

Monitoring and assessment of pollutants resulting from bench-blasting operations

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Abstract

Nitrogen oxides and carbon monoxide gases together with dust are known as the major pollutants arising during the blasting operations using the ammonium nitrate-fuel oil (ANFO) explosive at the Sungun surface mine, located in the northwest of Iran. The pollutants were monitored during some blasting operations at the mine. It was concluded that the gases and dust clouds initially went up to the peak height, and were then released in the direction of wind flow. A large volume of the pollutants in the form of clouds, which fell at the mine and its surrounding environment, was usually discharged again to the atmosphere due to other mining activities. It was also found that all kinds of pollutants at the mine imposed high risks to the ecosystem of the mine. The maximum concentration of the pollutants belonged to the particles with a size more than 20 microns. The southern part of the mine had a more potential vulnerability than its northwestern part, according to the monthly wind rose diagrams of Sungun. The investigations carried out at the mine and its surrounding environment have indicated that the current traditional blasting operations have discharged a considerable amount of pollutants into the mine and the Arasbaran protected area. The current blasting pattern should be improved, especially through analyzing and changing the stemming materials and length, in order to provide a safe environment for the ecosystem of the mine and the Arasbaran area.

Keywords: *Dust, Toxic Gases, Monitoring, Blasting, Surface Mining.*

1. Introduction

Open-pit and quarry are described as surface mining methods for exploitation of the ore-bodies starting from or near the ground surface. Surface mining activities often cause environmental pollution by producing and emitting dust, toxic fumes or gases. These pollutants can be produced during blasting, loading, hauling, and crushing processes, mineral processing and tailing disposal, waste dumping, and access road construction and development. It is not usually possible to avoid the production of pollutants; they must, however, be controlled. On the other hand, these pollutants can have some unfavorable influences on the ecology and environment, personnel safety and health, and equipment efficiency in the form of increasing depreciation. In order to reduce these

unfavorable environmental impacts caused by blasting based on legal environmental constraints, blasting operations should be accurately designed [1].

Huge tonnages of ore are often extracted by a large-scale surface mining operation, which potentially produces a large quantity of gas and dust. The blasting operation in quarries and open-pit mines usually has a low proportion in producing environmental pollutants, while being the major source of gas and dust generation and emission [2]. The pollutants caused by blasting operations are usually in the form of toxic or non-toxic gas and dust. The toxic ones are mostly carbon monoxide and nitrogen oxides [3].

Dust is defined as a fine particulate matter within the atmosphere, and there is not enough information about its size, shape, and chemical combination [2]. Quantity of the produced and emitted dust as a result of mining activities depends on various factors such as climatic conditions, geological and geomechanical characteristics, mining method, and supplied equipment. The dust quantity caused by blasting is also influenced by geological characteristics, rock engineering factors, porosity and discontinuities, blasting design parameters, and weather conditions. Although the dust resulting from mining activities can cause serious damage and injuries, it includes less components than that induced by urban activities.

Gases discharged after blasting are first separated from the dust, and then move up. Fragmented rock mass moves forward from the bench face after emitting gases and fumes [4]. The moved-up particles can be categorized into the following three groups:

- Coarse particles with a size larger than 500 microns, which fall down near the blasted block during 6 to 15 s;
- Particles with a medium size of 100 to 500 microns, which fall down more than 10 m far from the blasted block, depending on the wind speed and weather conditions;
- Fine particles with a size smaller than 100 microns, which may float within the atmosphere along 10 to 12 km.

A dust cloud consists of suspended fine particles within the atmosphere with the gases and fumes produced by blasting. It usually causes some environmental problems around the mining area.

Experimental Mine of Pittsburgh Research Lab and National Institute for Occupational Safety were used to collect and assess the toxic gas samples produced by the ANFO composition [5]. A research work was carried out as a basis for developing a computer model in order to predict the expected fume production based on the chemical composition.

In 2000, Rowland and Mainiero have studied the effective factors in the production of toxic gases during the ANFO detonation at Pittsburgh Research Lab, and have found that carbon monoxide production increased with increase in the fuel oil content, although nitric oxide and nitrogen dioxide production decreased [6]. Effects of some other factors such as the degree of confinement, water contamination, and aluminum content have also been considered on fume production of blasting agents.

Kumar and Bhandari (2002) have established a simulated model to predict the emission of dust due to blasting; however, they have not introduced any practical applications [7]. In this model, they considered the atmospheric stability with the wind velocity and direction in order to find dust concentrations at different distances from the blasting operation.

Methods used for quantifying the amount of dust production due to the blasting operation have been discussed along with the difficulties related to the dust sampling and quantification by Bhandari et al. [2]. They also proposed water-filled ampoules and balls in order to reduce the generated dust. This study was more exact than the other types of research works on the dust caused by blasting.

Muchnik (2004) has introduced an approach for reducing vertical gas and dust due to blasting at surface mining in order to improve the environment and safety around the mining area [4]. A charge combination has also been proposed for blasting without stemming going-off and gas and dust cloud outburst.

Harris and Mainiero (2008) have concluded that carbon monoxide (CO) might be produced due to blasting in an underground enclosed space [3]. They have also assessed some feasible ways for preventing the production and migration of CO in underground spaces.

A study has been carried out to introduce a new approach for measuring the emissions of NO_x gas by scanning and monitoring the resulting plume from blasting in open-cut coal mining [8]. This approach has been claimed to be simpler and more successful than others in the literature.

The utilization of a multi-scale predictive modelling approach using computational fluid dynamics (CFD) has been proposed for more accurate, numerical modeling of open-pit emissions [9].

A model based on CFD has been presented to predict the emission of fugitive mineral dust particles generated during surface blasting operations in the special wind direction [10]. Furthermore, the paths of the particles have been modelled using the Lagrangian particle tracking.

A CFD model has been developed using the ANSYS CFX 10.0 software to simulate the dispersion of dust resulting from blasting operation in several limestone quarries in the presence of the physical barriers, which were arranged adjacent to the blasting [11].

Bhandari (2013) has represented the modeling of dust cloud due to blasting by its emission and

difficulties in the associated measurements through a certain area [12].

Dhekne (2015) has monitored the environmental impacts of blasting, especially ground vibration, noise, and flyrock through some blast experiments in a limestone quarry [13]. It has been pointed out that gases and dust do not cause a major risk to the people around a quarry.

Environmental challenge is one of the most critical issues resulting from the mining activities in Sungun. In this mine, the environment is mostly polluted during blasting, tailing disposal, and waste dumping. Pollutants in the form of dust and toxic gases, which appear with the dimensions below 100 microns, and can move very long distances, have been reported as the major ones produced during the blasting operation at the Sungun mine. It is noteworthy that Sungun has long cold winters, and consequently, natural ventilation is not possible due to air inversion. This severs the impacts of the pollutants, and accordingly, mining operations may be stopped because of dangerous environment. The authors attempted to monitor the toxic gases, and dust pollutants cause the unhealthy atmosphere for the Sungun mine and the Arasbaran protected area. For this purpose, the authors first sought to find the concentrations of the toxic gases and dust produced during the blasting operations at the Sungun surface mine. Then it was attempted to assess if the pollutants might have bad effects, especially on the mine workers. Some blasts were considered to be operated, and the pollutants were monitored using specific instruments. Afterward, whether the current traditional blasting operations caused the production and discharge of a considerable amount of the pollutants into the mine and Arasbaran protected area was analyzed. Furthermore, a solution was suggested for providing a safe environment for the ecosystem of the mine and Arasbaran.

2. Method and materials

2.1. Sungun copper mine

The Sungun copper collection, located in the east Azerbaijan province and northwest of Ahar, is one of the most important Iranian surface mines [14, 15]. In the Sungun copper region, the estimated geological reserve is approximately 796 million tons of copper and molybdenum with the average grades of 0.61% and 240 ppm, respectively. The total estimated minable reserve is 388 million tons. The copper in the Sungun region is of scarn-porphyry type, which is called the Sungun porphyry copper-molybdenum deposit because of

the high volume of metalliferous reserve within its porphyry part and also the economic significance of molybdenum by-product. In the Sungun region, the porphyry copper ore deposit with phyllic alteration is being mined by the quarrying surface method.

The ore body in Sungun comprises several joint sets. The final quarry plan was designed to the depth of 762.5 m between the levels of 2362.5 and 1600 m with overall quarry slope and face angle of 37 and 68 degrees, respectively [14]. Therefore, a 31-year mine life period was taken into account in four working phases. Totally, 686 million tons of overburden was considered to be removed during the four phases. The production planning of the mine included 5 million tons of ore for the first year, annually, 7 million tons during the 2nd to 6th year and 14 million tons for the rest of the years. The stripping ratio was determined to be 1.68, which indicated 7.5 million tons of the total ore and waste during the first phase.

The Sungun surface mine has been equipped with three drilling machines, five hydraulic system shovels, twelve mine trucks with 50-ton capacities, and different supporting equipment for the production operation [14]. A number of 6095 holes with a total length of 58104 m, producing approximately 1217254 m³ of fragmented ore and waste, were drilled and blasted during the first three months of 2010. The drill holes were charged and blasted in 3 to 4 rounds per day during this period according to the available statistics.

ANFO together with boosters has been used as major charges at the Sungun mine. The most applicable boosters at the mine were 0.544, 0.454, and 0.907 kg. The 0.544 kg boosters were more applicable for 7.5-m bottom length of the blasting holes, whereas the 0.454 and 0.907 kg boosters were used, respectively, for the lengths of 7.5-10 m and 10-14 m. Cortex was used as a detonating cord with relays by the delay timings of 20 and 50 ms. It is notable that the fly rock and ground vibration were reduced by means of the Nonel system at the upper levels of the south of the mine in the approaching administration and laboratory buildings. The most conventional diameters of drill holes at the Sungun mine were 5, 5.5, and 6.5 in.

It was observed that a considerable amount of the blasting gas and dust was emitted to the atmosphere of the Arasbaran protected area, which has been listed in UNESCO as one of the unique worldwide ecosystems, in spite of all the

efforts to avoid the environmental difficulties around the Sungun mine.

Arasbaran is located 7 km far from northeast of the mine. This area covers 72465 ha of a specific land with a perimeter of about 134 km. Its altitude varies between 256 and 2896 m, and there are many rare plant and animal species in this area. Up to the present time, 785 species of various plants have been recorded in the Iranian Botany Journal, 55 species of which have been discovered for the first time. Therefore, it was listed as a wildlife biosphere by UNESCO [16].

2.2. Experiments

Some experiments were carried out in order to monitor the pollutants produced by the blasting operation at the Sungun surface mine. Obviously, a comprehensive design of the experiments was required to guarantee both the quality control and improvement of the experimental process. For this purpose, after having studied all the conditions

and parameters influencing the experimental results, the number of essential experiments was predicted.

The main parameters causing the pollutants as gas and dust as a result of blasting, which had a bad effect on the mine and its surrounding ecosystem, are as follow:

- carbon monoxide (CO);
- nitrogen dioxide (NO₂),
- nitrogen oxide (NO);
- fine and coarse dust.

They are known as the most dangerous sources of pollutants to be monitored at the Sungun copper mine.

2.2.1. Instruments

Table 1 summarizes the utilized instruments and devices for monitoring the pollutants during the experiments carried out at the Sungun copper mine.

Table 1. Instruments and devices utilized for experiments in Sungun.

Name	Application
Grimm 1.108	To measure dust concentration
Scout gas detector	To detect gas by 14 sensors
BW-Gas Alert Max	To alert gas by 4 sensors
Photo and video cameras	To take photos and videos
GPS	To record coordinates
Anemometers	To find wind direction
Digital barometer	To determine air pressure
Digital thermometer	To determine place temperature

2.2.2. Experimental procedure

The experiments were designed only by means of the available monitoring instruments and devices to record the maximum possible volume of the data. Therefore, a set of instruments such as a Grimm (a Scout gas detector, used for measuring CO, NO, and NO₂) was placed in a station during each experiment, and the positions of the stations were chosen in the flow path of the gases and dust clouds. In the best case, it was better to consider the positions of the stations adjacent to the blasting site in case there was no limitation with topography, climatic conditions, and blasting consequences. Each experiment was carried out according the following three steps:

- Step 1 (before blasting): The main processes in this step were coordination with the blasting team, recording the blasting and climatology data on specific forms, recording positions of the blasting site and crest of benches by means of GPS, performing an anemometers in the site, selecting suitable positions for the instruments considering the wind direction and speed, recording the positions of the stations for

instruments, preparing and initially setting the instruments, selecting the positions of the personnel for taking photos and videos during the blasting operation, and determining the C-Factor value. The blasting data were site position, number of holes, rock type, hole diameter, blasting method and system, hole length, and fly rock distance. The wind speed and direction and climatic conditions were recorded as the climatology data.

- Step 2 (during blasting): In this step, the instruments (set in step 1) were automatically turned on before starting the blasting operation, and the related data was continuously recorded. . Besides, cameras were used to take photos and record videos.

- Step 3 (after blasting): Finally, the activities associated with this step were carried out in both the blasting site and Sungun laboratory. The most important ones were turning off and picking up the instruments, collecting the fragmented rocks as samples, assessing the blasting consequences such as fragmentation and

fly rock, transferring the data for gas, dust, and photos from the related instruments to a computer, determining the soil moisture, sending the dust samples to a chemical laboratory, and analyzing the data.

2.2.3. Challenges

The main challenges were in the prediction of the wind direction and climatic conditions during the process of monitoring the pollutants. All the attempts for monitoring gas and dust would fail if the wind direction and dust cloud flow path could not be predicted. The wind direction might be influenced by the mine topography, even though it does not change, and is predictable, which causes some problems during the monitoring process. Before conducting the monitoring process during the main experiments, several blasting operations were initially assessed in different mine locations for more accuracy. The assessment was performed by taking photos and videos, recording the wind speed and direction, recording the stability degree of the atmosphere, and recording the emission of gas and dust clouds.

Another challenge was in selecting the most appropriate positions for the instruments and devices during the pollutant recordings because the wind direction was frequently changing. Besides, the fly rock, air, and ground vibrations, as bad consequences of the blasting operation, restricted the positions of the instruments. Thus normal distances of the fly rock and ground vibration were assessed before the instruments and devices were installed.

Moreover, there were some problems in asking for the permissions in terms of utilizing devices, capturing photos, and recording the data during the blasting operation.

2.3. Results and discussion

In 2014, mining capacity was increased to be double, according to the final production schedule of the Sungun mine. It imposed the use of huge blasts, which produced large amounts of toxic gases and dust. It was difficult to measure the concentrations of gases and dust, taking the gas and dust cloud characteristics into consideration. Other difficulties were the short-time interval for monitoring and the safety issues to set the monitoring devices near the blasting site. The upwind-downwind method, which is the most common method for measuring particulate emissions from a source, was applied for setting the monitoring devices. The safe distance to place the devices from the blast source was determined

where the gas and dust cloud was passed over that in the path of the wind.

After investigating several blasting operations at the Sungun surface mine, it was observed that the gas and dust caused by blasting were vertically directed from the upper parts of the benches. Later, the major part of a blasted rock mass was horizontally directed and fell into the bench face. It meant that gas and dust from the upper part of the blasted holes moved into the atmosphere some time earlier than those from the bench face. The results obtained at the Sungun mine were similar to those obtained by Muchnik [4].

It was also found that the gas and dust clouds initially went up to the peak height, and were then released in the direction of wind flow. The cloud could usually be seen for a few minutes. A great volume of gas and dust was in the form of a cloud felling at the mine and the surrounding environment. Some of the pollutants fallen at the mine were usually discharged again to the atmosphere due to other mining activities like the transportation and hauling operations. The emission of gas and dust was influenced by the climatic conditions such as the wind speed and direction, temperature, and atmosphere stability. Figure 1 shows the outburst of the gas and dust clouds due to the blasting at Sungun. Figures 1-A and 1-B illustrate the beginning and final outbursts of the cloud, respectively. It is notable that the gas outburst decreased the detonation energy and increased the explosive consumption.

The major field experiments for the purposes of monitoring pollutants were performed for several days during the blasting operation at the Sungun copper mine. Finally, two total experiments titled "EXP 03 22" and "EXP 03 30" were regarded as the main pollutant assessments. The second experiment was carried out 6 days after the first one. A summary of the data before blasting (step 1) for the experiments "EXP 03 22" and "EXP 03 30" is, respectively, given in Tables 2 and 3. These tables reveal the blasting pattern, positions of the blasting sites with the stations for the devices and cameras, and the climatology conditions. At the Sungun mine, dust together with the CO, NO, and NO₂ gases was observed as the major pollutant sources, which were produced and emitted due to the blasting operation.

First, all the data recorded by the Grimm 1.108 instrument were analyzed using the related Grimm software in a personal computer to find out the total concentrations of gas and dust. It is notable that the recording and sampling times were set to 6 s for the experiments during the blasting

operation, i.e. the instrument recorded the average concentration of gas and dust every 6 s. The experiment was carried out for several times per day with a 12-minute time duration. Figures 2 and 3 show the charts that indicate the concentrations of the gas and dust recorded by the Grimm instrument for the experiments “EXP 03 22” and “EXP 03 30”, respectively. The concentration charts are represented for the experiments based on the various sizes of dust particles. The interval between two experiments was one week.

As shown in Figures 2 and 3, the maximum concentration of gas and dust belonged to the particles with a size more than 20 microns in both experiments. It was 27033 $\mu\text{g}/\text{m}^3$ and 20779 $\mu\text{g}/\text{m}^3$, as observed during the experiments “EXP 03 22” and “EXP 03 30” (as in Figures 2 and 3), respectively. Table 4 summarizes the maximum volumes of the toxic fumes and gases recorded during the blasting operation at the Sungun mine.

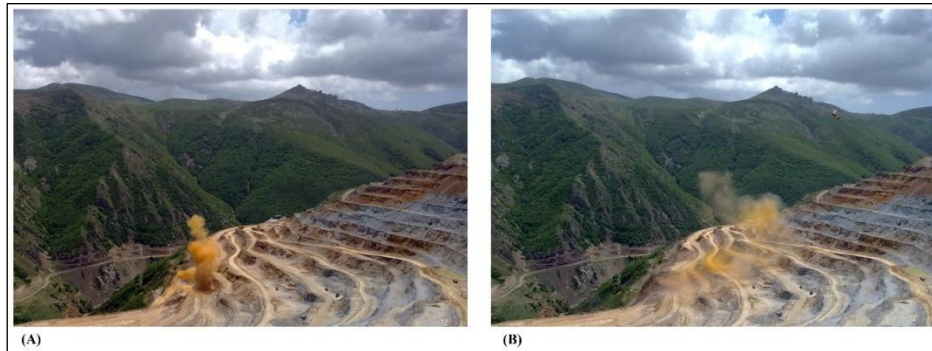


Figure 1. Outburst of dusts and gas cloud at Sungun: (A) beginning time of outburst; (B) final time of outburst.

Table 2. “EXP 03 22” experimental data before blasting operation.

Blasting data																
Rock type	Blasting time	Explosive	Number of holes	Hole diameter (cm)	Burden (m)	Spacing (m)	Average Hole length (m)	Stemming (m)	Specific charge (kg/m^3)	Number of rows	Booster type	Soil moisture (%)				
Monzonite	12:57:49	ANFO	35	12.7	2.93	4.41	11.16	4	0.47	2	2-lb	2.2				
Main recorded positions								Climatology conditions								
Station for cameras		Station for instruments		Blasting site				Wind direction	Wind speed (m/s)	Temperature ($^{\circ}\text{C}$)	Atmospheric pressure (hPa)	Moisture (%)				
1		2	3	4	5	9										
E46° 42' 52.5"	N38° 42' 41.2"	E46° 42' 29.9"	N38° 41' 51.3"	E46° 42' 31.6"	N38° 41' 52.8"	E46° 42' 31.3"	N38° 41' 52.7"	E46° 42' 30.5"	N38° 41' 54.7"	E46° 42' 30.3"	N38° 41' 54.7"	304 NW	3.6	20	776.7	53

Table 3. “EXP 03 30” experimental data before blasting operation.

Blasting data												
Rock type	Blasting time	Explosive	Number of holes	Hole diameter (cm)	Burden (m)	Spacing (m)	Average Hole length (m)	Stemming (m)	Specific charge (kg/m ³)	Number of rows	Booster type	Soil moisture (%)
Monzonite	12:57:12	ANFO	25	16.51	4.41	5.98	11	3.8	0.45	2	2-lb	1.8
Main recorded positions								Climatology conditions				
Station for cameras		Station for instruments		Blasting site				Wind direction	Wind speed (m/s)	Temperature (°C)	Atmospheric pressure (hPa)	Moisture (%)
1		2		3	4	5	9	4	3.8	18	777.1	44
E46° 42' 55.1"		E46° 42' 36.0"		N38° 41' 54.1"	E46° 42' 38.8"	N38° 41' 54.3"	E46° 42' 39.5"	N38° 41' 53.0"				
N38° 41' 40.6"		N38° 41' 54.1"		E46° 42' 39.6"	N38° 41' 54.8"	E46° 42' 38.8"	N38° 41' 53.1"	E46° 42' 39.6"	291 W			

Table 4. Maximum volume concentrations of toxic gases recorded during both experiments.

Experiment	Gas volume (ppm)		
	CO	NO	NO ₂
EXP 03 22	228	28.4	3.8
EXP 03 30	148	32.5	6.2

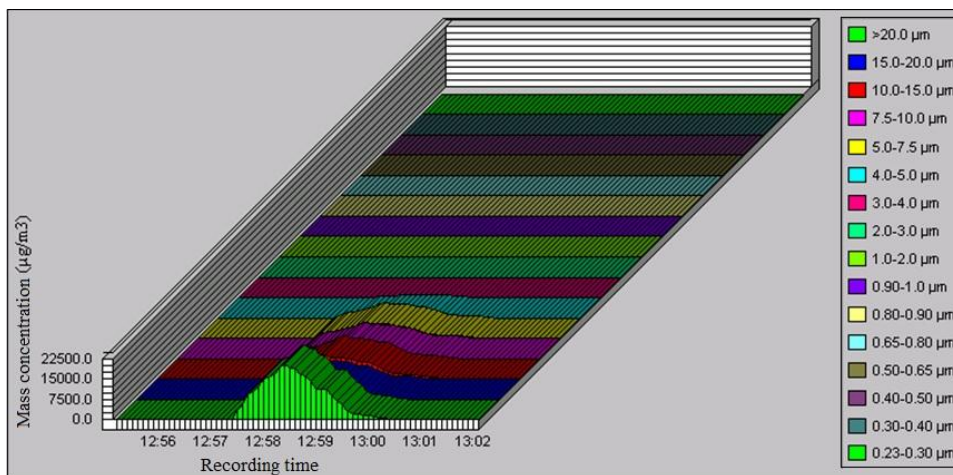


Figure 2. Concentrations of dusts and gases during experiment “EXP 03 22”.

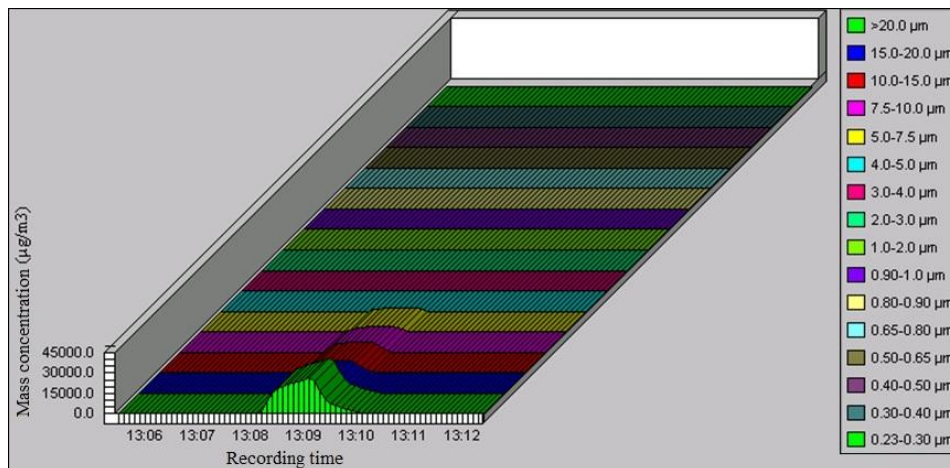


Figure 3. Concentrations of dusts and gases during experiment “EXP 03 30”.

Figures 4 and 5 demonstrate the maximum concentrations of total suspended particulate (TSP) during a certain period of time for the experiments, which were determined to be $54082.72 \mu\text{g}/\text{m}^3$ and $60545.96 \mu\text{g}/\text{m}^3$ during the experiments “EXP 03 22” and “EXP 03 30”, respectively.

It was seen that, during the experiments, the blasting gases were enclosed within the fragmented rocks after a long period of time from the beginning of the blasting operation. These enclosed the pollutant sources that might be suddenly released during other mining operations such as loading and hauling, which could endanger the health of the personnel.

Regarding monthly wind rose diagrams at the Sungun mine, the region can be categorized into the following blasting pollutant parts:

- Part 1: Northwest of the Sungun mine, influenced by the winds blowing from southwest during the cold months;

- Part 2: South of the Sungun mine, influenced by the winds blowing from north during the warm months.

The south part of the mine was more potentially vulnerable than its northwest part because of the low amounts of rain and moisture during the warm months. It meant that high degrees of moisture and rain could decrease pollutants. An area 5-km far from the blasting source can be predicted as an impact zone during the warm months. In other words, the concentrations of the pollutants may be lower at the distances further than 5-km from the blasting source.

The volumes of the gas and dust pollutants were determined, as given in Table 5, considering the amount of ANFO consumed annually during the blasting operation at the Sungun mine.

It is evident that all kinds of the pollutants produced during the blasting operation at Sungun imposed high environmental risks, as given in Table 5. Finally, the investigations carried out at the Sungun mine and its surrounding environments indicated that using the current traditional blasting operation, a considerable amount of gas and dust could be discharged into the mine and the Arasbaran protected area, which may negatively influence the respiratory system of the workers working even up to a distance 3-km far away from the blasting area. In some cases, the pollutants, particularly toxic gases, may cause the death of workers immediately after the beginning of the process. Among the pollutants, carbon monoxide is characterized as a gas without any color, taste, and smell. At normal conditions, from the chemical viewpoint, it is inactive and has a life time of about 2.5 months. The high concentration of carbon monoxide tends to absorb hemoglobin so that it can critically hamper human respiratory metabolism. Nitrogen dioxide can also put human health at risk. The main risk of this gas is in its oxidation and change into a new gas with more toxicity, which negatively influences the respiratory system of humans, and occasionally animals. There are some bad consequences like disorders in the sense of smell, respiration, nerves, and lung, especially when the gas concentration and exposure time are increased at the Sungun mine. It is notable that none of the workforce was present in the Sungun mine during the blasting operation. This meant that approximately 20 min after blasting, no one directly breathed in the gas and dust pollutants resulting from blasting. No serious breathing problem was reported. It can also be resulted considering the main wind direction and location of the Sungun mine. Considering the wind velocity and direction and

the dimensions of the particles, a large amount of the gas and dust pollutants released into the atmosphere of the Arasbaran protected area. As reported, the pollutants would obviously have a serious impact on this area.

In order to reduce the pollutants and solve this problem, the current blasting pattern should be improved, especially by analyzing and changing the materials employed for stemming, and also its length.

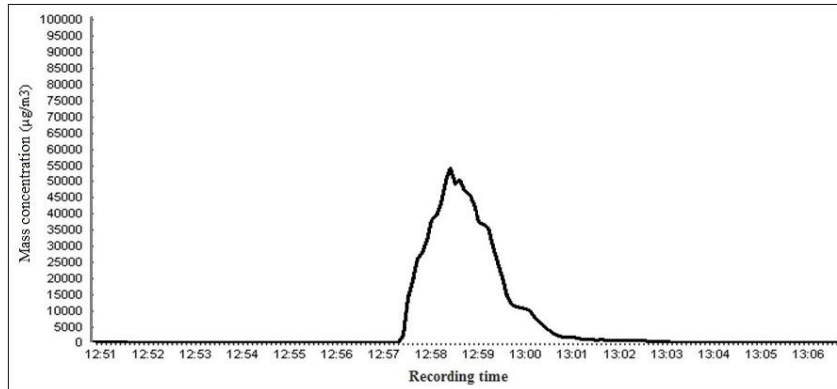


Figure 4. Concentrations of total suspended particulate during experiment “EXP 03 22”.

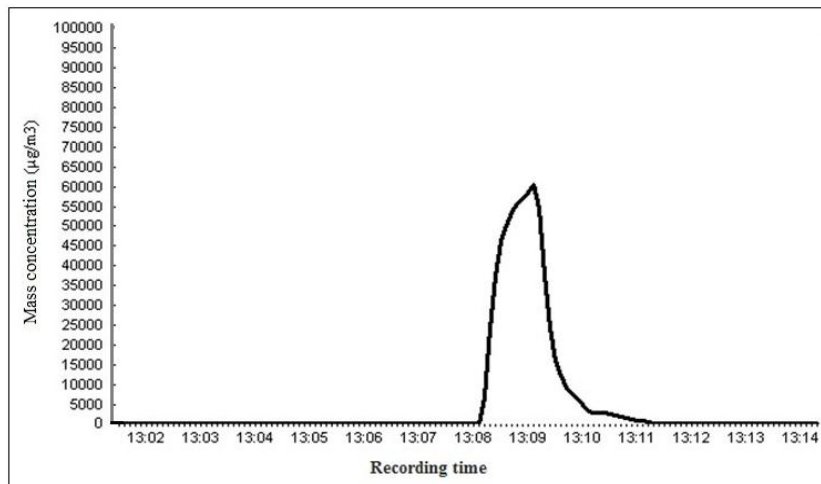


Figure 5. Concentrations of total suspended particulate during experiment “EXP 03 30”.

Table 5. Amounts of consumed ANFO and produced dusts and gases during blasting at Sungun.

Pollutants	Average amount per each kg of ANFO	Annual consumption of ANFO (kg)	Annual amount of emitted pollutants to the atmosphere
CO	8.814 L	2798324.7	24664433.9 L
NO	1.646 L	2798324.7	4606042.5 L
NO ₂	0.24 L	2798324.7	671597.9 L
Dust	4378.92 µg	2798324.7	12253639995.3 µg

3. Conclusions

A large volume of gas and dust was first produced through the blasting operation, especially at the surface mines, and then emitted to the atmosphere. Commercial explosives, as a combination of hydrogen, carbon, and nitrogen, are the major sources of pollutants. There is maximum detonation energy for fragmenting the rock mass if the oxygen equilibrium of the explosive is zero. Gases caused by detonation can appear in the form of steam, carbon dioxide, nitrogen, and some toxic and harmful gases such

as nitric oxide, carbon monoxide, and methane. These toxic gases pollute the mining area and its adjacent environment, which can endanger human (workers), animals, and plants.

CO, NO, and NO₂ gases together with dust were monitored as the major pollutant sources at the Sungun copper mine, which were produced and emitted due to blasting operations. In addition to some minor experiments, the two main experiments “EXP 03 22” and “EXP 03 30” were carried out using instruments such as gas alerts

and detectors, for measuring and recording the pollutants, especially within the mine. It was concluded that a huge volume of the pollutants fell at the mine, and were discharged again to the atmosphere due to other mining activities such as loading and hauling. It was also found that the maximum concentrations of the pollutants belonged to the particles with a size more than 20 microns. A large amount of the pollutants may be discharged into the mine and the Arasbaran protected area using the current blasting operation. A new blasting pattern and the controlling methods for the pollutants, especially by changing the stemming materials and length, can provide a safe environment for the ecosystem.

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پایش و بررسی آلودگی‌های ناشی از عملیات آتشیاری در معادن سطحی

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چکیده:

گازهای منو و دی‌اکسید نیتروژن و منو کسید کربن به همراه گردوغبار به‌عنوان اصلی‌ترین آلودگی‌های ناشی از عملیات آتشیاری در معادن سطحی مس سونگون واقع در شمال غربی ایران شناخته شده‌اند که در آن آفرو خرج اصلی است. در این معدن، این آلودگی‌ها طی عملیات آتشیاری مختلفی مورد پایش و نظارت قرار گرفت. نتایج نشان داد که ابرهای دربرگیرنده این گازها و گردوغبار، نخست تا ارتفاع مشخصی بالا می‌روند و سپس در جهت جریان باد پخش می‌شوند. معمولاً حجم زیادی از آلودگی‌ها که به شکل ابر بوده و در داخل معدن و محیط اطراف آن فرونشسته‌اند دوباره بر اثر سایر فعالیت‌های معدنی به اتمسفر وارد می‌شوند. نتیجه دیگر این که تمامی انواع آلودگی‌ها در این معدن، ریسک‌های زیادی به اکوسیستم معدن تحمیل می‌کنند. بیشینه غلظت آلودگی‌ها به ذرات با ابعاد بیش از ۲۰ میکرون مربوط بود. مطابق با دیاگرام‌های گل‌سرخ‌ی بادهای ماهیانه، بخش جنوبی معدن پتانسیل آسیب‌پذیری بیشتری نسبت به بخش شمال غربی داشت. ارزیابی‌های انجام شده در این معدن و محیط‌زیست اطراف آن نشان داد که طی عملیات کنونی آتشیاری میزان قابل‌توجهی از آلودگی‌ها به محدوده معدن و منطقه حفاظت شده ارسباران وارد می‌شود. به‌منظور ایمن‌سازی محیط برای اکوسیستم معدن و منطقه ارسباران پیشنهاد می‌شود که به واسطه تحلیل و ایجاد تغییر در مواد و طول گل‌گذاری، الگو و طرح آتشیاری کنونی معدن بهبود یابد.

کلمات کلیدی: گردوغبار، گازهای سمی، پایش، آتشیاری، استخراج سطحی.