Mining Rescue
Service of Mongolia

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INTRODUCTION TO MINING: A THEMATIC REFERENCE BOOK



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MINING RESCUE SERVICE OF MONGOLIA

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Content

Foreword

The Parliament of Mongolia enacted amendments to the Minerals Law and Land Law in July 2010; the government adopted a Regulation for Extraction of Minerals by Artisanal and Small-Scale Mining in December of the same year. These enactments provided artisanal miners with the basis upon which to formally engage in artisanal and small-scale mining operations.

With mineral extraction via artisanal and small-scale mining legalised, the regulations requiring individuals engaged in artisanal and small-scale mining to be organised into partnerships, local governments to take areas under local special needs and allow local people to use them on a contract basis, and artisanal and small-scale miners required to rehabilitate mined land have been put into practice for compliance. In addition, individuals engaged in artisanal and small-scale mining have faced an inescapable necessity to engage in mineral extraction only after they have appropriate understanding about, and knowledge of, mining operations.

Therefore, the Swiss Agency for Development and Cooperation (SDC)-supported Sustainable Artisanal Mining (SAM) Project and the Mining Rescue Service have been collaborating on the occupational safety-related issues of artisanal and small-scale mining in Mongolia through a cooperation agreement. Under this cooperation, we have jointly organised occupational safety trainings at least twice a year in those aimags and soums where artisanal and small-scale mining operations take place. Hence, we have designed and published this booklet, which provides a basic understanding about mining operations, including perceptions on how to prevent potential accidents, how to properly excavate, and how to place safety supports for artisanal and small-scale miners with the objective of reducing and preventing potential accidents during artisanal and small-scale mining operations.

P. Urjinlhundev, National Director of the SAM Project

General understanding of mineral resources

Mineral resources are defined as mining rocks from which any type of useful substance or mineral is separated using modern technology. All of Earth's topsoil contains crumbled rocks that contain various types of minerals.

Generally, minerals are classified as emanating from two types of deposits: A crumbled rock or alluvial deposit and a crumbled and unbroken hard-rock deposit in terms of their natural existence and occurrence. This type of classification is pertinent to non-burnable mineral resources. A "classic" representative of these types of minerals is gold. Burnable or flammable mineral resources are usually sedimented, or repeatedly deposited, in sea and ocean bottoms and are formed through high pressure and the effects of temperature.

For example, the process of coal formation began about 300 million years ago and lasted for about 85 million years, according to research. Considerable resources of flora species throughout those years became a coal source material.

The coal we currently use is classified as lignite, bituminous and anthracite depending on the conditions of formation and lasting periods. Coal, as a main representative of burnable or flammable minerals, is dominated by carbon, while also containing many other substances and elements. Similarly, mineral resources of non-burnable ore have a relatively compound structure but at the same time have a single compound. Examples of these types of minerals include gold and diamonds.

Mineral extraction and mining operations are undertaken in the upper parts of the Earth's crust. Earth has the following three compositional layers:

1. The crust (Lithosphere)
2. The mantle (Astenosphere)
3. The core

When we talk about minerals, we inevitably need to talk about mining rocks. What, then, are mining rocks? Mining rocks include those starting from sand and gravel through to the hardest rocks. All these materials contain different types of useful minerals to different extents. Humans learned to separate useful minerals from mining rocks many centuries ago. Since then, they have improved and developed upon what they learned to reach the current technological level. The work undertaken to disconnect and haul rocks from their natural existence prior to mineral separation is called mining works.

The minerals that are dug and extracted from the Earth's subsoil cannot be replenished (if they were to be replenished, it would be beyond the span of current humankind). Therefore, we must be smart and careful when engaging in mining and extraction work. At the least, we must refill mined areas and restore those areas with nutritive soils. However, it is difficult to explain why there has been no progress seen, despite knowledge and discussion about these important tasks. It is an appallingly sinful deed.

Mining works

A set of work related to minerals extraction from open pit and underground mines is called mining works. Mining works in open pit mines include the following primary processes:

1. Drilling
2. Blasting
3. Digging/loading
4. Transportation
5. Unloading mineral-bearing ore at mills and processing plants
6. Stockpiling

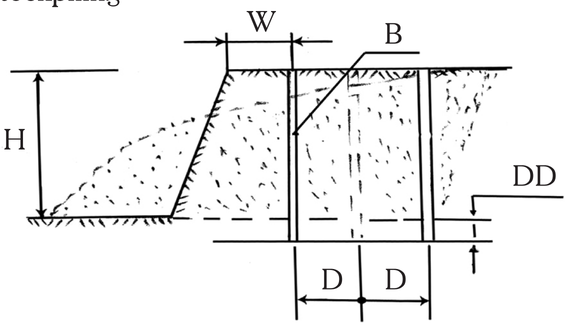


Figure 1. A working platform in an open pit mine after drilling and blasting

H – Height of the bench

W – Width of the safety strip at the edge

D – Distance between the boreholes/Quarries in a row

DD – Depth of additional drilling

B – Borehole/Quarry

Work in underground mines includes the following primary processes:

1. Drilling
2. Blasting
3. Ventilation
4. Supports
5. Loading
6. Transportation

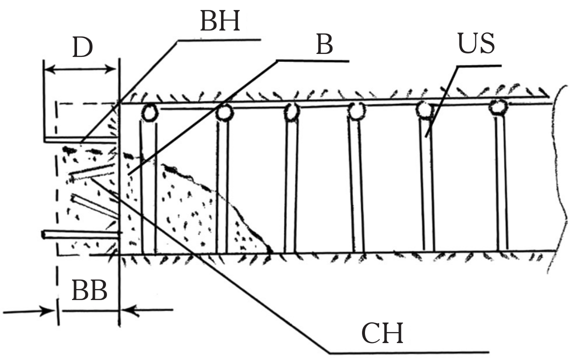


Figure 2. A working platform and bench in an underground mine after drilling and blasting

D — Depth of the blast hole
BB — Bench formed after blasting
CH — Cut hole
BH — Blast hole
B — Bench
US — Underground supports

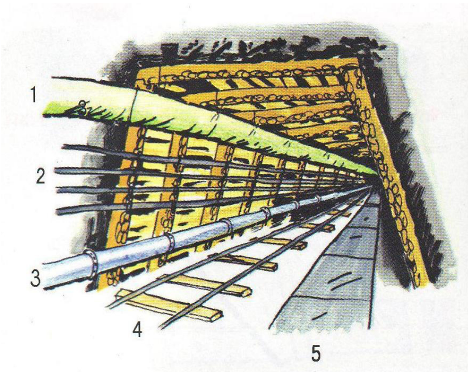


Figure 3. Underground mine (1 - Ventilation duct; 2 - Electric power cable; 3 - Water pipeline, 4 - Railway, 5 - Walkway for workers)

Drilling and blasting are crucial technological components of both open pit and underground mines. Ventilation and safety supports are also particularly important for underground mining works.

Mining work performance is usually dependent on these optimally designed solutions, which provide the basis for the prevention of major accidents and injuries. Each work component related to applicable technologies is also regulated by operational safety rules and regulations, with a specifically designed code and standard.

Openings and excavations in underground mines

An empty space purposely created in the Earth's subsoil for mineral resource exploitation and exploration is called an opening/excavation for mining. For its purposes, an opening/excavation is classified as follows: An opening/excavation for exploration and an excavation for exploitation (mining). Opening/excavations for exploitation or mining are made for main (primary), preparatory and extraction purposes.

Openings/excavations in underground mines are differentiated as vertical (shaft), horizontal (tunnel) and sloped (incline) openings. The following are simple definitions of some popular openings/excavations for different purposes and locations.

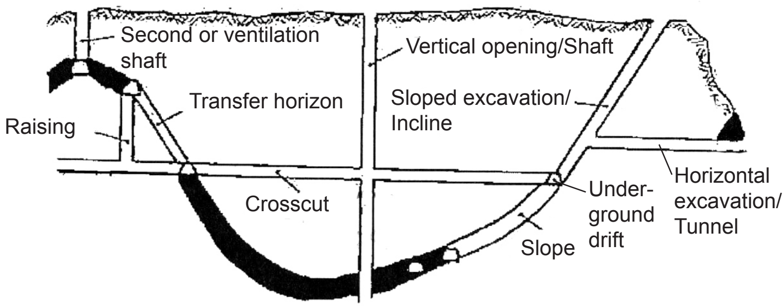


Figure 4. Names of the excavations:

One. Vertical opening (shaft): The main and secondary shafts to a mine are used for the entry and exit of miners, the hauling of materials and minerals, and to allow for the flow of fresh, cool air and the removal of stale or affected air. The main vertical openings (shafts) are the most important “veins” that link operations on the surface to all work below ground in an underground mine.

- A second or ventilation shaft has a direct exit to the surface, with a modest depth and a small cross-section area that is used for ventilation and the hauling of materials both in and out.
- A raising has no exit to the surface and a small cross-section area; it is short and is used for special tasks.

Two. Horizontal excavation (tunnel): This is used for the exploration of mineral deposits. In particular, it is developed in mountainous areas.

- A crosscut has no exit to the surface; it mainly forms angles at the ore body strike area and is used for different purposes, such as for transporting.
- An underground drift has no exit to the surface and is excavated along the ore body strike area and its body or waste rock; it is used for various purposes.

Three. Sloped excavation (incline): This is used for different purposes, including openings for mineral extraction.

- A slope has no an exit to the surface and is excavated below the final level reached by the main entrance through the mineral resource body, ore body or waste rock for different purposes, including the hauling and transporting of minerals.
- A transfer horizon has no an exit to the surface and is excavated above the final level reached by the main

entrance through the mineral resource body, ore body or waste rock for different purposes, including the hauling and transporting of minerals.

Each type of mining work has specific criteria and parameters. For example:

- Changes in the amount of rock mass released from a 1m quarry depending on the diameter and depth of the drilling borehole in an open pit mine
- Inputs (units) of blasting materials
- Ratios of sizes or volumes of excavators' buckets and the backs of trucks used for loading and transporting
- Soil stripping ratio, etc.

In addition to the drilling and blasting work in an underground mine:

- Defining the cross-section areas of excavations/quarries is crucial.
- Types of safety supports and the selection of materials, etc.

Mine requirements

The mining industry and mine works are very difficult and risky activities. Underground mine works in particular are riskier than those in open pit mines. Accident-free and safe performance in a mine is the result of accurate efforts and the right attitude of all personnel, from workers to senior or managing officers of the mine. Everyone working on site must be adequately trained (through demonstration trainings) on how to prevent potential accidents and risks, as well as the appropriate emergency responses. It is important to select and recruit qualified and trained people in the relevant fields, and to remain vigilant while paying particular attention to frequent practices and the monitoring of social issues. It is also important to ensure miners attend trainings on occupational safety and health issues, and to evaluate and test their abilities and knowledge with incentives and rewards.

Although mine requirements have specific details and elements, compliance with the responsibilities and requirements specified in the Law on Occupational Safety and Health is obligatory for everyone working in a mine.

Responsibilities of mine workers

All miners must realise that the health and lives of their co-workers are directly dependent on their actions, performance and compliance with operational safety and health regulations on site.

Figure 5. Miners must regularly be given occupational safety and health instructions

One of the features of a miner's working environment is that the condition of the workplace is often changeable and new with each step forward. Instructions and rules on how to work on a bench and the Law on Occupational Safety and Health are available for use and compliance. However, they are often recognised as general instructions and are used or followed up on in practice based on incidents that have occurred.

Rules and instructions are often refined and advanced; however, it is possible to reflect upon and cover each detail of the changeable and new workplace conditions that are found during the bench-forming process. Therefore, miners must be responsive, calm and self-controlled, careful and thoughtful, and quick to make decisions.

Figure 6. Maintaining regular (daily, hourly and constant) monitoring and control of workplace conditions

The important responsibilities of miners and mine workers include a thorough understanding of, compliance with, and efficient use of rules and instructions pursuant to working in a mine. In addition, miners and mine workers are responsible for ensuring the safety of both themselves and others working on site.

First aid

Injuries are common, from different types of accidents or during regular working processes at a mine. Common injuries include wounds to the body, joint dislocations, broken bones, being pressed or stuck between objects, and other mechanical side effects. Miners and workers can also suffer breathing difficulties due to a lack of air and toxic gas emissions. They can also be hit by blast waves or suffer electric shocks. Therefore, miners should be able to give first aid to victims of accidents.

The immediate and correct application of first aid and emergency services to victims is important for access to further medical services and for saving people's lives and health. Thus, the main responsibilities of miners or mine workers include having a comprehensive understanding of, and the ability to provide, first aid and emergency services.

The appropriate emergency response is dependent on the type of accident. However, it is important to take immediate action to eliminate the cause of injury (such as letting the victim wear a gas mask, freeing the victim from an object under which they may be pressed or stuck, and turning off electricity) prior to the commencement of first aid if the accident situation remains the same.

First aid should be given in sequence, including ensuring the respiratory tract is free from obstruction, undertaking cardiopulmonary resuscitation, and stopping any bleeding.

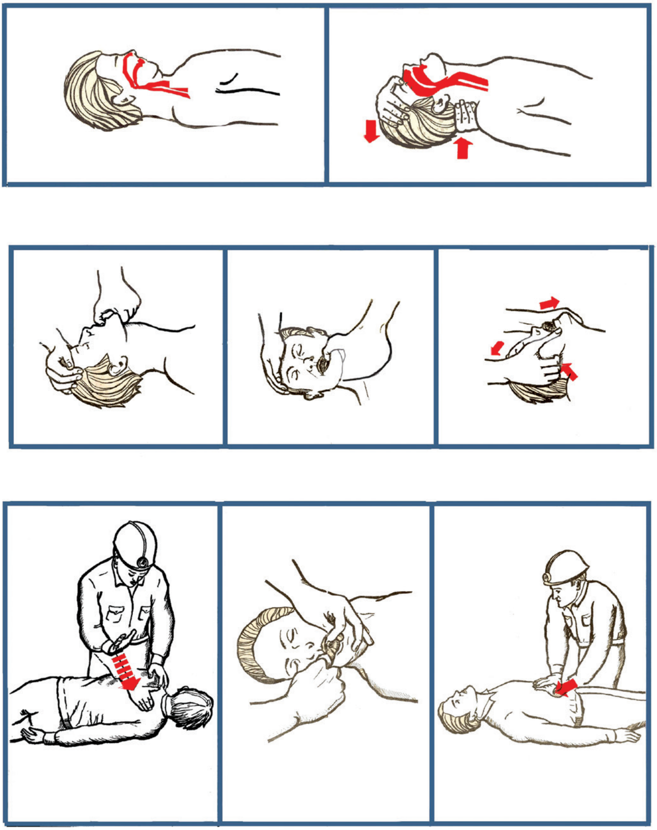


Figure 7. Ensuring the respiratory tract is free from obstruction

In keeping with the sequence suggested above, the person providing first aid should take immediate action consistent with the actual situation. In addition to the provision of first aid, it is also important to immediately report the accident to the relevant bodies/bodies. This will enable the victim to access to medical aid without delay.

Miners and mine workers must be knowledgeable about human anatomy and physiology in relation to first aid. For example, the human body consists of four main parts:

1. Covering such as skin and mucous membrane
2. Supporting or joining parts such as bone and sinew
3. Muscles
4. Veins

These main parts comprise various interacting and functional bodily organisms. For example, they contain skeletal, muscular, blood, respiratory, digestive, excretory, sensory, incretory and nervous systems. The skeletal and muscular system contains bones, muscles and sinews, while the blood circulatory system consists of veins and the heart. Blood vessels have three major types: Arteries, veins and capillaries.

Respiratory organs include the upper respiratory tract (the nasal cavity, the conjunction of the end of the nose and pharynx, and the upper part of trachea), the trachea, bronchi and lungs. This system also includes the diaphragm.

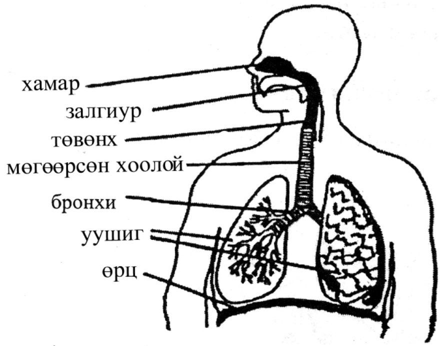


Figure 8. Respiratory organs

The nervous system includes the brain, spinal cord and peripheral veins (branching out from the brain and spinal cord into the rest of body).

The digestive system includes the mouth cavity, pharynx, stomach, small and large intestines, liver and pancreas. Excretory organs include the kidneys, bladder and urinary tract.

Sensory organs include the eyes, ears, skin and mucous membrane, as well as the tongue. Skin protects the entire body from negative external effects, regulates body temperature, and daily excretes 0.5-0.6 litres of liquid sodium along with other substances.

Different types of accidents and injuries can cause death. There are two types of death: Clinical and biological.

A victim is alive for three to five minutes during a clinical death. If first aid is given during this time frame, the victim will recover. If not, clinical death becomes biological or true death.

Clinical death:

- Unconscious
- Breathing stopped
- No arterial pulse
- Mydriatic pupils, unresponsive to light

In such a situation, first aid such as clearing the respiratory tract, cardiopulmonary resuscitation and artificial breathing or airing of the lungs and blood circulation are helpful.

Different organs can be injured in accidents; hence it is necessary to be knowledgeable about the provision of first aid by attending trainings organised in the field.

A first aid kit:

No.	List of items	Quantities
1.	Denatured alcohol (methylated spirits) 15.0	1 piece
2.	Iodine extract 15.0	1 piece
3.	Sterile non-latex gloves	1 pair
4.	Thermometer	1 piece
5.	Flashlight (with batteries)	1 piece
6.	Adhesive wound dressings	10 pieces
7.	Pencil	1 piece
8.	Notebook	1 piece
9.	Safety pins	10 pieces
10.	Non-pointed scissors	1 pair
11.	Adhesive tape (2x40)	1 piece
12.	Roller bandages (6cm, 8cm, 12cm wide)	5 pieces each
13.	Sterile pressure bandage	5 pieces
14.	Sterile cotton bandage (7x14)	1 piece
15.	Cotton (50g)	1 piece
16.	Sterile pads (5x5, 10x10, 20x20cm)	5 pieces each
17.	Triangular cotton bandage (150x150x80cm)	5 pieces
18.	Cotton swabs (100 pieces)	1 bag
19.	Cotton mask	1 piece
20.	Sodium liquid (27.9g)	1 bag
21.	Soap	1 bar
22.	A bag for first aid kit	1 piece

Figure 9. First aid kit

Preventing accidents and injuries

An injury is damage or harm to a body part resulting from an accident.

To prevent potential accidents, the law and regulations on occupational safety and health must be complied with. However, in practice it is difficult to ensure that prevention is a 100 percent guarantee. Thus, it is worthwhile adopting a system of accident insurance.

Unlike other workplaces, mines represent a high degree of risk and accidents. Overall, mine accidents are the result of improper (careless) or erroneous human activities. The main causes of accidents resulting from improper human activities include:

- Carelessness
- Indifference and forgetfulness
- Greediness or a mercenary attitude

- Ignorance
- Apparent rude acts

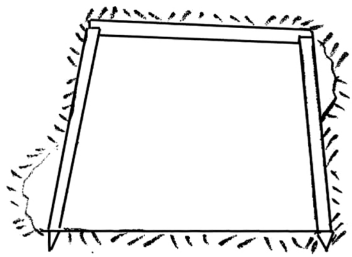


Figure 10. Breaks in excavation walls

Therefore, the prevention and avoidance by miners and mine workers of the improper acts listed above is crucial in order to prevent potential accidents. In addition, safety inspections play an important role.

The legal and regulatory framework for prevention, including international, national, territorial, industrial and mine-level acts and documents, must be complied with in practice.

Each accident should be officially recorded, analysed and assessed to determine the cause and the technical and organisational measures that need to taken in order to prevent a reoccurrence. These actions are some of the major tasks that need to be undertaken in order to prevent potential accidents and to mitigate accident risks. Therefore, it is efficient to broadly mobilise the community and to ensure these types of preventive actions are in place.

Ventilation and air quality in a mine

Airing or ventilation is often regarded as the most important "vein" of a mine. Miners should not be required to enter and work in underground mines with inadequate ventilation. Being asked to work in such conditions is an act of non-compliance with occupational safety and health rules.

The main purpose of mine ventilation is to provide sufficient quantities of fresh air to all working places within an underground mine.

The purpose of ventilation or airing is:

- To adequately replenish oxygen for miners working underground
- To remove toxic and hazardous pollutants, including gases, dust and smoke emitted from underground or underground mining operations

To adequately replenish fresh air in an underground mine, it is important to properly use a ventilation system. Fans should be placed on the surface.

Mechanical ventilation

It is sufficient to use the small fans that provide additional ventilation in large-scale mines. There are also fans available that are powered by electricity and a pump.

In most instances, ordinary fans are used. For mines with longer excavations, centrifugal fans are more suitable for ventilation. It is advisable to regularly check if airing channel resistance and fan pressure are consistent.

A fan with a 400mm diameter, 1.5-3 kWh capacity and ~ 1000Pa pressure is optimal for a 100m long excavation in an underground mine.

Flexible ducts made of plastic material are predominantly used to transmit air blown by the fan.

In relation to the installation of ventilation or airing systems, the following rules should be adhered to:

- There should be no obstacles in the fan's suction
- A protective bar must be placed over the fan
- Undamaged air ducts should be used for ventilation
- When placing an air duct, folding or divergence should be avoided in order to ensure access to free airflows at longer distances
- The end of an air duct should, as much as possible, be closer to the mining bench (for example, it should be at a maximum of 10m in an excavation area with a $4m^2$ cross section)

Mine workers or miners must be provided with normal and safe workplaces, defined by whether there are sufficient quantities of air.

Lack of air has also become a concern for deep open pit mines, and hence considerable funding is directed at resolving this issue.

Normal fresh air on the surface, at sea level:

Gases in air	Concentrations (%)
Oxygen	20,95
Nitrogen	78,08

Carbon dioxide	0,03
Argon	0,93
Other mixture	0,01
Water vapour	0-4

Compared with the air blown by a fan, the air in a mine is polluted. Oxygen is often lost through the toxic gases emitted during mining works, the oxidation process (oxidants), the air exhaled by workers, and the gases emitted from mining rocks and water. Thus, airing or ventilation should be regularly conducted in mines.

A mine must have two excavations through which there are two air ducts: One to introduce fresh and cool air, and another to remove stale or affected air from the mine. Air in a mine contains various gases and dust from raised from minerals and rocks. Mine air predominantly contains concentrations of O_2, N, CO_2, CO, SO_2, NO_2, and N_2O_4, H_2, NH_4, CL (chlorine), and CH_4 (methane) after mining and technological work is undertaken. If the concentration of oxygen (O_2) in the air falls below 13 percent, it is deadly. Below 16 percent, the flames of safety lamps are extinguished. After blasting in a mine, highly toxic gases such as N_2O_4, NO_2 or nitrogen oxides, sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) are present in the air.

The air in an underground mine must be regularly controlled and maintained through airing or ventilation in accordance with occupational safety and health rules. The level of oxygen in mine air is impacted upon by concentrations of the following gases:

- Carbon dioxide (CO_2)
- Sulfur dioxide (SO_2)
- Hydrogen sulfide (H_2S)
- Carbon monoxide (CO)
- Methane (CH_4)
- Hydrogen (H_2)

In addition to these gases, airborne dust in mine air (from coal and rocks) also displaces oxygen. According to the operational safety rules for underground mines, the oxygen content of mine air must be no less than 20 percent. The minimum duration required to ventilate the vicinity of an underground bench is at least 30 minutes; work must be started after the contents of gaseous contaminants are measured.

The table below shows the permissible amounts of gaseous contaminants in underground mine air.

No:	Gaseous contaminants	Chemical formula	Permissible amounts	
			%	mg/m^3
1	Carbon monoxide	CO	0.00160	20
2	Nitrogen dioxide	NO_2	0.00025	5
3	Sulfur dioxide	SO_2	0.00035	10
4	Nitrogen sulfide	H_2S	0.00066	10

If concentrations of these gases are higher than the permissible levels, they pose a threat to human lives and health. Before miners are allowed to enter mine benches, the concentrations of gaseous contaminants in the mine air must be measured and inspected.

In underground mine airflows, the concentration of methane (CH_4) should not exceed 1 percent in mining sections and preparatory and mining quarries, 0.75 percent in mine wings, and 0.5 percent in airflows entering preparatory and mining quarries, as well as in "camera" sections.

The gas content in the air of an underground mine is regularly inspected in accordance with a quarterly work plan that is approved by the mine's chief engineer. The Mining Rescue Service officer measures and inspects concentrations of methane, carbon oxides and oxygen. Hydrogen and carbon oxides occur in coal seams where coal burns naturally and in fumelike areas, while gases such as carbon and nitrogen oxides are emitted after blasting. Gas-resistant rubber containers should be used for air sampling. Sampled air should not be stored for more than 12 hours in the container. The air sampled is analysed in a laboratory under the Mining Rescue Service.

When relative air humidity exceeds 90 percent, the air temperature in mining, preparatory and other quarries should not exceed 26°C. When the air temperature influences normal working conditions, mechanical cooling should be used.

Gases in the mine air

The air in a mine is always in motion. Cold air is present in the lower part, while hot air is present in the upper part.

The air pressure at sea level is 20^0C, with 760mm of mercury column pressure.

Pressure is reduced and becomes sparse as it rises from sea level, changing by 1atm every 12m.

If a person inhales 4-4.5 percent of O_2 and exhales the same percentage of CO_2, the remaining percentage of oxygen (O_2) will be 20.95-4.5=16.55 percent.

The following are details on gases present in mine air.

Oxygen O_2

O_2 is a colorless, odourless and tasteless gas that is slightly denser than air; it is life-supporting, burns, supports outbursts, and has a high level of oxidation. When no oxygen is present, burning and outbursts do not occur. According to the hygienic norm, the level of oxygen present must be at least 20 percent (in volume) in the air. When the oxygen level is 16-17 percent, asphyxiation takes place and fume dies out. When it is 13 percent and 3-4 percent respectively, people die and burning ceases altogether.

Burning: Heat is discharged when a reaction with O_2 (oxidation) takes place. For example, coal burning means $C+O_2 = CO_2+Heat$.

Burning good-quality coal discharges 7000kcal of heat; gas burning discharges 10,000-11,000kcal of heat.

To stop burning in a mine, a cover is used for the reduction of oxygen. When the level of oxygen is reduced, a large amount of carbon monoxide (CO) is emitted ($2C+O_2 = 2CO$).

Carbon dioxide CO_2

CO_2 is a colorless, odourless and tasteless gas that is two times less dense than air. In a mine area, it is emitted from coal ore oxidation and from human exhalations. It does not burn or explode, and it stops oxidation, hence it is widely used in fire extinguishers.

At low pressure, it easily transforms into a liquid form. Carbon dioxide fire extinguishers are used for electrical fires and flammable liquid fires. When the airflow is stablised, it exists at the bottom of an excavation. In a mine, it is likely to accumulate up to 25 percent in shafts such as underground blast holes and raising wells.

According to mining industry operational safety rules, the permissible level of carbon dioxide should not exceed 0.5 percent in the workplace and 0.75 percent in airflows in wings and levels. In the passway (excavation) of a former bench, it should not exceed more than 1 percent.

Carbon dioxide has no particular hazardous effect on the human body, and is used in fizzy drinks and carbonated water.

Toxic gases

If emissions from mine excavations contain CO, NO and SO_2, there are toxic gases present.

Carbon monoxide CO

CO is a colorless, odourless and tasteless gas that is lighter than air. It is toxic and explosive. Large amounts are emitted during mine fires and gas and dust explosions, exploding at 13-74 percent.

CO is extremely toxic. A concentration of 0.01 percent has a toxic effect; 0.1 percent results in death.

According to underground mine operational safety rules, the permissible amount of CO is 0.0016 percent (in volume), 20 mg/m^3.

When inhaled, its penetration capacity into the blood through the lungs is 300 times higher than that of oxygen (O_2). Disintegrating the blood's red corpuscles, it is integrated with iron (Fe). During this process, the following reaction takes place:

$$2Fe + 3CO = Fe_2O_3 + 3C$$

Large amounts of CO accumulate after fires and blasting, as well as in roof parts after excavation work is undertaken in a mine. If it combines with other non-coal organic compounds, it emits other types of toxic gases.

Nitrogen oxides

Chemical formula	Gas names
NO_2	Nitrogen dioxide
NO_3	Nitrate
N_2O_5	Dinitrogen pentoxide
N_2O_3	Dinitrogen trioxide
NO	Nitrogen monoxide

Nitrogen oxide has an acrid smell and is reddish brown in colour. It is water soluble, toxic, denser than air and non-explosive. When concentrations are 0.0025 percent and 0.025 percent respectively, the result is poisoning and death. The permissible amount is 0.00025 percent. Large amounts of nitrogen oxide are emitted after blasting or gas and dust explosions. Due to high pressure and temperature, the following reaction takes place as it combines with N and O_2 in air:

$$N_2 + 2O_2 = 2NO_2$$

Symptoms of poisoning are predominantly seen in the mucous membrane of the mouth and the inner parts of the eyelids.

Sulfur dioxide SO_2

Sulfur dioxide (SO_2) is colourless, has an acute smell and a specific taste, and is toxic. It is denser than air and is water soluble. When it dissolves in water, it has an acidic quality:

$$SO_2 + H_2O = H_2SO_3$$

A concentration of 0.04-0.05 percent may cause death. The permissible amount is 0.00035 percent. It may be oozed out depending on the particular coal properties of a mine. It is emitted during blasting and explosions.

Hydrogen sulfide H_2S

Hydrogen sulfide is colourless and has a pronounced bad odour. It is water soluble, explodes and burns, and is denser than air. At a concentration of 0.025 percent, poisoning occurs, affecting the central nervous system through the respiratory organs. The permissible amount is 0.00066 percent. It is emitted via the decay of organic compounds.

$$H_2S + O_2 = SO_2 + H_2O$$

The most explosive gases in a mine

Readily explosive gases in a mine include CH_4 and H_2. Other gases of organic compounds are also included in this group. Of these gases, the most commonly present is methane (CH_4), which accumulates naturally in large amounts. Degrees of methane accumulation are defined based on the level of emissions from a mine. There are four degrees: One, two, three and four (the highest). Methane is lighter than air and predominantly accumulates in the roof parts of quarries. Methane emissions are classified into two categories:

1. Ooze out (suddenly, in a large amount)
2. Emissions from minerals

Methane is explosive, flammable, non-toxic, colourless, odourless and tasteless.

Mines with methane hazards are listed below based on methane (CH_4) emission levels:

1. $5m^3/t$ (per 1 tonne in an opening)
2. $5-10m^3/t$
3. $10-15m^3/t$
4. More than $15m^3/t$
5. Sudden hazardous emission

Permissible amounts of CH_4 in a mine should not exceed:

1. 1 percent in return airflow
2. 0.75 percent in wing airflow
3. 0.5 percent in the workplace
4. 2 percent in an unused or supported quarry

Methane is explosive in the range of 5-16 percent and burns at more than 16 percent.

Methane is explosive, with a high intensity at 9 percent. Explosion and burning rates are as follows:

1. No explosion if the concentration of oxygen (O_2) is less than 12 percent
2. Burning if the concentration of CH_4 exceeds 16 percent
3. An explosion may occur if the combination of CO, H_2 and CH_4 exceeds 4.3 percent and oxygen (O_2) more

than 12 percent

In explosions, other types of gaseous contaminants are produced as the gases present are broken up.

Hydrogen H_2

Hydrogen is an odourless and tasteless gas that is almost 14 times lighter than air. It is explosive and flammable. According to operational safety rules, an explosion will take place if the composition is in the range of 0.5 percent and 4.3-74 percent in a mine's recharging area.

Free hydrogen (H_2) is poisonous to humans. It is released in large amounts when gas and dust explosions and fires are extinguished with water in a mine:

$$H_2O \rightleftarrows 2H_2 + O_2$$

It accumulates in large amounts in the roof parts of accumulator recharging areas.

The concentration of oxygen in the air of an underground mine is likely to be displaced due to the exhalations of miners and mineral oxidation. The aforementioned gases occur in large amounts as the working areas in underground mines descend lower.

The table below details what happens when the level of oxygen is depleted.

Levels of oxygen (%)	Responses
19	Candle and lamp fumes are reduced by 50 percent
17	Hyperpnea worsens as the concentration of carbon dioxide increases
16	Candle and lamp fumes become smaller

15	A feeling of dizziness and a higher pulse rate
13-9	Loss of orientation, vomiting, headache, lips turn blue, loss of consciousness
7	Loss of consciousness, convulsions, fatality
Less than 6	Fatality/death

When the level of oxygen is displaced, concentrations of other gases increase. When the concentration of oxygen is drastically reduced, even non-toxic gases pose a risk of asphyxiation.

Reminders

When oxygen in the air is displaced, people lose consciousness faster than they would if they sank in water. Loss of consciousness is followed by convulsions and a cessation of breathing. Causes of oxygen displacement in underground mines include:

- Oxygen is captured by water, some types of rocks, ore and coal
- Inhalations by people in limited spaces
- Replacement by carbon monoxide and dioxide, and other gases

In areas where airflows are poorly exchanged, air quality should be regularly inspected and assessed.

Gas-detecting devices

Measurements are taken via various methods. There are a number of relatively affordable methods available to detect a range of gases. One of them is a tube-measurement gas detector that is suitable for artisanal and small-scale mining.

This device consists of a gas-detection tube and a pump for calibration. The pump absorbs the air, which is measured in a measurement tube/channel.

The following gas detectors are required for artisanal and small-scale mining:

- Tube/Channel of oxygen (suitable for any mine)
- Tube/Channel of carbon dioxide (suitable for any mine)
- Hydrogen sulfide (a wet mine)
- Carbon monoxide and dioxide and methane (underground coal mine)
- Sulfur dioxide (sulfide ore mine)

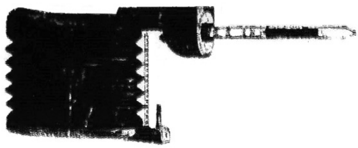


Figure 11. External view of the detector, used for different types of gases

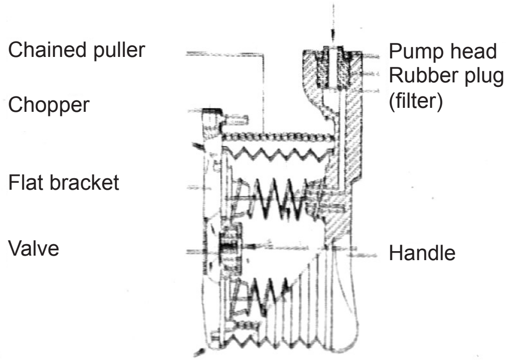


Figure 12. Internal view of the gas detector

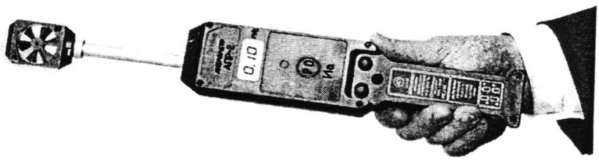


Figure 13. Airflow speed detector

Gas concentrations and locations

It is important for artisanal miners to know where gases are emitted from and are present in a mine.

Depending on their densities, gases in a mine are stored and accumulated in seams, not in its main airflows. Gases are emitted and present in mines, particularly those lacking appropriate ventilation.

The density of methane is almost equal to air density; hence, it is often accumulated in a nearby roof, while carbon dioxide is present on the floor of a mine because its density is higher than air.

Slight differences between gas and air densities do not impact on their locations. For example, the density of carbon monoxide is the same as air, and it is found in the air composition.

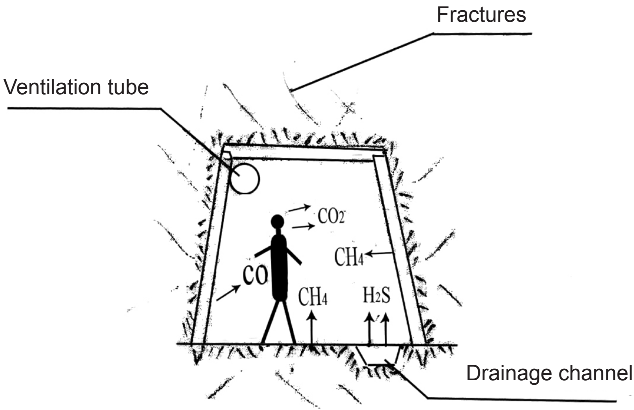


Figure 14. Sources of gaseous contaminants emitted into mine air

The most dangerous gas, given its explosive nature, is methane (CH_4), which is emitted from coal and rocks. In order to prevent the hazards posed by these gaseous contaminants, good-quality ventilation must be provided. In addition to gaseous contaminants, dust particles of different sizes in a mine can cause damage to, and poison, human organs when inhaled; they can also be explosive. Again, good-quality ventilation within the mine is a key means of prevention, as well as ensuring workers are equipped with personnel protective equipment (PPE) and devices and apparatus to suppress the dust. To ensure safety in a mine, the control and monitoring of gas and dust emissions and air quality is vital. For this, various types of gas detectors and measuring devices are used. The "SHI" series detector used in Russia is used for methane and carbon dioxide within a

0-6 percent level within a mine. “GKh” series detectors along with a glass tube containing chemicals to ascertain reactions and measurements are used for different types of gases aside from methane. For example, the “GKh”-M detector is used to detect 12 types of gases.

Some advanced gas detectors and measuring devices used in countries that have a high level of mining technology have been employed in Mongolia, which is advantageous for the country.

Sampling

From air samples taken to determine gas emissions in air composition, the average air quality per cross-sectional area of an excavation/quarry should be defined.

During air sampling, the air temperature is measured and concentrations of methane and carbon oxide are detected using portable devices (such as the “GKh” detector).

Samples of carbon monoxide and methane are taken from an excavation’s roof parts, while samples of carbon dioxide are taken from the bottom of an excavation. Sample containers are prepared using a manual pump for the intake and outtake of fresh air through a rubber/plastic bag. Air is absorbed in the requisite amount and is then tightly closed.

When sampling from an excavation that has a medium cross-section, the person taking the sample stands against the airflow and collects air by moving the container at arm’s length between the roof and the bottom of the excavation/quarry. Because humans exhale 3.6-4.2 percent of CO_2, the sample-taker will avoid this.

Samples from shafts and other vertical excavations are taken in a perpendicular position against airflow in the horizontal area. If pressed by grush five times, smooth five pressures are used for air sampling in all cross-sections.

Safety supports in an underground mine

Before providing details on safety supports in an underground mine, it is important to consider the force applied to the supports and mountain pressure. Mountain pressure and the levels generated in vertical and horizontal excavations are dependent on a range of factors, including the steadiness or hardness of the excavation's medium rocks, the fall angle and fissures, actual depth, the cross-sectional area of the excavation, the type of excavation, the technology and techniques used in the excavation, and the distance from other excavations.

Although accurate pressure estimation is an important indicator, it is barely defined in practice.

Figure 15. Wooden frame supports

Collapses often occur when empty spaces and imbalances around those spaces are created in mountain rocks as a result of excavation.

A roof collapse due to the Earth's gravity is more intense.

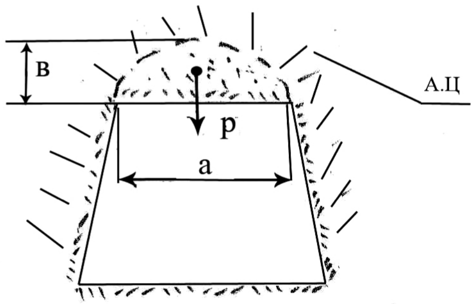


Figure 16. Pressure on a quarry/excavation roof

B — Depth of empty space in a roof resulting from collapse

P — Force giving pressure

A.Ц — Fissure in the rock

a — Width of the excavation roof

What is mass pressure (rock strength)? It is defined in many ways. For the purpose of this guide the theory of M.M.Protodyakonov is used, which determines mass pressure by the weight of collapsed rocks within a natural imbalance zone.

Wooden frames have long been used for safety supports in mines. However, in recent years wood has been replaced in order to maintain the environmental balance and to protect forest resources. Wooden safety supports are not a long-term solution; they decay within three years and are flammable. Replacing them with more durable and longer-lasting materials, such as metal and concrete, is desirable.

Other materials such as anchors, sprinkled concrete supports, and chemicals injected between rock fissures for hardening have also been introduced. The rocks surrounding excavations are supported and made stable to prevent loosening and potential collapse. However, considering current practice, the use of wooden frames for mine supports should be retained.

Therefore, artisanal and small-scale miners need to learn about, and be trained in, the use of wooden frame supports. The main technical specifications of wooden frame supports include varieties, dampness and the diameter of wooden materials. In practice, 10 percent of wooden frame supports is potentially reused. Cross-sections of the excavations supported by wooden frames become smaller and the supports are built in the shape of a trapezium in most instances. Constructing supports of this shape is labour-consuming; however, supports can be of different shapes. Wood used for mine supports must be peeled off, and its life span and durability can be increased with the use of substances that prevent decay.

Metal supports are placed in main and preparatory excavations that are to be worked for more than three years.

In comparison with wooden frame supports, more than 30-50 percent of metal supports are potentially reused. Cross-sections of excavations supported by metal are more than those supported by wooden frames, with supports built in different shapes. It is important to fully stuff empty spaces behind all frame-shaped supports, avoiding the potential concentration of mountain pressure on a single point.

Anchor supports, which are widely used in current practice, differ from frame-shaped supports and are regarded as being efficient for well-matched areas. Anchor supports can be made of wood, metal and plastics, and can be combined with other types of supports. These combined supports are more reliable.

For excavations to be used for a longer time period, concrete, iron concrete and cast supports are used.

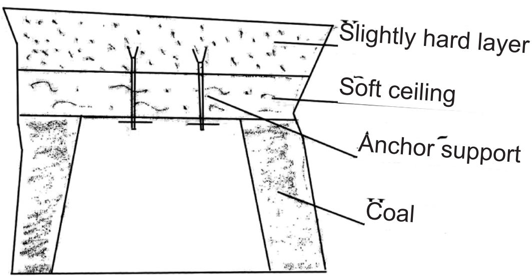


Figure 17. Anchor supports

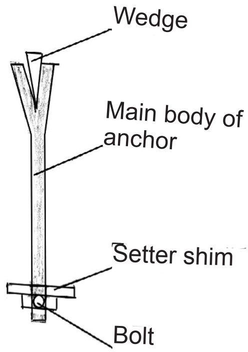


Figure 18. Anchor support for placing

Reinforced iron concrete is also used for supports, and is used in excavations dug by access machinery.

In recent times, sprinkled concrete supports have been widely used. This type of support is a mixture of cement, sand and other binding agents. It is sprinkled via high pressure between rocks to fill and bind in order to prevent potential collapses.

Three to four centimetre-thick sprinkled concrete supports are able to bear one tone of mass without a binding mixture.

Overall, excavation supports are used for the following purposes:

- To restrict, limit and protect
- To prevent the potential breaking of collapsed rock mass (in motion) into excavation areas
- To prevent rock collapses by reinforcing and hardening rocks

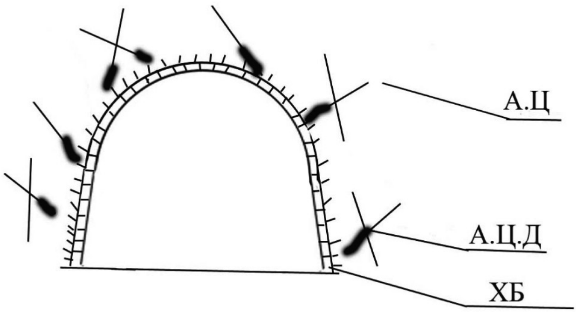


Figure 19. A view of sprinkled concrete supports

А.Ц – Fissure

АЦД– Reinforced mixture between fissures

ХБ – Hardened and reinforced supports

Anchors and sprinkled concrete supports are used to reinforce and maintain balance between mountain rocks.

Ordinary frame-shaped supports are classified as subsiding and non-subsiding. Subsiding supports are used in unstable zones such as cleaning (utilisation) zones. To prevent potential subsidence and the deformation of these supports, the ends of wooden frame supports are sharpened and the connections between the legs and beams are regulated for metal frame supports

Appendix 1

Physical-chemical properties of natural and emitted gases present in mine air

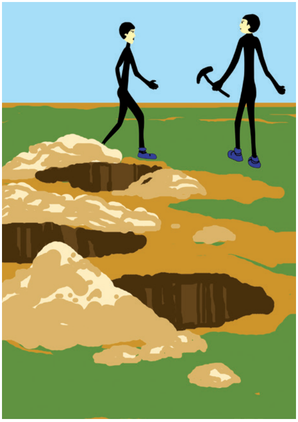
No.	Gases	Weight	Physical properties	Locations	Limits of explosion	Poisoning levels	Permissible amounts	Causes of emissions in mines
1	O_2mj-32, oxygen	1.11	Colourless, odourless, tasteless, life-supporting		Supports all types of burning and explosions. No burning and explosion in O_2 free meduim.	Difficulty breathing at 17%; causes fatalities at 12%	Not less than 20%	Ventilation
2	N_2, mw-28, nitrogen	0.97	Colourless, odourless, tasteless		Non-explosive	Non-toxic	Not more than 78.08%	
3	CO_2, mw-44, carbon dioxide	1.52	Colourless, with a slightly oxidized taste, puts off burning; non-toxic and water-soluble	At the bottom of excavations	Non-burning; non-explosive	Causes fatalities at 15-20%	0.5% at working benches; 0.75% in wings; 1% at outtake flows; 2% in closed boreholes	1. By inhaling; 2. From the decay of organic compounds; 3. From coal acidification; 4. From country rock, empty spaces and fissures in coal bearing seams; 5. During fires; 6. During gas and dust explosions; 7. During blasting
4	CO, mw-28, carbon monoxide	0.97	Colourless, odourless, toxic, explosive	Around roofs	Heat emissions at 12.8-75%, 630c-810c	Poisoning starts at 0.01%; poisoned at 0.1%.	0.0024	1. During fires; 2. During gas and dust explosions; 3. During blasting; 3. From internal combustive engines

5	N_2S, mw-34	1.19	Has rotten egg smell; toxic; explosive; water-soluble		4.3-45.5%	It smells at 0.0001%; poisoned at 0.02%; causes death at 0.1%	0.00066%	1. From the decay of organic compounds; 2. During incomplete blasting; 3. Emitted along with other gases from coal and rocks
6	$SO_2$8 mj-34, sulphide gas	2.2	Has acute smell; toxic; water-soluble		Non-explosive	Poisoning starts at 0.002%, severely poisoned at 0.04-0.05%	0.00035%	1. From the burning of sulphide-bearing coal; 2. During blasting; 3. Oozes out from coal seams
7	NO_2, mw-60, nitrogen dioxide	1.6	Red gray coloured; smells like garlic; toxic; water-soluble		Non-explosive	Severely poisoned and fatalities at 0.02%; poisoning is felt within an hour	0.0008%	During blasting, it combines with oxygen and nitrogen in the air due to high temperatures
8	CH_4, mj-16, methane	0.55	Colourless, odourless, tasteless; burns; explodes; emits blue fumes	Around roofs	Explodes at 5-16% and high explosion at 9.5%.	Non-toxic	0.05% in working benches, 0.75% in wings; 1% in outtake flows; 2% in closed benches	Oozes out suddenly and continuously from country rocks and coal fissures
9	H_2, mw-2, Hydrogen	0.069	Colourless, odourless, tasteless	Around roofs	Explodes at 9.5-74.9%	Non-toxic	Not more than 0.5%	1. Battery recharge places; 2. When fires are extinguished with water

Appendix № 2

Operational safety instructions for artisanal and small-scale mining

Incorrect:



Leave openings without protection and refilling

Correct:

Build protection at openings and refill

Incorrect:

No use of stable and well-built stairs

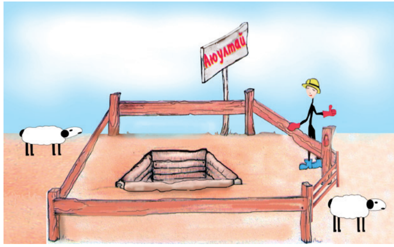
Correct:

Use of stable, well-built stairs

Incorrect:

Working in a shaft that has no livestock enclosure or warning sign

Correct:



Working in a shaft that has a livestock enclosure and warming sign

Incorrect:

Working in a mine that has no adequate supports or roof protection

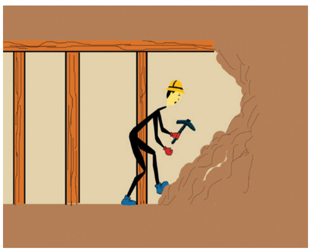
Correct:

Working in a mine that has adequate supports and roof protection

Incorrect:

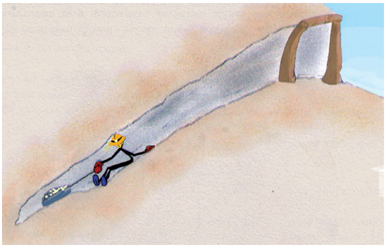
Working in a mine without PPEs (Such as hard hats, gloves, working boots, protection belts)

Correct:



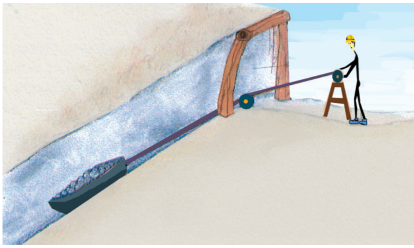
Working in a mine with PPEs (Such as hard hats, gloves, working boots, protection belts)

Incorrect:



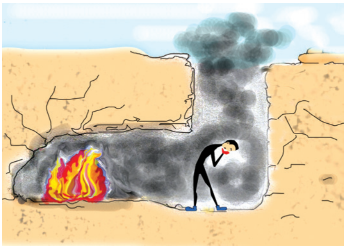
No use of mechanised tools (such as a windlass)

Correct:



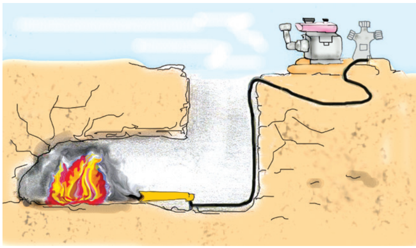
Use of mechanised tools (such as a windlass)

Incorrect:



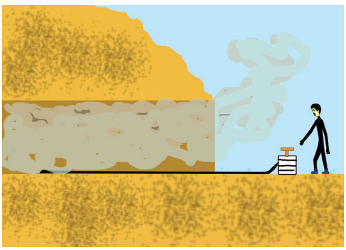
Working without ventilation (alluvial deposit)

Correct:



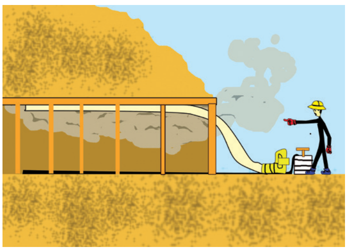
Working in a ventilated area after the land is melted by fire (alluvial deposit)

Incorrect:



Working without ventilation (hard rock deposit)

Correct:



Working with ventilation (hard rock deposit)

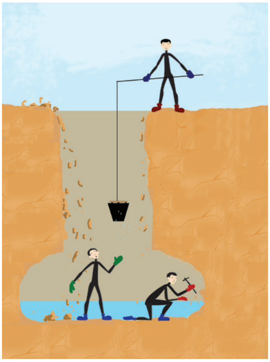
Incorrect:

No warning sign at the tunnel opening from where toxic gases are emitted

Correct:

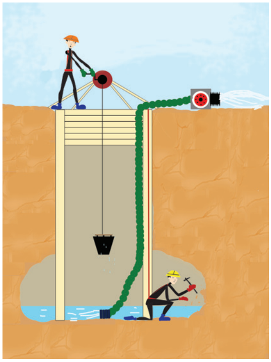
A warning sign at the tunnel opening from where toxic gases are emitted

Incorrect:



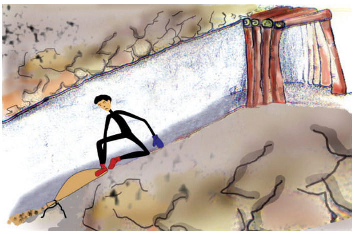
No pump is used when water is removed

Correct:



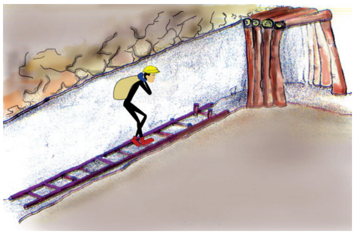
A pump is used when water is removed

Incorrect:



No stairs are used in a sloped tunnel

Correct:



Stairs are used in a sloped tunnel

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