water, soil, air, plants, wildlife and social life of local communities by exploiting valuable minerals and economic development. Lack of attention towards the pillars of sustainable development in the long-term can turn into serious damages to environment and social life of local communities. There would probably be needed to spend multiple times more than the added value earned by the mineral production in order to recompense the environmental and social damages caused by unauthorized mining. Therefore, from the late 2001 the beginning of mining activities in the Bauxite mine of the village of Tash has caused challenges for the environment, natural resources and social issues. Some of the most important of which are loss of water reserves in the region, the pollution of ground and surface waters, soil erosion, susceptibility of the region to dust, loss of vegetation and rangelands, the endangerment of wildlife, flooding due to inappropriate tailings depot. This paper addresses to the causes of these pollutions and how to stop further damages of the process.

Key words: Environment Impact Assessment, Bauxite, Mineral Resources.

Introduction. The future of Bauxite mines in Iran is based on production of 1.5 million tons of Aluminum to 2025 horizon. Lack of the primary substance of this strategic metal is one of the main challenges of the industry. It has led to the import of Alumina powder into the country. More than 500 thousand million tons of Alumina powder was imported during 2017 and around 70 percent of the primary substance of the Aluminum production units of the country are imported. The Bauxite mine of Tash is located in Semnan province, in Shahroud city next to the village of Tash. It is considered one of the Alumina mines of Iran which is working under the supervision of Iranian Mines & Mining Industries Development & Renovation Organization. This company is the only producer of Alumina powder in Iran. The deposit type of this layered mine is a layer of AlOOH ore and the bedrock of Tash is lime and dolomite deposit. 93 bore holes along with 6573 meters of drilling has been done for further discovery studies. The production capacity of this mine is 300 to 400 thousand tons per year and it is 13.13 km^2. 1.4 million tons of Bauxite has been extracted so far. Against this harvest, 1.86 million tons of tailings were harvested. Tailings up to a ratio of 56 to 1 are also possible. This means to hit rock bottom economically. The ultimate volume of tailings dump is also estimated about 62 million tons [Ashofteh et al, 2019].

1. Geology of the area under study. The lenses of Bauxite of Tash are organized based on textural and mineralogical ingredients which are zoned from the bottom to top with lower clayey layer, shale Bauxite unit, hard Bauxite unit and upper clayey layer.

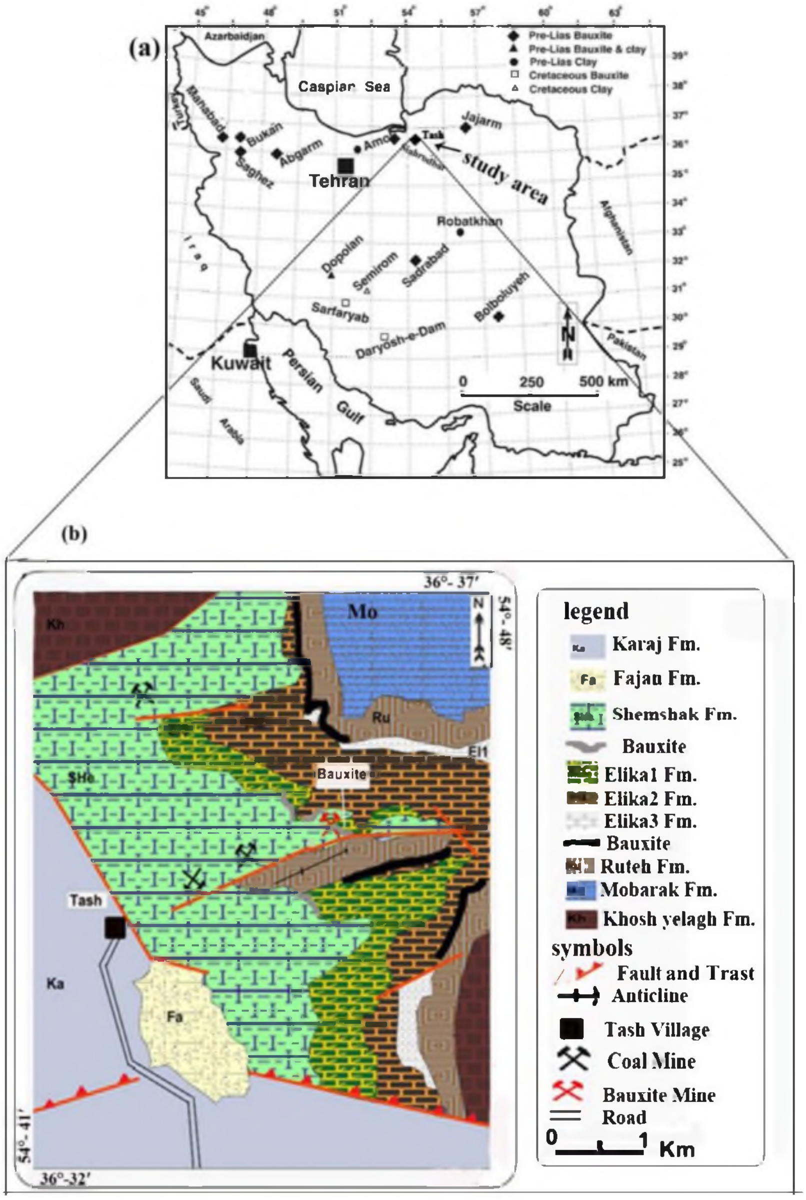

Figure 1 – Map of the geological units of the area under investigation

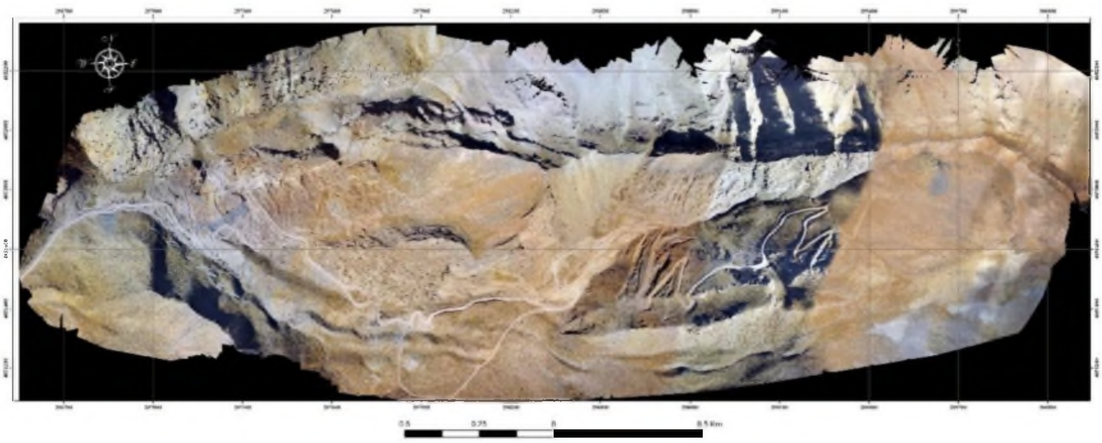

Figure 2 – Satellite image of Tash

1.1. Lower kaolinite layer. This layer is located above the Elika dolomites and under the Bauxite of shale. It is whitish gray and it has 30 to 85 centimeters thickness. The chemical and mineralogical composition of this layer in different parts of the mine is heterogeneous. The main minerals are kaolinite in some parts and in other parts illite and diaspores make up the main ones. This lack of homogeneity is caused by the differences in circumstances in the sediments. This layer is enriched with Bauxite if drainage conditions are appropriate and when the drainage condition is inadequate, clay minerals such as illite and kaolinite are made. This is part of the shale layer that has been separated from the Bauxite by two factors. The first factor is direct contact with carbonate rock which has a totally different condition from shale Bauxite conditions. The other factor is the drainage and fluid motion manner in this layer [Aghanabati, 2006].

1.2. Shale Bauxite unit. This layer is located above the lower kaolinite layer and below the hard Bauxite layer. The thickness of the layer changes based on the sediment's environment. It is mostly 0.5 to 2 meters thick. Shale Bauxite is dark red, brown, usually layered and very fragile. Hematite minerals are often found in the form of nodules. The chemical and mineralogical admixture of this layer mostly shows the enrichment of moving elements such as K, La, Mg, Na, Pb, Rb, Sr and the depletion of elements such as Cr, Ga, Mo, Nb, Th, Zr. This elemental behavior is seen in most karst Bauxite deposits [Nabavi, 1976].

1.3. Hard Bauxite unit. This unit forms the main ore deposit. It is called hard Bauxite, industrial Bauxite, and hard diaspora. It is around 3 to 10 meters thick and is founded in the colors gray, green, red and brown. The Aluminum percentage of this part is very high. It sometimes even goes up to 80 percent. The chemical and mineralogical composition elements reveal the fluctuation of the reductive and oxidizing conditions during the formation of this unit. By the presence of red Bauxite, the oxidation conditions are caused. This process can be ascribed to the exogenous oxidation of iron ores and the formation of secondary iron oxides and hydroxides which is formed in the oxidized environment of the continental margins. In addition to secondary iron ore minerals, anatase, boehmite and diaspora are formed in oxidation conditions in which the admixture of boehmite and hematite reveals the oxidizing and acidic circumstances of the environment. The resuscitation condition is defined with the presence of the green Bauxite enriched with chamosite. The iron needed for these minerals to be made is received from the iron and sulfur oxides of the bacterial revival of the environmental sulfates. Chamosite is formed in low pressure environment with a low pH between 7 to 8 and an Eh higher than -0.2. The amount of active silica is higher in the hard Bauxite than other Bauxite units. This makes problems with Alumina production [Abedini et al, 2019].

1.4. Upper kaolinite unit. This part is hardly found in some parts of the ore under the shales. The chemical and mineralogical admixture of this layer is almost homogenous and mainly made up of kaolinites. It is possible that the Aluminum enriched minerals of this layer be secondary meaning that Aluminum clay minerals including kaolinite and halloysite react and make aluminum minerals because of the similarity of the chemical behavior of Aluminum with silica. New minerals are found in the Bauxites in the kaolinite mettle in the form of veins and membrane. The main part of this layer is destroyed due to erosion. One of the obvious signs of this layer is the presence of concretions and hematite nodules. The separate presence of the Aluminum and iron layers in concretions is the result of subtractive ironing. The formation of concretions is the result of epigenetic processes. The main mineral of nodules are hematite. They are caused by fluctuations in the surface of the ground waters. If there are nucleuses in the centers of the nodules and they also contain concretion circles, they are called pisoid and macro pisoid tissue. If they don't have nucleuses and contain no concretion circles, they are called iron nodules and the texture is called nodular tissue. The low energy level of sediment area and the lack of appropriate nucleuses lead to the formation of this tissue. The existence of concretions and lateritic nodules in the area confirm that the dilution containing silicate gel with other sub-elements along with hematite are shaped in karstic activities [Esmaeili et al, 2010].

Figure 3 – Aerial picture of the Bauxite mine of Tash

2. Geomorphology of the area of study. Mount Shahvar with 4017 meters height is one of the highest mounts of the eastern Alborz mountain which is located in Semnan province. The average height and the maximum mining catchment area 3394 and 3891 meters. One of influential parameter is the vegetation. There are unique varieties in Shahvar region. Onobrychis cornuta and juniperus in the area which grow in steep stopes have an important role in stabilization of the soil and controlling the floods. The areas with steep slopes for example greater than 65 degrees have a very wide mining range. Slope is one of the influential parameters on the amount of runoff, erosion and sedimentation of the basins. The basin slope is also an influential element on the longitudinal slope of the waterways and as a result the energy of surface currents. One of the parameters that affect the surface flow share of total downfall is also the slope. The more is the slope, the less becomes the rally time. Therefore, in steep slope basins, higher discharge can be expected than low slope basins [Abedini et al, 2019].

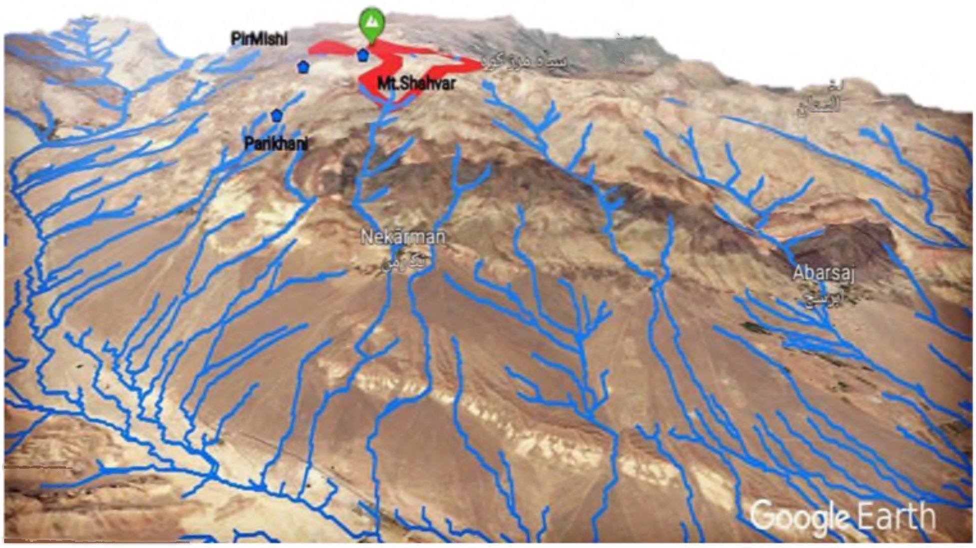

Figure 4 – Basin of Bastam-Shahroud and its gully and river system

3. Environmental issues of Bauxite mining of Tash. One of the most important environmental issues of Bauxite mining of Tash is the disappearance of vegetation, wild life, decrease in animal husbandry.

3.1. Dust creation. Some of the important reasons for the creation of dust and dust in this area are as the following:

Explosions, existence of screeners in the mine, destruction of vegetation, erosion of soil, commuting of the trucks, disposal of tailings and soil, mining machinery activities and incorrect management of waste.

3.2. Threat to groundwater resources. Bastam watershed area is made up of smaller watershed areas which were gathered due to thousands of years of rainfall and storage of rainwater in groundwater aquifers. The entire area of Bastam-Shahroud is made up of storage and and is fed by the reservoir in the basin. The karstic cavities of the limestone in this area are water reservoirs. They are one of the strategic water reserves of Iran. Mining activities specially the explosions has caused a risk of destruction of reservoir rocks of the water resources of the area. Mining is done in the northern borders of the watershed area of Bastam-Shahroud which is next to the watershed of Aliabad in Gorgan. Extensive destruction of the watershed boundary causes the topographic slope to shift northward in the catchment basins. Therefore, the water sheds to the watersheds of Aliabad in Gorgan and as a result the water supply of Shahroud area faces a serious problem. It is possible to extract bauxite from lime formation over 200 million years old up to 800 meters depths. There is a risk of disappearance of water reserves in the area if the open exploitation of the mine continues. Negative influences of mining activities on the water reserves can be stopped by conducting precise studies, banning explosions and gathering extra tails of the mine. Based on the studies conducted, there is 235 million m^3 water in this area which equals the amount of water in the reservoir of the Karaj dam (200 million m^3) which reveals the importance of conservation of this source.

3.3. Pollution of ground waters and surface. There is no proof that confirms the pollution of ground waters and surface with heavy metals like arsenic, plumbum, chromium and nickel but the preliminary studies show that mining activities in the area has caused a rise in the amount of Mg, Al, Si and Na to the density of 1,8 ppm, 273 ppb, 14,9 ppm and 3,5 ppm. Without the mining activities, the densities were 1 ppm, 59 ppb, 0.8 ppm and 0.7 ppm. Based on the declaration of the head of the village of Tash, the amount of water running from Shahvar springs has had a prominent decrease in comparison to the past.

Table 1 – Summery of the data related to Bauxite mine of Tash

Row	Additional Description	Description	Title
1		1986	The first report on the mining potensial
2		2008	Exploratory studies
3		2008	Mineral range registration
4		1300 Hectare	Mineral area
5		2010	Exploration license
6		6573 Meters	Drilling rate for exploration
7		2013	Certificate of discovery
8		2014	Issuance of operating license
9		1,4 Million tons	Mine utilization rate so far
10	The average tailing ratio is 14: 1	1,86 Million tons	The rate of tailings mining so far
11	According to recent studies, it is 8.3 million tons	775 Thousand tons	Total mine storage in license
12	That increased up to 350,000 tons	140 Thousand tons	Annual allowance for mine harvesting
13		300 People	Direct employment in the mine
14		1000-1500 People	Indirect employment in the mine
15		300000 Rial	Cost of exploitation of per ton of Bauxite
16		300000 Rial	Cost of exploitation of per ton of tailings

3.4. Creation of floods due to tailings depot in waterways and valleys and inadequate tailing management. Since the beginning of mining activities in Bauxite mine of Tash, 1400000 tons of Bauxite has been exploited. Against 1860000 million tons of tailings were carried out. Based on previous studies, the amount of dump exploitation in the mine is 14 to 1. The maximum range is 56 to 1 economically. Therefore, during the next years a huge mass of waste (more than 10 million tons) will be created. Inadequate management and lack of a plan to organize this amount of waste is one of the most important challenges of bauxite mine of Tash. Nowadays, tailing dumps are poured into valleys and water ways which leads to high possibilities of flood creations. Floods have caused a lot of trouble in Tash in 2018. Therefore, the most important problems caused are disappearance and destruction of vegetation, blocking the waterways and the threat of destruction of the watershed's border. In other valleys empty of tailing dumps, no flood has happened but in the village flood has happened because of mining depot in the valley and blockage of waterways.

4. Statement of the problem. Water samples of the Tash region were sent to the laboratory of Iran Mineral Processing Research Center and analyzed by the titration method to determine water hardness. The hardness degree of these samples was discovered to be lower than the World Health Organization (WHO) standard. Water hardness was ranked as good adopting Schuler's standard. The TDS parameter was measured by a multimeter to determine water quality. According to the WHO standard, the TDS of all samples except 2W exceeds the standard. The presence of calcareous and marl units as well as long distance passed of water resources can be an explanation for the high TDS. The rise in TDS correlated with mineral activity has resulted in the more dissolution of the material. Assessment of MI and HPI index revealed that all samples were contaminated and non-drinkable. The pH, also known as acidity, is one of the chemical characteristics of water. The "Iran Standard 1053" defines the allowable pH of water between 6.5 and 8.5. The pH measurement of the water samples revealed that their pH concentration ranged from 6 to 8.3. The pH concentration of all samples follows the Iran Standard 1053, but the 2W sample obtained from the contact site of Elika and Shemshak formation has a pH of 6. This shows the influence of Shemshak's coal formation.

4.1. Water quality evaluation based on the Metal Pollution Index. This index is a measure to determine the impacts of heavy metal pollution on water quality. This index was proposed by Tamasi & Cini (2004).

$$MI = \sum_{I}^{N} \left(\frac{ci}{(MAC)i} \right)$$

In which, *Ci* is the concentration of each element in the water and (*MAC*)*i* is the number of the metal element. If *MI*>1, the water is not drinkable. According to this, all samples are consequently contaminated and non-potable. The 2w sample obtained from the Bauxite mine had the highest contamination.

4.2. Water quality evaluation based on the Heavy Metal Pollution Index. This index was proposed by Mohan et al (2008).

$$HPI = \frac{\sum wiqi}{\sum wi} \tag{1}$$

In which, Wi is the weight ratio of the *i*th component, that is calculated by the standard inverse.

$$Wi = 1/Si \tag{2}$$

qi is the quality rate of the *i*th component, that is calculated with the following equation.

$$qi = \sum (Mi(-))/(Si) * 100 \tag{3}$$

In this equation, Mi is the concentration of the *i*th component, and Si is the standard value of the *i*th component. The (–) sign shows the numerical difference of two values, which is neglected. If *HPI*>100, the water is contaminated by heavy metals, and if *HPI* = 100, it is at risk of heavy metal contamination. Ultimately, if it is *HPI*<100, the water is not contaminated by heavy metals.

Table 2 – The concentration of non-metallic cations in water samples

rl	TDS	HCO_3	SO_4	Cl	NO_3	K	Na	Mg	Ca	Sample
0.57	4221	130	19	8	5	1.29	1	22.6	33.9	1
0.72	347	120	22	6	5	1.21	1	18.8	37.9	2
0.68	2727.9	125	25	8	5	1.25	1	20.1	36.2	3
0.72	2463.3	115	22	6	5	1.29	1	19.6	36.9	4
0.75	456	100	33	8	5	1.2	1	19.6	33.3	5
0.70	403.83	110	27	8	5	1.34	1	19.5	36	6
*	600	120	450	250	45	0	200	50	100	WHO

Results. 1. Most samples are higher in TDS than The World International Standard. Rise of TDS in mines can be caused from the mining activities which lead to more dissolution of substances. The existence of lime and marl units as well as long distances to water resources can be a reason for the high TDS.

2. The hardness of the water is rated well based on the Schuler Standard. The hardness in water samples is lower than the WHO standard. The dominant anions and cations are calcium bicarbonate in most samples. Determination of water shows two complexion of calcium bicarbonate and magnesium bicarbonate in the study area. The reservoir is made of calcareous dolomite. Evaluation of ionic index showed that the above index for water samples in the study area is less than one and their class is $Na\text{-}SO_4$.

3. The pH density of the samples differs from 6 to 8.3. The pH value was 1053 Iranian Standard in all samples but the sample taken from the contact site of Elika and Shemshak composition has a pH of 6 which reveals the effect of Shemshak coal composition. Analyze of MI index of all samples are polluted and non-potable. The highest pollution was at the Bauxite mine site. HPI evaluation results revealed that water resources were polluted with heavy metals and were not potable. The highest level of pollution is from northeast of the bauxite mine site.

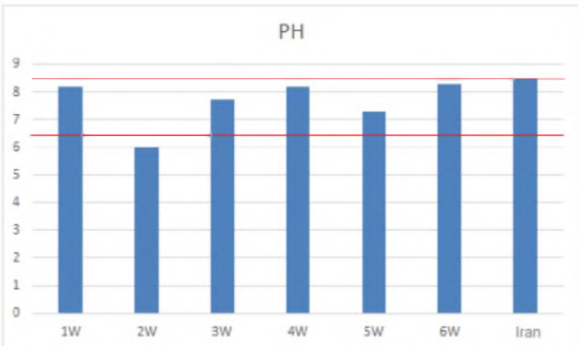

Chart 1 – PH concentration chart of water samples and comparison with Iranian Standard

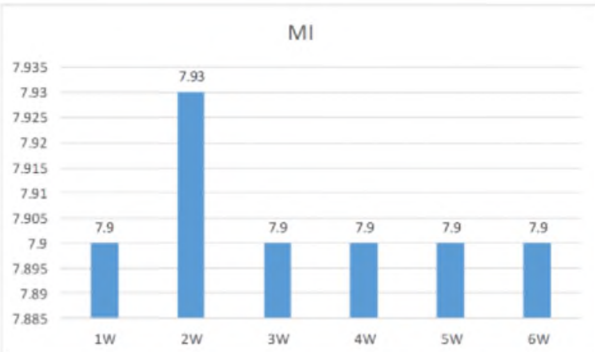

Chart 2 – Diagram of metal index MI water samples

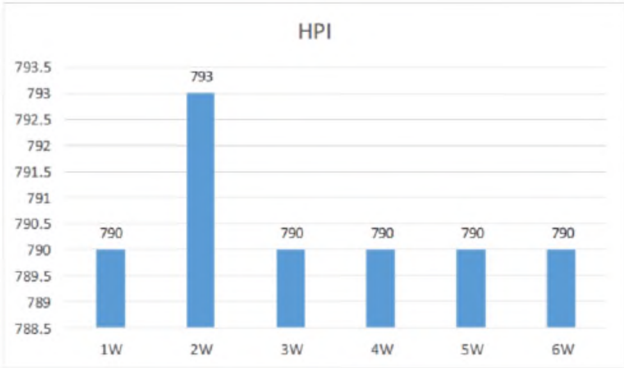

Chart 3 – Diagram of metal index HPI water samples

Suggestions. There are a few suggestions in order to stop more damages and prevent this process.

1. Using sharp drill.
2. Decrease the number of fireworks and work-related scarring.
3. Use of machinery equipped with dust absorption and treatment system.
4. Decrease the slope of the mine dump wall and install drainage covered with clay.
5. Prevention of extraction and loading of bauxite in the area of juniperus.
6. Stopping too much truck traffic or commute back and cleaning the freight root and mulching.
7. Keeping the tailings wet and away from waterways and rivers.
8. On time service of mining equipment and removal of old machinery and collection of burnt oil from the mine.
9. Creation of an artificial channel and lake in downstream to direct floods and build a pipeline to direct surface water.
10. Reconstruction of destroyed areas.

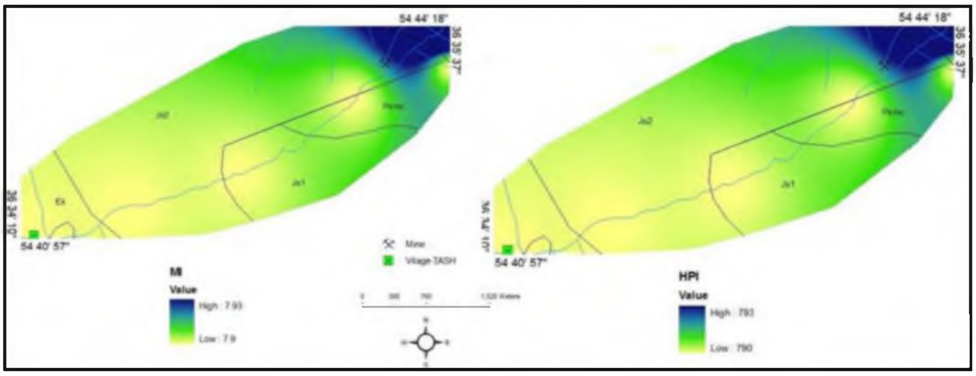

Figure 5 – MI and HP metal index zoning map

Acknowledgement. The authors would like to sincerely express their gratitude CEO of Iran Alumina Company, Eng. Toraj Zare, for his financial and intellectual support that contributed to this research.

Alireza Ashofteh[1], Ali Abedini[1], Dariush Esmaeily[2]

[1]Урмия университеті, Урмия, Иран;
[2]Тегеран университеті, Тегеран, Иран

СОЛТУСТІК ИРАННЫҢ СЕМНАН ПРОВИНЦИЯСЫНДАҒЫ ТАШ БОКСИТ КЕН ОРНЫНЫҢ ҚОРШАҒАН ОРТАҒА ӘСЕРІН БАҒАЛАУ

Alireza Ashofteh[1], Ali Abedini[1], Dariush Esmaeily[2]

[1]Университет Урмия, Урмия, Иран;
[2]Тегеранский университет, Тегеран, Иран

ОЦЕНКА ВОЗДЕЙСТВИЯ НА ОКРУЖАЮЩУЮ СРЕДУ МЕСТОРОЖДЕНИЯ БОКСИТОВ ТАШ В ПРОВИНЦИИ СЕМНАН, СЕВЕРНЫЙ ИРАН

Information about authors:

Ashofteh Alireza, PhD in Economic Geology, Department of Geology, Faculty of Sciences, Urmia University, Urmia 5756151818, Iran; sa.ashofteh@urmia.ac.ir; https://orcid.org/0000-0003-1385-6468

Abedini Ali, Full professor and faculty member, Department of Geology, Faculty of Sciences, Urmia University, Urmia 5756151818, Iran; a.abedini@urmia.ac.ir; http://orcid.org/0000-0003-0615-4855

Esmaeily Dariush, Full professor and faculty member, School of Geology, College of Science, University of Tehran, Tehran 14155-64155, Iran; dsmaeili@ut.ac.ir; https://orcid.org/0000-0001-7296-1909

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