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Worker safety and health management system for mining companies

Presented by Raid Mosbah

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Raid Mosbah

Dedications

Words cannot express the gratitude, love, respect, and recognition as well as I feel. I simply dedicate this bachelor's thesis to:

My dear mother **Naima***: the source of tenderness and the epitome of dedication, always encouraging me. You have done more than any mother could do to ensure her children following the right path in their lives and studies.*

To my beloved, father **Tahe***r: dedications cannot express neither the love, nor esteem, nor devotion and respect that I have always had for you. Nothing in the world matches the efforts you put in day and night for my education and well- being. This work is the fruit of your sacrifices for my education and training over the years.*

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forget.To my very dear friends.

To all the members of my class.

To all my teachers since my early years of study.

To all those dear to me whom I have forgotten to mention

Raid Mosbah

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Acronyms

E_{min}: Minimum acceptable illumination;

F_d: 1.2/2 depreciation factor;

S: Illuminated area;². Z:

Utilization factor;

E_h: Horizontal illumination,

h: Height of the suspension of the lighting fixture (h = H - 0.5 = 3)

F_d: Depreciation factor, which for mining conditions is equal to 1.2 ÷ 2.

I_d: Light intensity according to the direction of the lighting fixture.

L: Length of the illuminated gallery

F_d : Depreciation factor F_d = 1,2 for mining conditions

$\sum PL$: Total power of the lighting fixture in (kW)
n_r: Efficiency of the lighting network, $n_r = 0{,}9$
n_l: lighting fixture efficiency, $n_{l=1}$
$cos\varphi l$: Power factor of the lighting fixture,$s\varphi l = 1$
cos ; n_L ; Power factor and lighting fixture efficiencyL:
Length of the gallery (m)
γ: Conductivity of the lighting cable for copper (γ = 50 m/mm²)

General introduction

Mining works is a high-risk industry, due to its complex and hazardous process and working environment. Effective safety and health management in mining systems is crucial to protect workers and ensure sustainable operations. This introduction covers key aspects of safety worker roles and health management practices in the mining industry.

Safety Workers in Mining depends on the roles and Responsibilities of the safetyofficer who is the first responsible for implementing and monitoring safety policies,procedures and prevention. They conduct regular inspections, identify hazards, and ensure compliance with safety regulations.

In the second hand the health and safety, engineering is inclined to design safety systems and protocols in purpose to prevent accidents and eventual risks. They analyze data to improve safety measures and develop emergency response plans.

Mining rescue teams are specially trained personnel who respond to emergenciessuch as mining collapses, fires, hazardous material spills, etc.... They are equipped with specialized equipment and training to conduct rescue operations. In addition, occupational health specialists are focused on the health and well-being of workers.They still monitoring health conditions in mining workplaces, manage health programs, and ensure the healthy environment, free from harmful exposures.

The importance of safety and health management is summarized to the followingsprincipal factors:

- Worker protection: ensures the physical and mental well-being of miners, reducing the risk of injuries and occupational diseases.

- Operational Efficiency: a safe work environment minimizes disruptions caused by accidents, leading to improved productivity and efficiency.

- Legal and Financial Implications: Compliance with safety regulations avoids legal penalties and reduces costs associated with accidents and health-related absenteeism.

- Reputation and Trust: Commitment to safety and health management enhances the company's reputation, building trust among stakeholders, including employees, investors, and the community.

Effectively, safety and health management in mining is essential for protecting workers, ensuring regulatory compliance, and promoting sustainable mining practices. Continuous improvement and adaptation to new challenges and technologies are vital for advancing safety standards in the mining industry.

Therefore, we focused on study Boukhadra underground and open pit of iron mining and thus, we will try make a contribution to find the best solution that can theaccidents in mining works zones as well in front as in transport gallery.

We g two solutions. The first one is to do an intelligent lightning according to thepoint-by-point method with captures and feels human been movement in galleries toturn on lights automatically. The second one is to install a red lights and a ringtonesas an alarm signal system, in critical times of danger that the workers can hear and see clearly.

The resent work is divide to three chapters. The first is generalities about Boukhadra mining. It talks about position, history, production capacity, quality of itsiron mining, the exploitation mode, transport, etc......

The second chapter makes on highlight the security of mining workers and occupational diseases' both occurred by undesirable atmospheres and electrical dangers .

In the third chapter, we propose a lighting system for transport galleries using the point-by-point method, with motion sensors to reduce electrical consumption, as a length of 30 meters is sufficient to ensure the visibility of people or vehicles that may cross the gallery

Additionally, in the same network, an audible alarm system and red light signaling are included to alert personnel in case of danger, particularly during explosive work.

Finally, the present study ends with a general summary conclusion.

Chapter 1

General notions about Boukhadra mine

1.1 History

Boukhadra iron mine is one of the oldest deposits in Algeria. Its history is divided into two main periods:

- The Exploration Period
- The Exploitation Period

The Romans were the first to exploit the area, mining all the copper veins. From 1896 to 1903, a group of private exploiters conducted initial explorations for zinc mining. In 1903, the MOKTA-EL HADID Company acquired the concession and initiated exploration through a network of galleries between the 845 and 1225-meter levels.

From 1926 to 1966, the MOKTA Company found the concession no longer profitable and sold it to the OUENZA Company, which undertook the exploitation of the deposit. However, it was not until 1950 that significant research was conducted, and improvements in mining methods were made, including open-pit and underground conditions. The figure 1.1 shows a superficial view of the open pit of the mine [1].

Fig 1.1 Boukhadra Mine

Following the nationalization of Algerian mines, SONAREM (created in 1967) took over the exploitation of Boukhadra deposit. Subsequently, EN.FERPHOS, established in July 1983, continued the operations at Boukhadra.

Since the nationalization of the mining industries on May 6, 1966, the national company SONAREM has managed Boukhadra mine, achieving an annual productivity of 800,000 tons since 1970. At SONAREM's request, geological and geophysical research was conducted in the region, covering significant areas with the aim of identifying other potential sites. Today, exploratory drilling is carried out to delineate and evaluate the reserve categories of the southern deposit.

It was only in 1971 that the project for underground exploitation of the southern deposit was developed. In 1972, the project for gallery exploitation was presented to Boukhadra unit, which occupied the second place in iron production after El- Ouenza [2,3].

1.2 Geographic location

Boukhadra mine is located in the extreme eastern part of Algeria, near the Algerian-Tunisian border, between the longitudes 8° 01' and 8° 04' East and the latitudes 35° 04' and 35° 50' north.

The Djebel Boukhadra forms an isolated massif with steep shapes, rising above the Morsott Valley, where altitudes range between 700 meters and 800 meters. However, the highest point of this mountain reaches 1463 meters.

This iron deposit is situated 44 km north of the city of Tebessa, 200 km south of Annaba, 18 km from the Algerian-Tunisian border, and 47 km from the Ouenza mine.[4,5]

- State Boundary
- Municipal Boundary
- Like any company, it consists of various technical and administrative departments.
- The annual production varies between \(5 \times 10^5\) and \(10^6\) tons. The company's electricity supply comes from the El-Aouinet center.
- The company's organizational structure is as follows:

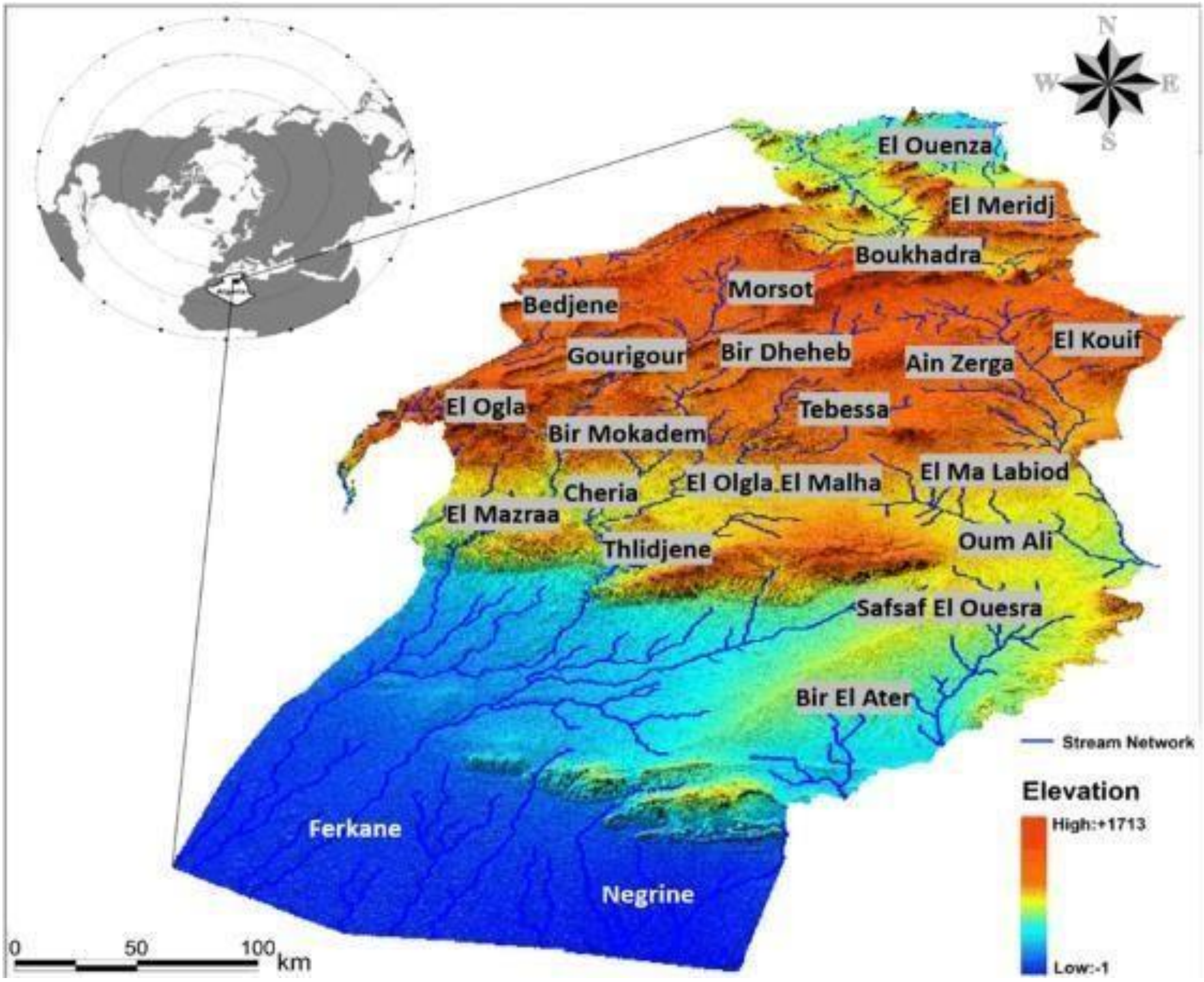

Fig 1.2 Geographical location [4,5]

1-3- Company Overview

Boukhadra mining exploitation is characterized with the open as well as theunderground pit. The main quarry sites are:

- The downstream
- The beggar
- The ender
- The peak
- Ain Zazia (beginning of operations)

- The underground areas

Like any company, it consists of various technical and administrative departments[2].

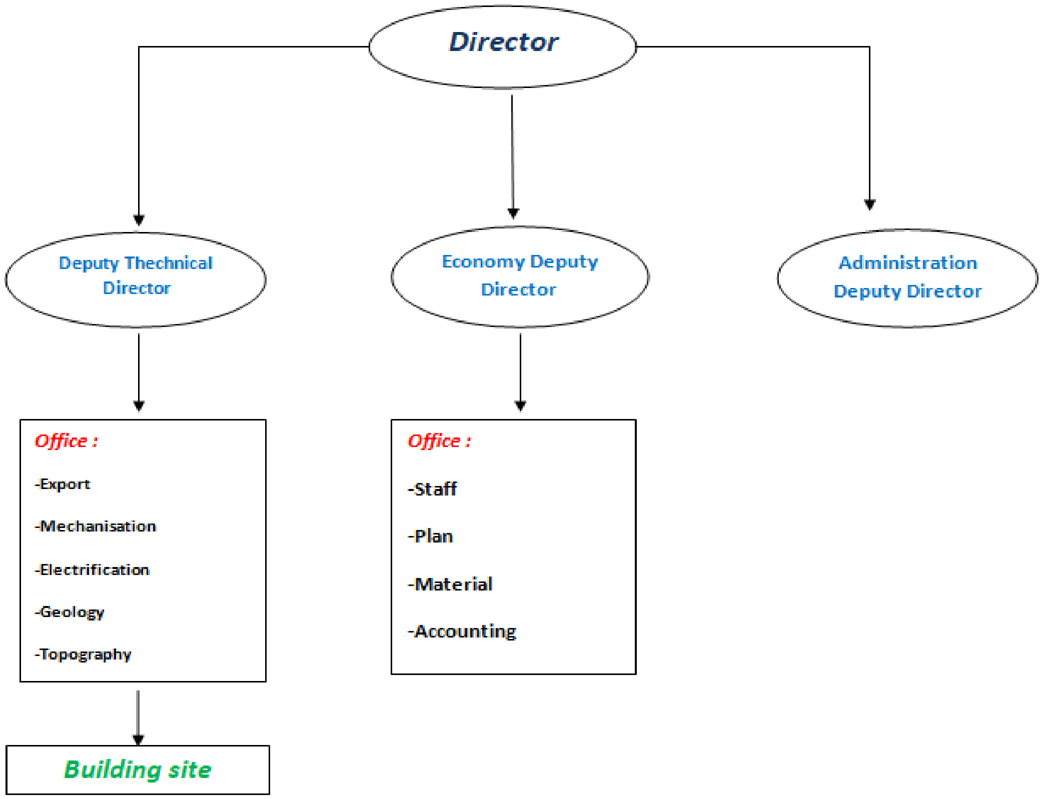

Fig 1.3 Company Structure of Boukhadra mine organigram [1,2]

Boukhadra Company operates based on a set of offices, which include:

a) Study Office: his role includes:

- Construction of new machines.
- Systematic study of equipment and their maintenance conditions.
- Geological and topographical conditions.
- Supply of production.

b) Methods Office:

The functional task of the Methods Office (B.M) is to define and determine the maintenance and servicing conditions. This also includes specifying the location and duration for parking the machinery.

c) Compatibility Office:

The accounting service of the company determines how the operational budget for each process, such as maintenance, equipment purchase, mission bonuses, salaries, etc., will be established and managed. In all cases, the cost of each process is part of the production costs and is included in determining the cost price.

1.5 Opening stage of the deposit

General Information

The term "opening of the mining field" refers to the development of a network of openings that provide access to the deposit from the surface and ensure the possibility of creating preparatory and communication works between the surface and the mining operations. In all cases, the works must ensure:

- An air inlet.
- An air outlet.
- Transport routes for the extracted products, equipment, and personnel.

The modes of opening are classified according to the type of main mining works that provide access to the deposit and are:

- Opening by surface gallery.
- Opening by vertical shaft.
- Opening by inclined shaft.
- Combined opening.

b) Opening mode of the deposit

The choice of the opening mode is influenced by several factors, including [2,3]:

- Topographical factors
- Geological factors
- Hydrogeological factors
- Technical mining factors
- Productivity

1.6 Mode of Opening the Deposit

The figure bellow shows the different levels of transport and exploitation galleries [2-4].

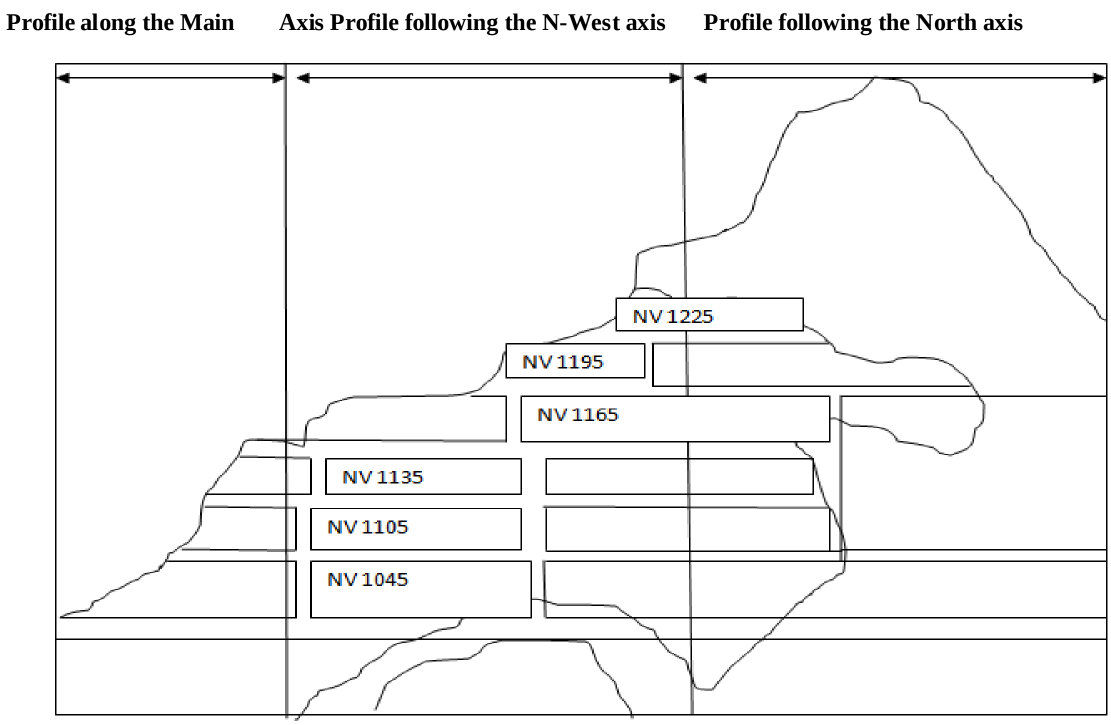

Fig 1.4 Undergrounded pit level [1]

1.7 Opening Mode

The main daytime entrance to the depths of Boukhadra deposit is made through old galleries with cross-sections between 6 ± 8m². The construction of the levels, which are distributed in stages, are at: 1105, 1165, 1225, 1285 meters.

The mining of the ore is carried out between the 1105 m level, called the base level, and the 1285 m level, called the head level. This distribution includes three (03) phases:

1st phase: includes the levels 1225, 1255, 1285.

2nd phase: includes the levels 1165, 1135, 1425.

3rd phase: includes the levels 1105, 1135, 1165.

The underground district is connected to the surface by directional galleries dug at each level and parallel galleries. Recently, galleries have been dug in the surrounding rocks, and the mined ore at the upper level will be cleared through rolling galleries with a tipping chimney.

A main rolling gallery is dug at the 1105 m level, where ore transport will be carried out at this level by wagons pulled by locomotives. The support for all the works is planned based on the properties of the structures as well as the physico-mechanical properties of the rocks and their lifespan.[1-5]

1.8 Exploitation Method

The iron deposit is characterized by a grade of 55%, and the massive ore is stable, with a dip angle of the ore body between 60 and 80 degrees. Based on a techno-economic comparison conducted by the operators, surveyors, and economists, and appropriate for a detailed study to determine the existing (applicable) exploitation method, the chosen method is "sublevel stopping with empty rooms."

The mining works carried out using this method are characterized by increased productivity and reduced extraction costs of the ore, as well as the manageability and simultaneity of technical operations. The exploitation takes place in the zones, particularly the V south vein "underground part," which is characterized by a 51.47% iron content, limiting dilution to 0.03%. However, due to the existence of mineralized zones in contact with the ore body, dilution increases to 67% for certain blocks. In the first zone, the grade is sufficiently high, between 55% and 56% iron. The equipment allows for a dilution level of 7 to 8% after analyzing the mining conditions at Boukhadra mine. The following exploitation methods are planned:[1-5]

- Induced caving at the level with blasting by deep holes.
- Induced caving at sublevels with long-hole blasting.
- Exploitation system with magazine chambers and long-hole blasting from chimneys.
- Sublevel exploitation system with vertical trench blasting by long-hole.

1.9 Characteristics of the useful Ore

The useful ore under the conditions of Boukhadra is composed of:

- Sulfur [S]: 0 - 1%
- Magnesium [Mg]: 0.14%
- Lime [CaO]: 3%

- Barium Silicate: 0.2%
- Manganese [Mn]: 2%
- Silica [SiO2]: 10%

- Iron [Fe]: 55%

1.10 Transport Mode

A shaft located between the levels 1225 and 1285m is used for the transportation of extracted ore from the upper levels. The loading and drawing of the mineral is made by Emico 925 LHD shovel. From the 1225m level to the open pit mine corridor (level 1105m), two variants are planned, with the most suitable one tobe adopted:

- Main transport gallery (from 1225m to 1105m).
- Quarry truck from the 1195m level.

From the 1225-meter level, the ore is transported via a shaft to the 1105m level for which, a loading chamber is located at the 1225m level. It is necessary to prepare a loading chamber with a vibrating table, and 10t capacity wagons are be provided to transport the ore to the quarry corridor.

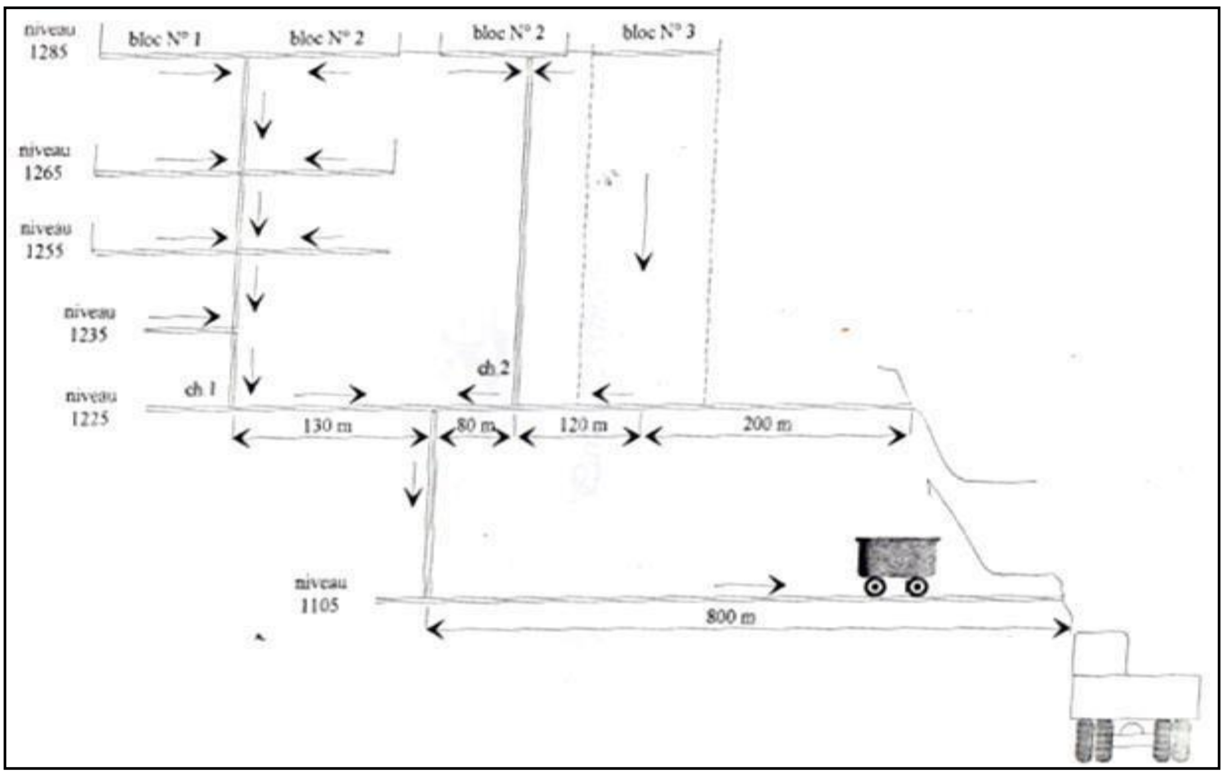

Fig 1.5 Quarry truck Transport

***Chapter* 2**

Protection against work accidents and mining industrial risks

Protection against dust is crucial in various environments to maintain health and safety. Dust particles, often microscopic, can originate from sources like construction sites, manufacturing processes, and natural events such as dust storms. Exposure to dust can lead to respiratory issues, skin irritation, and other health problems

2.1 Nation on work protection

Work protection represents a vast system of measures intended to preserve the moral and physical health of the worker, for this it is necessary to perfect production processes and create healthy and safe working conditions [5,6]. Workprotection has different parts, namely:

- Work legislation (number of working hours; number of days/weeks etc.)
- Safety technology
- Work hygiene
- Protection against fires.

2.2 Definition of work accident and professional occupational disease

A work accident is a material event of a sudden and violent nature, which comes from an external cause occurring during work or at the workplace. In addition to work accidents, there are occupational illnesses, which are mainly due to two factors:

- The harmful atmosphere in which staff fulfil their professional obligations.
- Harmful physical agents: noise, vibrations, heat, harmful radiation, insufficient lighting, and so on.

Noticed: A work accident is an unexpected and sudden abnormal event (malfunctionof the man/machine system), on the other hand, an occupational illness comes fromlong-term work in a harmful environment.

2.3 Causes of work accidents

Investigations carried out into work accidents show that each accident is the result of several factors. The accident has multiple prior causes, which may be technological: Due essentially to the imperfection or defect and malfunction of the equipment used or to its poor operation or/and causes of an organizational nature due to non-compliance with regulations or to the ignorance of the worker [7].

2.4 Nature of injuries due to work accidents

The figure presented below illustrate the percentage of injuries commonly occurred in place work

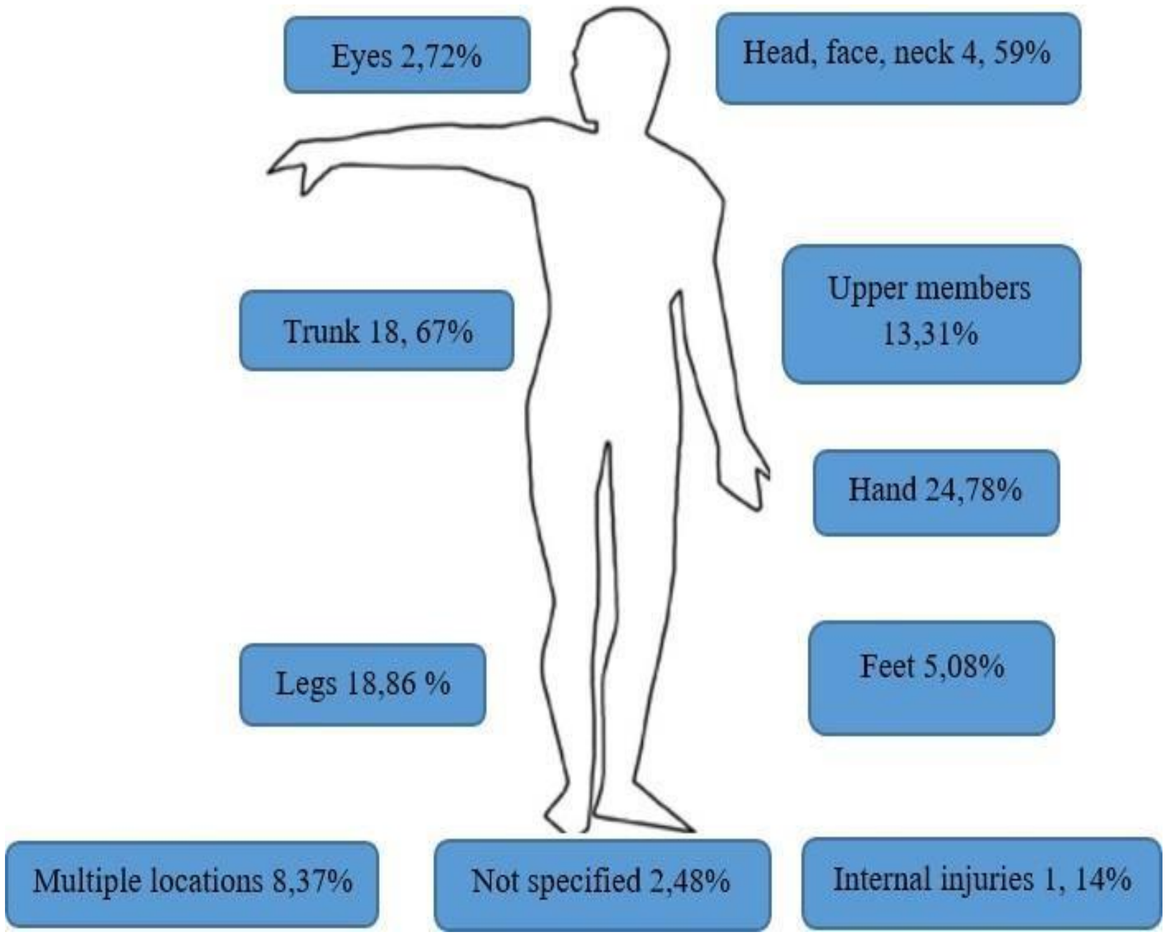

Fig 2.1percentage of injuries commonly occurred in place work

2.5 Classification of accidents

Based on statistical data, work accidents are classified into several types:

a) According to the industrial type;

b) Depending on the continuation and duration of work capacity;

c) According to technological causes;

d) According to the nature and site of lesions: according to this last classification, it is known that the most vulnerable organs are the hands, feet and head.

2.6 Regulatory framework in Algeria

The Ministry of Work, Employment and Social Security, responsible for occupational safety and health in link with the institutions concerned and social partners, ensures the development and implementation of the policy and national programs for the prevention of occupational risks. This national policy is part of the international approach and the orientations and recommendations of the International work conference, which recommended action plans for the promotion of safety and health at work as part of the global strategy in matters of safety and health at work. However today, considering Algeria's orientation towards a market economy, the Ministry of work has initiated a reconfiguration of prevention action in order to allow companies, which have taken or must have the necessary framework to their adaptation. We present to you below the laws (or at least the main ones) concerning this topic [1,2].

2.7 Laws relating to work accidents and occupational diseases

- Ordinance No. 66-183 of 06/21/1966 providing compensation for work accidents and occupational illnesses

- Order of 03/22/1968, relating to the tables of occupational diseases.

- Order of 01/07/1971, relating to the classification of occupational diseases.

- Executive Decree No. 97-424 of November 11, 1997, establishing the conditions of application of Title V of Law No. 83-13 of July 2, 1983, amended and supplemented, relating to the prevention of work accidents and illnesses professionals.

2.8 Regulations relating to Health and Safety

Hygiene, health and safety at work today hold an increasingly prominent place in company strategy and management, because beyond the human and social harm caused by a work accident or an occupational disease, the economic impact is often considerable.

The establishment of a safe and healthy workplace requires each country to develop an effective national occupational safety and health (OSH) system. As part of a bilateral collaborative effort between government and industrial partners, and social; in particular, legislation, standards as well as compliance control mechanisms, in accordance with the orientation of international conventions No. 187 and No. 197 relating to the promotional framework for safety and health at work.

Let us cite the laws adopted in Algeria, which frame the present subject:

- Law 88-07 of 01-26-1988, relating to hygiene, safety and occupational medicine.

- Executive Decree No. 91-05 of 01/19/1991, relating to general protection requirements applicable to HS in the workplace.
- Executive Decree No. 93-120 of 05/15/1993, relating to the organization of occupational medicine.
- Interministerial order of 02-04-1995, establishing the standard agreement relating to occupational medicine established by the employing organization and the health sector or the competent structure or authorized medicine.
- Executive Decree No. 96-209 of 05-06-1996, establishing the organizational composition and operation of the national council of HS and occupational medicine.

2.9 Regulations relating to occupational accidents and illnesses

- Ordinance No. 66-183 of 06/21/1966 providing compensation for work accidents and occupational illnesses Order of 03/22/1968, relating to the tables of occupational diseases.

- Order of 01/07/1971, relating to the classification of occupational diseases.

2.10 Regulations relating to health promotion and work inspection:

- Ordinance No. 76-79 of 10/23/1976 relating to the public health code.
- Law n°85 of 02-16-1985, relating to the protection and protection of health, amended by law n°88-15 of 05-03-1988, law n°90-17 of 07-31- 1990 and law n°98-09 of 08-19-1998.
- Law n° 90-03 of 06/02/1990, relating to work inspection, modified and supplemented by order n° 96-11 of 10/06/1990.

2.11 Specific risks in mining companies

Mining is a very dangerous job: Mining employs nearly 30 million workers, with nearly 10 million of those in only coalmines. An estimated six million more people work in small-scale mining. Minors encounter a set of limiting conditions and circumstances specific to their workplace; even by being deprived of natural light or ventilation [2-9].

Despite the efforts undertaken, the significant number of deaths, accidents and occupational illnesses affecting miners worldwide makes mining the most dangerous activity taking into account the number of individuals exposed to risk. Although representing just 1% of the global workforce, the sector accounts for around 8% of fatal accidents. Despite the non-existence of official and reliable statistics concerning injuries, we can have an idea in view of the significant number like the number of workers affected by disabling occupational diseases such as pneumoconiosis, hearing loss and effects linked to vibrations.

Due to the dangerous nature of mining, the international organization of Workers (IOZ) has always been concerned with improving the working and living conditions of miners, from the adoption of the Hours of Work (Coal Mines) Convention, 1931 (No. 31), to the (No. 176) on Safety and Health in Mines, 1995.

Compendiums of good practices have also been developed and adopted to provide guidance to ensure the safety of mining operations in both surface and underground mines [10].

Despite the progress made in prevention, the accident rate is higher in mining companies; notably underground mines, compared to other industrial fields

2.12 Some examples of accidents in mining operations

a) Fires and mine fires: a fire in a coalmine in Australia

Fig 2.2 Mine fire in Australia

b) Ignition of firedamp and explosive dust

Fig 2.3 Shot of firedamp in Villars 68 dead 7 Combustible dust

c) Instant release of gas

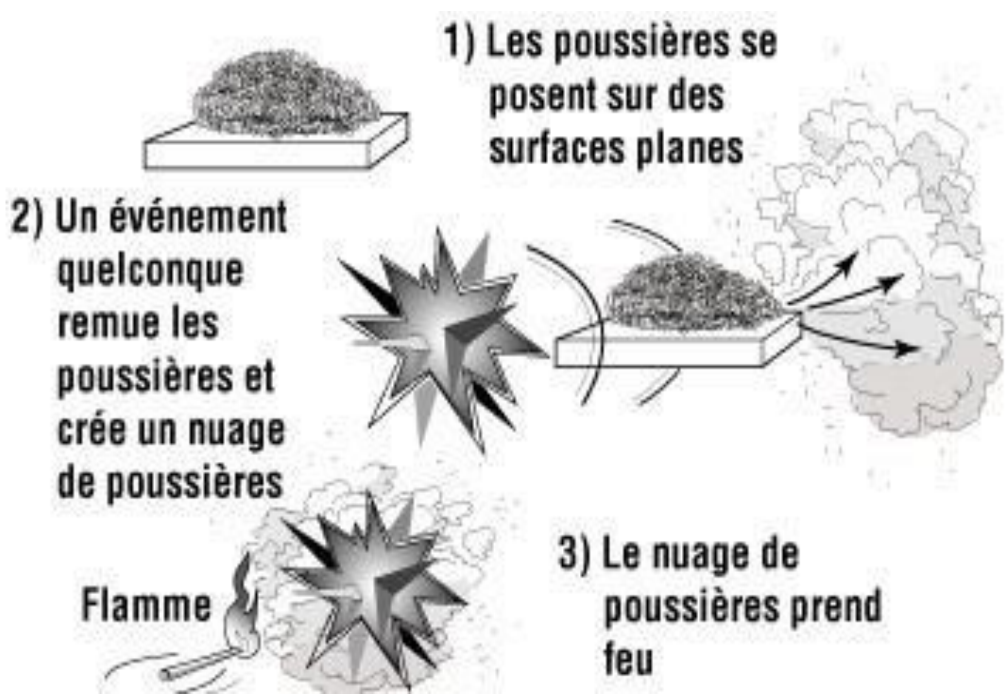

Fig 2.4 Explosive materiel

d) Failed explosives

Fig 2.6 Explosion in a Geneva gallery mine, 8 dead

e) Accidents due to electric current. 28 injured, one missing in coal mine accident in Poland

Fig 2.7 presentation of werker in mine

f) Landslide and rock fall

Fig 2.8 Five dead in Bosnia mine collapse China

Fig 2.9 Collapse of a coalmine leaves 19 dead

g) Risks of falling or traffic….

Fig 2.10 Thousands of deaths each year in mines

Underground work constitutes an environment where the risks inherent to any industrial activity are increased.

Fig 2.11 Explosion in an iron mine

2.12 - General provisions for combating harmful atmospheres

The operator of an open-pit mine should ensure that workers were not exposed to pollutants suspended in the air, harmful physical and chemical agents, or other risks present in the workplace.

The works manager should establish an appropriate procedure to assess air quality and identify physical or chemical agents that may be hazardous in the atmosphere near the mining operation and any locations within the mine or its vicinity where personnel may be required to work or to circulate.

National legislation should specify and periodically review exposure limits for all pollutants suspended in the air and harmful physical and chemical agents that may be encountered in the workplace.

The mine operator should take necessary measures to ensure that safe work methods are applied to the extent possible.

When necessary to minimize risks to workers, the works manager should prepare written instructions outlining the principles to been followed in such circumstances. They should also makes arrangements to inform all workers of potential risks and precautions to take when hazardous substances may be present in the mine.

The legislator must specify the necessary standards for protecting workers in mines. Special attention should be given to the characteristics of these mines and their specific risks [5].

1.13 Protection against airborne dust

1.13.1 Introduction

It is useful to recall that a large quantity of mineral dust forms during dry drilling of mine holes and blasting, operation of shears, shear-loaders, and rock drills, ore crushing, at the level of silos, loading, and transportation. Mining technology inherently involves rock fragmentation and the generation of significant amounts of dust. Some of this dust settles inside the mine while another portion, suspended in the air, is released into the external atmosphere through the return air current.

Mine dust can be toxic or non-toxic depending on its mineralogical composition (lead dust, chromium dust, manganese dust, etc.). Breathing air containing non-toxic dust (such as silica dust, coal, asbestos, siderosis, nepheline, etc.) over the long term can lead to occupational lung diseases. Under certain conditions, coal, pyrite, and sulphur dust can even form an explosive mixture with air.

The intensity of dust formation and the state of ventilation determine the amount of dust present in the air. The quantity of dust formed during a specific task is called the dust formation intensity and can be expressed in milligrams per second (mg/s), milligrams per minute (mg/min), or particles per second (particles/s). For example, scraping loading produces 30 to 130 mg/s, dry drilling 130 mg/s, and wet drilling with water injection 8 mg/s. The gravimetric method for measuring dust content involves passing dusty air through a filter that retains it. The dust content in the air is calculated in milligrams per square meter based on the amount of dust collected and the amount of air passing through the filter.

The dust content in the air for rocks containing more than 10% free silica (SiO2) is set at 2 mg/m3, while the dust content for other minerals is higher but does not exceed 10 mg/m3.

The explosive properties of coal dust are particularly significant because it heats up and releases inflammable gas. According to experiments, the explosiveness of coal dust depends on its properties and the quantity suspended in the air. Increasing the gas content of coal reduces its explosive properties, but increasing ash and moisture increases them. Coal layers containing more than 10% volatile matter are considered dangerous in terms of dust.

2.13.2 Measures to be taken

Dusting, splitting, or wetting the gallery walls before blasting in mines, and prohibiting the use of open flame lamps, are the main methods to prevent explosions and ignition of pyrite and Sulphur dust. To prevent dust ignition and the spread of explosions, dusty mines are equipped with the same safety measures for the use of open flame, electrical equipment, and explosive work as firedamp mines.

In such mines, additional measures are taken to reduce dust formation: vacuuming, watering, and lime painting of walls. The fight against the formation of dust clouds and the suppression of explosive properties of dust involve periodic splitting of galleries using inert shale dust, which increases ash content up to 60% in non-firedamp mines and up to 80% in firedamp mines.

To ensure working conditions compliant with current legislation and to reduce the influence of harmful substances on the human body, preventive measures are recommended, such as:

- Fighting dust production at its source.
- Main / or secondary ventilation.
- Personal protective equipment.
- Mechanization and automation of the most exposed workstations.

2.13.3 Ventilation standards

The more gas emissions there are, the more clean air is needed to dilute them, as the quantity of air supplied to the mine must ensure the safety and hygiene of working conditions.

In general, it is necessary to supply a mine with an amount of air such that the oxygen content in active workplaces is not less than 20% and the carbon dioxide content is higher than 0.5%. It is accepted that the carbon dioxide content increases up to 1% in the return air.

In addition to diluting carbon dioxide and maintaining oxygen content, in mines where methane has been observed, the clean air must dilute the methane released in proportions such that the return air from separate sections contains no more than 1%, and the general return air contains no more than 0.75%. Normally, to dilute methane, much more air is required than to maintain its purity in terms of oxygen and carbon dioxide.

It is necessary for a person to have at least 6 m^3/min of air in areas where a non-firedamp mine is operated. The largest number of people underground at the same time determines the total amount of air required.

The calculation of air requirements in metallic mines is based on the explosive consumption. In mines classified according to their methane content in category I, it is necessary to provide at least 1 m^3/min for each ton of ore extracted per day. In category 2 mines, it is necessary to provide 1.25 m^3/min, and in category 3 mines, it is necessary to provide 1.5 m^3/min.

The amount of air required in non-category mines is determined based on the quantity of methane actually released, provided that its concentration in the air does not exceed 0.75%, while still remaining above 1.5 m^3/min for each ton of average daily production [5].

To calculate the quantity needed for ventilation, you can use the followingformula:

$$Q = \frac{q \cdot 100}{p \cdot 24 \cdot 60 \cdot 60}, \; m^3/s,$$

Where q represents the quantity of gas, in m^3, released in the mine over 24 hours; p is the gas content in %, for which the dilution of the released gas complies with the prescribed standards.

Air samples are usually taken in rubber-stopper bottles or in burettes (glass tubes with short capillary tubes welded to both ends equipped with ground-glass stopcocks). The bottles and burettes are brought to the sampling locations filled with water. The water is allowed to drain .

The water (in the burette, the upper stopcock is first opened and then the lower stopcock), and thus, they are filled with air from the mine, after which the container is sealed again.

The containers with their air samples are dispatched to the laboratory for analysis. The ventilation supervisors or team leaders check systematically the firedamp in all working areas.

At the intake and return air of the galleries and panels, as well as in the layers where the presence of methane has not been recognized, firedamp checks can be performed once per shift. The results of the checks conducted during each shift should be recorded in reports signed by the individuals who conducted them. The data from the reports must be entered on the same day in the "Firedamp Measurement Register," which is kept in the mine for one year and signed by the ventilation chief.

2.13.4 Fighting against the formation of dust

Specific means must be used to limit the production and emission of harmful dust. Any dust remaining after the use of control measures should be diluted and removed through active and optimal ventilation from the outset, in order to achieve acceptable concentrations.

Let's take a few examples of the main methods to combat the formation of dust in underground mines:

- Drilling and blasting in the mine with ordinary water injection or special additives.
- Dry removal of dust during various technological processes such as drilling, unloading of dumpers, etc.

- Fine spraying of water in areas of intensive dust formation (wet suppression) such as storage silos, ore transfer points, mining faces before and after blasting, etc.
- Active ventilation of galleries.
- Injection of water under pressure into the coal seam before its extraction.

Let's take a few examples of combating atmospheric dust:

- During the drilling process of mine holes, the most effective method of combating dust is through water injection through a central (axial) orifice of the drill bit.

- Dry dust extraction is sometimes used. This system is typically integrated into the rock drill, and extraction can be axial or lateral.
- Air dusting (or ventilation) Air dusting is carried out during the intake of fresh air from the outside and also during its exhaust to the outside. The former case protects the health of workers, while the latter case protects against the risk of atmospheric pollution.
- Personal protection: In practice, there are three types of masks, namely:
- Dust or gas filtering mask,
- Isolating mask: This type of mask is used temporarily in case of an emergency. These devices are equipped with exogenous regeneration cartridges and have an autonomy period not exceeding 8 hours.
- Masks with additional air and oxygen supply.

When mining activities produce dust inside or around a mine, the works manager should:

- ➢ Take necessary measures to reduce or eliminate this dust.
- ➢ When practically infeasible, provide appropriate equipment to prevent inhalation of dust.
- ➢ Appropriate measures should be taken to combat airborne dust at all workplaces, loading, unloading, and transhipment points for materials and waste, crushing facilities, and on haulage roads where poor visibility may create unexpected risks.

When combating airborne dust, particular attention should be paid to the following circumstances, operations, or locations:

- At the face after blasting in mines;
- During drilling in rock without dust suppression devices;
- At loading or unloading points;
- In all haulage roads of the mine;

- In all crushing, screening, and processing facilities, especially at transfer points of conveyor belts;
- During stone cutting and polishing work;
- In abandoned workings spoil heaps, and similar locations where dust raised by the wind can become excessive.

The works manager should ensure that mechanical ventilation is provided and operational in all areas where the atmosphere is stagnant, dead-end galleries, and other poorly ventilated areas.

The competent authority should establish standards regarding dust concentrations and specify methods of sample collection for both open-pit and underground mines [5].

2.14 Harmful Gases

Normal ambient air has a typical composition of 79% nitrogen, 20.96% oxygen, 0.04% carbon dioxide, and water vapour. The water vapour content is subject to various conditions. However, in underground mines or confined spaces with limited gas permeability, it becomes essential to remove contaminated air and replace it with fresh air.

The fresh air circulating through underground mining works undergoes chemical and physical changes. Generally, the oxygen concentration decreases, and the carbon dioxide concentration increases due to the respiration of workers, lamp combustion, wood decay, machinery, and, on the other hand, various harmful gases released from the rocks themselves, gases formed by mine blasting, and dust.

It is evident that the intensity of air contamination depends on the processes mentioned, including the concentration of gas released from the ore and waste rocks in which the work is carried out, the speed of air circulation, and the dimensions and capacity of the mine. Therefore, the slower the air circulation in larger underground works, the stronger the pollution

Due to their properties, gases originating in mines are very different: methane (CH_4), carbon dioxide (CO_2), Sulphur of hydrogen (H_2S), Dioxide of Sulphur (SO_2), and during explosive blasting, among others, nitrogen oxide (NO) and carbon monoxide(CO) are formed. Massive saturation of the mine atmosphere with carbon monoxideoccurs during underground fires and explosions of coal dust, especially firedamp.

Underground mines are also distinguished by humidity, temperature, atmospheric pressure, and density. The purpose of mine ventilation, besides supplying workplaces with fresh air, is to maintain temperature and humidity at normally acceptable levels. Mine atmosphere and ventilation are governed by international safety standards.

2.15 Mine Atmosphere

During technological processes, harmful substances to human health are formed in the atmosphere, such as carbon cycles (CO, CO_2), nitrogen cycles NO and NO_2, hydrogen sulfide H_2S, sulfur dioxide SO_2, firedamp, and various dust particles mixed with ambient air.

In such conditions, there is a risk of visible or invisible alteration to the human body, which can cause either immediate or long-term effects. Occupational diseases such as lung attacks, cancer, lead poisoning (chronic affection by lead salts), skin lesions caused by circuits, and consequently decreased work efficiency can occur.

In order to implement measures to combat harmful atmospheres, they must first be recognized, defined, and the intervals of their toxicity concentrations determined. In mines, the existing gases are as follows:

Oxygen: As previously mentioned, the oxygen content in the mine decreases due to human respiration, lamp combustion, slow oxidation of organic and mineral materials, and the dilution of oxygen by mine gases.

For the maintenance of health and workability of personnel working in extreme conditions hundreds of meters underground, the oxygen content in active workplaces, according to safety standards, should not drop below 20% of the ambient air volume. However, a considerable decrease in this oxygen content in the air occurs during underground fires and explosions of flammable gases and dust. Pathological manifestations in humans may appear if the oxygen content is below 17%, and the risk of death is present if the content is below 12%. The simplest indicator of oxygen content in the underground atmosphere is the carbide lamp or the ignition capacity of any fire, which has the characteristic of extinguishing with a decrease in content below 17.5%.

Carbon dioxide (CO_2): Carbon dioxide is colorless, odorless, and tasteless, slightly acidic, and has a density of 1.52. It is weakly toxic. It is irritating to the eyes at concentrations of 5 to 10%. A concentration of 3% affects respiratory intensity, which even at rest becomes twice as rapid, not to mention the excessively tiring work. At 6%, breathing becomes very difficult and weakness may manifest in the body. Above 10%, fainting is probable, and at more than 20%, the risk of death is indeed present. Carbon dioxide is usually emitted from surrounding rocks, coal, as well as decaying wood, the respiration of humans and animals, various combustions, and the fermentation and decomposition of organic matter.

The release of carbon dioxide by coal and surrounding rocks occurs gradually and does not pose a danger. However, in certain coal deposits, rapid release and sudden eruptions are possible. In France and China, there have been cases of firedamp releases and coal projections leading to fatal accidents. Pollution of the mine air by carbon dioxide occurs during firedamp and coal dust explosions as well as during underground fires.

According to the quantity of gases emitted per ton of ore produced per day and the daily production, mines are classified into categories:

- ***Category I:*** Mines characterized by a CO_2 emission of up to 5 m3/t;

- ***Category II:*** Mines with a CO_2 emission of 5 to 10 m3/t;

- ***Category III:*** Mines with a CO_2 emission of 10 to 15 m3/t;

- Mines with a CO2 volume exceeding 15 m3/t are classified as out of category.

Safety regulations and standards require a carbon dioxide content below the range of 0.5 to 1% in all underground workplaces. A carbon dioxide content of up to 1.5% can be tolerated with proper ventilation and movement of fresh air.

Indeed, safety regulations and standards mandate maintaining carbon dioxide levels below the range of 0.5 to 1% in all underground workplaces. However, up to 1.5% carbon dioxide content can be tolerated provided there is proper ventilation and circulation of fresh air.

Carbon monoxide (CO) has the particularity of being undetectable by the human senses because it is a colourless, odourless gas, and its specific weight is close to that of air (0.97). Its toxicity results from its high absorption by the haemoglobin in the blood (250 to 300 times greater than oxygen). For this reason, even in the presence of a low concentration of carbon monoxide, there is a deficit of oxygen in the body. With a high concentration of CO in the blood, death is almost certain.

In mines, particularly underground, carbon monoxide (CO) can be present during fires, explosions of coal dust, and when using explosives. When mixed with air, CO is combustible and can become explosive beyond the limits of 15%.

The hygiene standard for CO in the air concerning worker safety in mines is set at 0.0016%. Here are some symptoms and effects on the human body with different concentrations of CO in breathable air:

- ✓ At rest, for a few hours with a concentration of 0.01% in the air, CO has no serious influence.
- ✓ With a concentration of 0.1% and after an hour, there is intoxication that is not dangerous.

- ✓ With 0.15 to 0.20%: the intoxication is rather severe.
- ✓ At 0.5%, death can occur after 20 to 30 minutes.
- ✓ A concentration of 1% causes instant loss of consciousness.

The carbon monoxide content is measured during rescue operations using palladium chloride, in the solution of which a dark precipitate forms. There are also other methods of measurement; in particular, a special device called the Carbon Monoxide Dosimeter C-1 has been developed at the Makeevka Institute in Russia.

Hydrogen Sulphur and Sulphur of gases: Hydrogen Sulphur (H_2S) is a heavy, highly toxic gas with a characteristic smell of rotten eggs (specific gravity 1.14). Its concentration in the air exceeding 0.1% is dangerous to human life. With 6% of hydrogen sulfide in the air, a detonating mixture is formed. The formation of hydrogen sulfide in mines results from the decay of wooden materials; it is released in a pure state through fractures and cavities.

Sulfurous gas (SO_2) is highly toxic. It corrodes mucous membranes, especially those of the eyes. For this reason, it is called the "eye eater". Even a brief stay in an atmosphere containing 0.05% of this gas is dangerous to life. Sulfurous gas is sometimes emitted along with firedamp and hydrogen sulfide.

Nitric oxide (NO): formed during an explosion by combining with the oxygen in the air, becomes nitrogen dioxide (NO_2), which is a highly toxic gas that irritates the mucous membranes (eyes, nose, throat), as well as the bronchi and lungs.

Here are some symptoms and effects on the human body with different concentrations of NO_2 in breathable air:

- NOx content below 0.004% is not dangerous to human health.
- Above 0.08%, it poses a risk of death.
- Between 0.004 and 0.08%, it constitutes a serious health hazard; therefore, it is strictly prohibited to enter the work areas after blasting in the mines until they are adequately ventilated.

Methane (firedamp): Of all the gases that can exist in mines, firedamp is unequivocally the most dangerous. It is a mixture of pure methane (CH_4) with a little ethane and ethylene, hydrogen, carbon dioxide, nitrogen, etc.

Methane forms on the surface of porous coal or rocks at the same time as coal. A small portion, in the form of free gas, fills the fissures and cavities in the ore. It is also found in surrounding rocks.

Its presence and diffusion can be distinguished by either regular and continuous release from the pores of the coal ore, temporary release over a longer or shorter period from visible fissures and cavities, or instant release in large quantities over a short period, accompanied by the projection of large masses of coal or rocks. These quantities are more significant the deeper the mine.

Methane, colorless and odorless, accumulates near the roof, especially in the dead-end sections of the rising galleries, as its density is 0.554. It is combustible, andits large accumulations are dangerous, causing a significant decrease in oxygen content. A mixture of 5.5 to 6% methane in the air is explosive.

In addition to coalmines, methane is also found in potash mines and in some metal mines if the deposit is near coal-rich layers containing this gas.

With a methane concentration of 2% in the air at the worksite, the supervisor must immediately stop work and evacuate all workers from the face. Periodic and systematic sampling is essential to determine the methane content in the air.

In gassy mines, special safety lamps, battery-powered locomotives, and explosion-proof electric motors are used. Additionally, certain restrictions have been adopted regarding explosive work (such as the use of safety explosives, etc.).

Currently, to reduce the abundance of gas in mines, artificial degassing of the layers is practiced by extracting methane through boreholes from the surface and using it in industrial or domestic applications. Such a degassing method is widely used in the Ruhr mines and in France.

2.16 Combating Harmful Gases in Mines

All toxic gases or vapours that are likely to be present or escape from a furnace or other installation should have approved devices installed to neutralize or render them harmless.

- These devices should be used at all times.
- If there is a risk of explosion from gas, dust, or vapors in any part of an open-pit or underground mine, the manager of the works should take appropriate preventive measures.
- The discharge of gas effluents into the atmosphere must be done according to the prescriptions of the current legislation.
- No one should be allowed to approach a work face after blasting with explosives until the gases produced by the blast have dissipated.
- When fluids or sledges drained or pumped from any source can release harmful gases, all sumps, manholes, reservoirs, or other water accumulation points should be effectively sealed and watertight.
- If these last operations have not been performed or in case of oxygen deficiency, workers entering the confined space should be equipped with

approved respiratory equipment.

- Anyone called to enter such spaces should be trained in the use of the provided respiratory equipment and assisted by another person stationed in fresh air [5-11].

2.17 Noise

- Standards limiting the extent of noise as well as peak levels to which a worker may be exposed daily must be adhered to.
- No worker should be exposed to unacceptable noise or peak levels exceeding the established standard unless they are wearing an approved hearing protection device.
- An investigation into the sound levels to which each worker at each installation and site is exposed to daily should be conducted at regular intervals.
- The results of the investigation into sound levels should be recorded in a register maintained permanently at the mine office.

2.18 Vibrations

The manager should take measures to minimize the adverse effects of vibrations on the health of miners.

2.19 Toxic products

- All toxic products used inside or around an open-pit mine should be stored, handled, and used in a manner approved by the competent authority.
- Only authorized competent persons should have access to toxic products.
- Emergency showers and eyewash stations should be installed, if necessary, at appropriate locations.
- When work at a mine is suspended or abandoned, all toxic products should be evacuated and disposed of using approved methods.

2.20 Environment Protection

The operator of a mine should ensure the implementation of an environmental protection program at every stage of the mining project, from feasibility study, planning, and execution to mine closure. This program should include guidelines regarding:

- The site selection of the mine:
- Hydrological studies:
- Mining method:
- Evaluation and monitoring of tailings and other residues:

- Prevention of mine fires and pollution of air by spoil heaps
- Reclamation plan
- Procedures for closure, abandonment, reforestation, and restoration of sites in a manner that poses no risks to human safety or threats to the environment.
- The environmental protection program should be submitted to the competent authority for approval before the start of operations [12].

2.21 Tests and Measurements

The detailed characteristics of the methods and testing instruments used to monitor air pollution, liquid effluents, and physical hazards should comply with the regulations of the competent authority.

2.22 Clothing and Personal Protective Equipment (Personal Protection Means)

Individual protective equipment and protective clothing should be worn in cases where it is impossible to prevent risks, namely:

- ✓ Appropriate protective clothing or equipment and face shields or goggles for welding, oxy-cutting, or working with molten metal, or for any other operation that could cause eye injuries;
- ✓ Appropriate protective clothing covering the entire body for handling corrosive or toxic products or other substances that could cause skin injuries
- ✓ Protective gloves for handling materials or performing tasks with risks of hand injuries;
- ✓ A safety helmet in case of falling objects;
- ✓ Appropriate safety shoes;
- ✓ Safety belts and ropes for fall protection;
- ✓ Life jackets or safety belts in case of falling into water;
- ✓ Hearing protection equipment;
- ✓ Highly visible fluorescent bands for helmets and clothing.
- ✓ Personal protective equipment should be provided free of charge.

2.23 General Conduct Guideline

Anyone who notices a risk to the life or health of workers or to the mine should:

- ➢ Take immediate measures to eliminate this risk.
- ➢ If this is not possible, promptly alert the individuals at risk, ask them to leave the area, move away, and report to the supervisory staff.

Fig 2.12 Individual Safety protection wears

2.24 Safety Signals

- Open-pit mines should use the same system of safety signals, symbols, and colors.
- Signage governing vehicle traffic on the roads of an open-pit mine should comply with the guidelines approved by the national authority.
- All safety signals, symbols, and colors should be explained to newly hired workers.

2.25 First Aid and Emergency Care

- The minimal equipment of a first aid center should be considered according to the type and size of the open-pit mine, as well as the qualifications and number of required rescuers.
- -The organization of first aid and emergency treatments in case of accidents should comply with the following provisions:
- An adequate first aid kit should always be accessible in the mine.

- A properly trained rescuer should be available at all times.
- A treatment room located in a suitable and easily accessible location allowing for the transportation of the injured should be provided.
- The works manager should take all necessary measures to transport the injured to the hospital or a similar treatment center.
- A register should be kept at each first aid station, where it is possible to record the names of individuals who have received care as well as information about the injuries sustained and the treatment administered.

2.27 First Aids Training

Some supervisory staff members should undergo training courses to obtain a recognized first aid certificate.

2.28 Worker Safety Management System

This system is a set of interrelated elements aimed at establishing a protocol and objectives for workplace safety and health, and achieving these objectives. The application of a systemic management method in the workplace ensures the level of prevention and protection and its continuous evaluation through appropriate improvements.

In order to create and maintain a safe working environment and comply with occupational health and safety (OHS) requirements according to national laws and regulations, employers are required to take the necessary measures to implement a safety management system.

The system should include the essential elements - policy, organization, planning and implementation, evaluation, and improvement action - as presented in the figure below.

2.29 Analysis of workplace accidents and occupational diseases

The study and analysis of workplace accidents and occupational diseases aim to establish and then detect the common causes that lead to their occurrence.

The analysis of the causal tree of the accident, considered as a consequence of a system malfunction, allows for the development of preventive measures aimed at eliminating hazardous and harmful conditions. The analysis methods are:

2.29.1 Statistical Analysis Method

This method is based on the examination of workplace accidents over a specific period of time. It helps to identify patterns in the variations of injury levels. The following statistical relative rates are used:

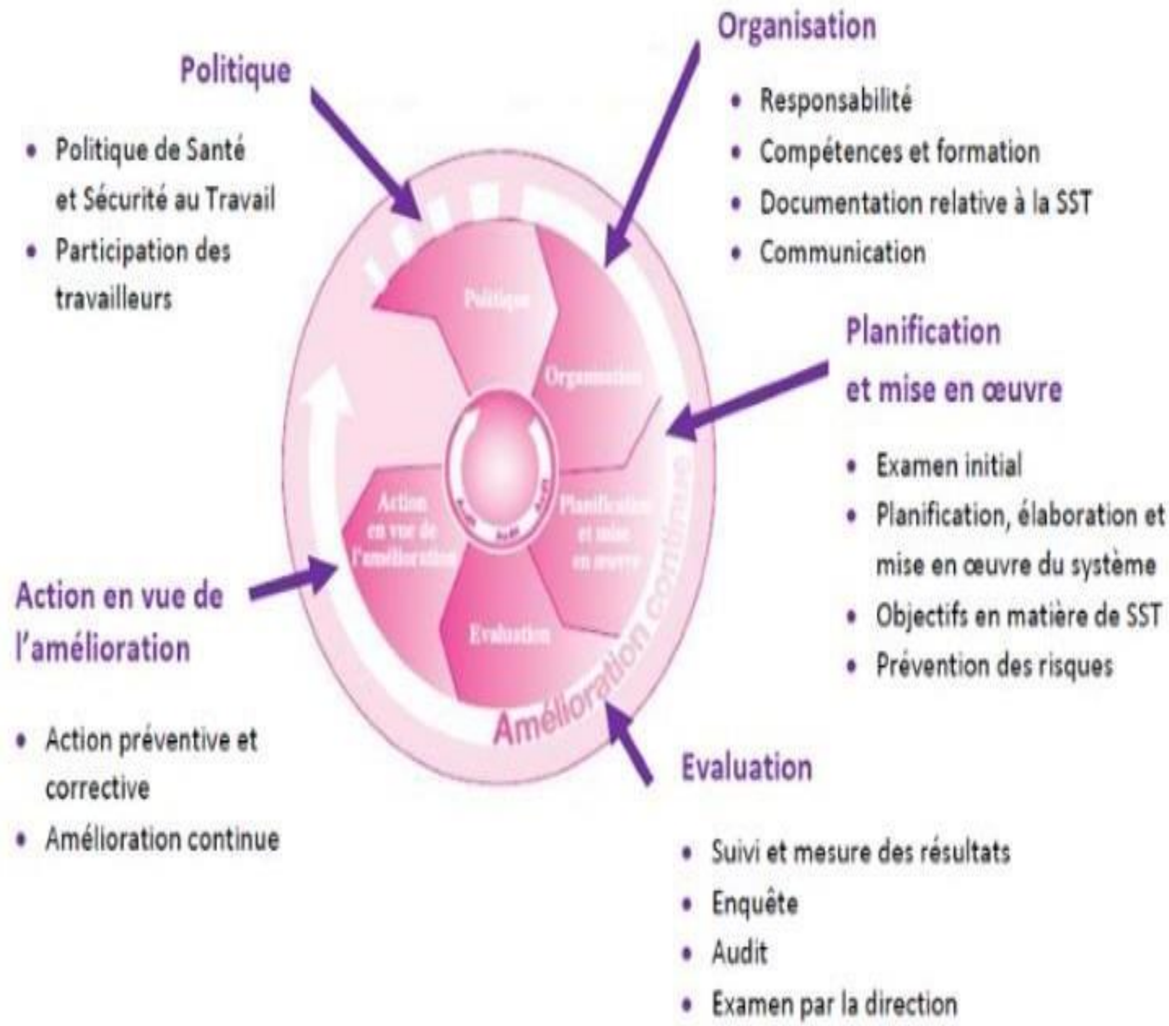

Fig 2.13 The security management cycle

- Frequency rate , Severity rate , Hazard rate

A/ Frequency rate: This is the ratio of the number of accidents (A) with work stoppage during a specified period of time x 10^6 to the number of working hours for all staff for the same period:

$$\mathbf{T_f = (A.10^6/H)}$$

B / Severity rate: This is the ratio of the number of lost days x 10^3 to the number of working hours.

Note: The number of lost days in case of death is 6000 days (according to the regulations of the social security fund).

$$T_g = (J_p.10^3/H)$$

J: number of lost days

H: number of working hours per year

A: number of accidents in one year

C/ Hazard rate: The hazard rate characterizes the degree of safety of the company. It is calculated by multiplying the frequency rate by the severity rate.

$$T_d = T_f . T_g$$

Note: In the case of partial permanent disability (partial disability), this is determined by the social security doctor and evaluated as a percentage of the 6000 days of permanent disability (in the case of death).

2.29.2 The topographic method

This method involves examining the causes of workplace accidents at the locations where they occur.

So, all accidents are identified on the workshop floor plan or at the site, and the dangerous sections requiring the implementation of preventive measures are marked.

2.30 Preventing Workplace Accidents and Occupational Diseases

Preventing accidents involves a set of technical, organizational, and psychological measures that encompass two aspects:

a) The technical prevention aspect

b) The organizational prevention aspect

Technical prevention: Technical prevention deals with eliminating accidents caused by hazardous systems such as:

- Assessment of hazardous machinery
- Hazardous methods...

Organizational prevention: Organizational prevention deals with workplace accidents caused by hazardous human actions. It includes three specific forms: Training, Information, and Promotion.

A - Training: This involves implementing a safety training strategy to support and complement technical measures. Safety training is essential. It allows for the identification and understanding of risks. Therefore, the entire staff must be exposed to the specific technical safety aspects relevant to the technology used.

Training certain workers in first aid, according to some statistics, can save the lives of injured workers, as the consequences often depend on the effectiveness and promptness of the first aid provided.

B- Information: Its goal is to inform the personnel about safety matters. Information is disseminated among the staff in the form of instructions. Two types of instructions can be identified:

General Instruction: In fact, this instruction is for anyone who has just been newly recruited, to acquaint them with the work methods and the harmful and dangerous places.

Detailed Work Point Instruction: This is provided for new workers or those who have changed their workplace.

C- Propaganda: It's a necessary means to create and develop a safety mindset among all workers. The widespread dissemination of basic messages aims mainly to create reflexes.

Posters and television serve to raise awareness through visual and audiovisual support of basic information aimed at conveying a very simple message by attracting attention with colors or subjective expressions related to the standards and regulations of the company, often encouraging compliance with safety measures.

The organization of the prevention of accidents at work and occupational diseases is established according to the specific labor legislation of each country.

2.31 Electrical security

2.31.1 Generalities

Electricity, the most widespread source of energy, has become familiar through its use in industrial or domestic environments. Nevertheless, it remains an abstract concept for many people since it is invisible and can only be detected by detection and measurement devices. This invisibility makes it extremely dangerous because only an informed individual will exercise caution. The risks associated with improper use are therefore poorly understood, leading to numerous accidents, some of which can be severe, among both informed and uninformed individuals.

In this section, we will cover the dangers associated with the use of electricity and provide training on various ways to avoid them, including learning first aid and how to provide initial care to electrocuted individuals.

2.32 Different risks of electrical accidents

2.32.1 Current sources

Tab 2.1 Current sources

Direct current	**Alternative current**
Batteries	Alternators
Accumulator batteries	Inverters
Semi conductors converters	Network grid
Rotating machines (generator)	
Indeed, regardless of the source, there is a danger.	

2.32.2 Electrical accidents

Electrical accidents have the following main effects on the human body:

- Electrification: Reaction to accidental contact with electricity
- Electrocution: It is electrification that can lead to death
- Falls: Consequences of electrification
- Electricity can also cause fires or/and explosions
- Burns from arcs, projections and sparks

60% of injuries are burns. 6% are internal injuries. Hands and head are the most affected.

2.32.3 Causes of electrical accidents

The origin of the accident depends on the types of contact between the person and the live element [11,12]. These types of contact are of two kinds:

- Direct contact: person's contact with an active electrical part

- Indirect contact: person's contact with a mass accidentally energized due to insulation failure.

- Short circuit: contact made by a metallic object between a mass and an active part under voltage or between two active parts under voltage.

2.32.3.1 - Unipolar direct contact

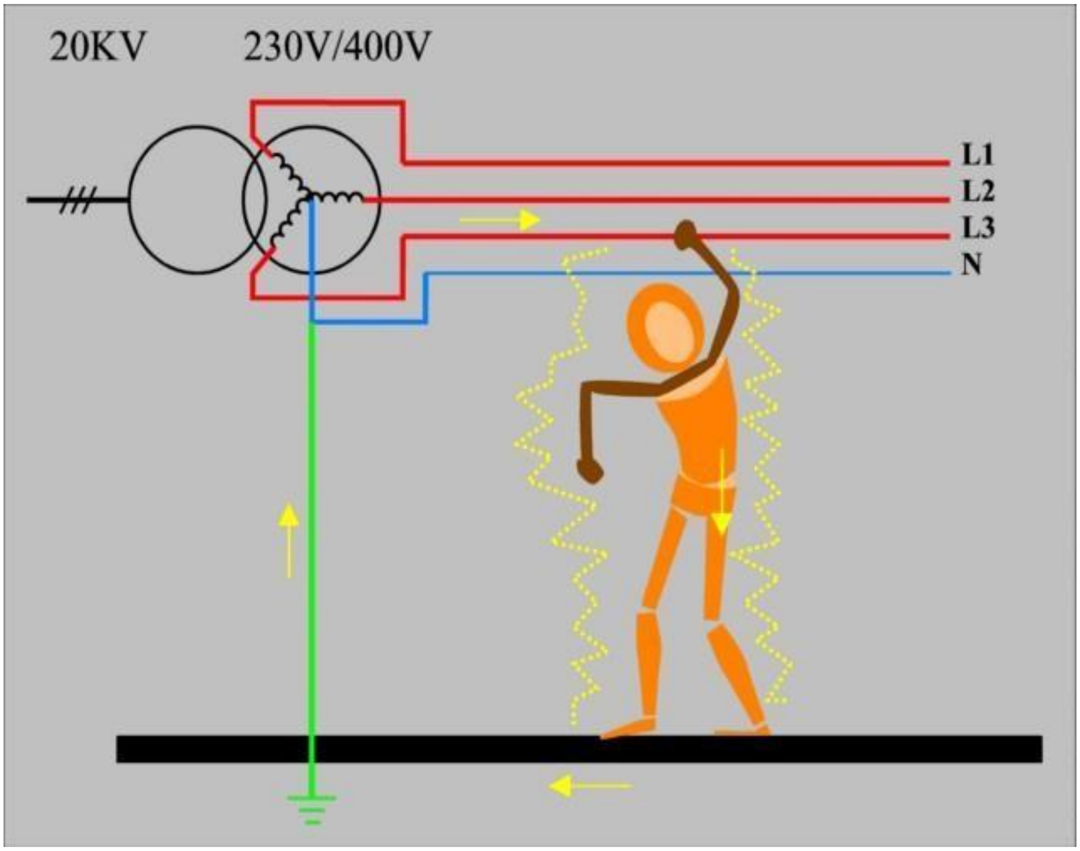

Fig 2.14 Contact with an active phase, very frequent

2.32.3.2 Bipolar direct contact

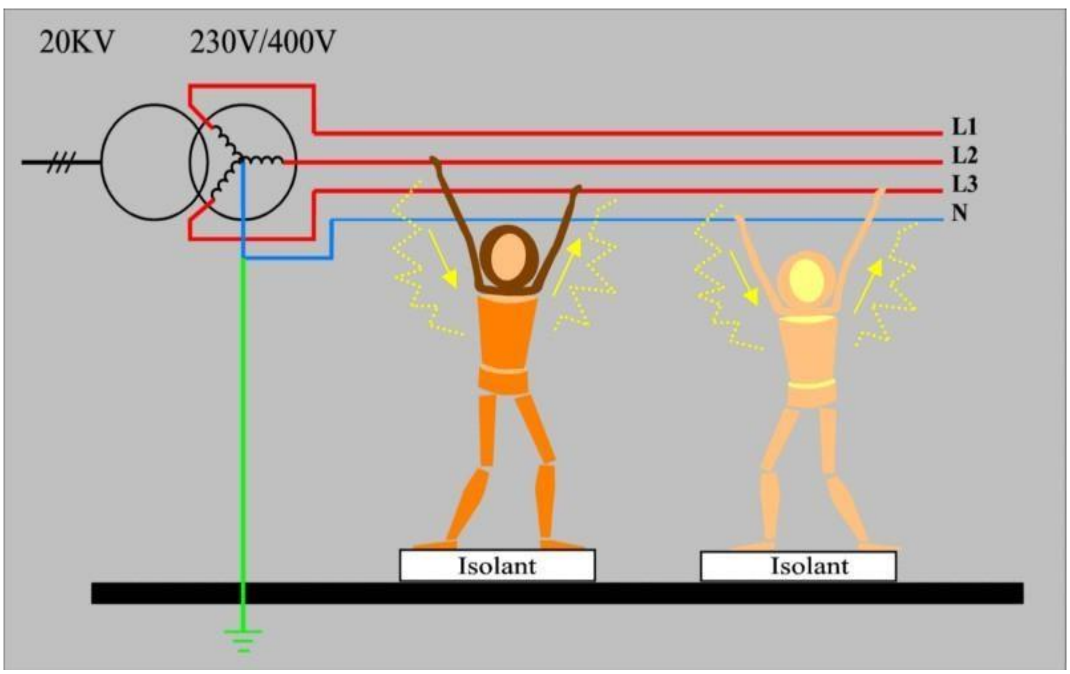

Fig 2.15 Contact between two active phases, and one phase and one neutral

Protection against indirect contacts must be ensured through systematic monitoring of electrical installations. This monitoring should be carried out frequently, and any defects or anomalies observed must be rectified promptly.

2.32.3.3 Unipolar indirect contact

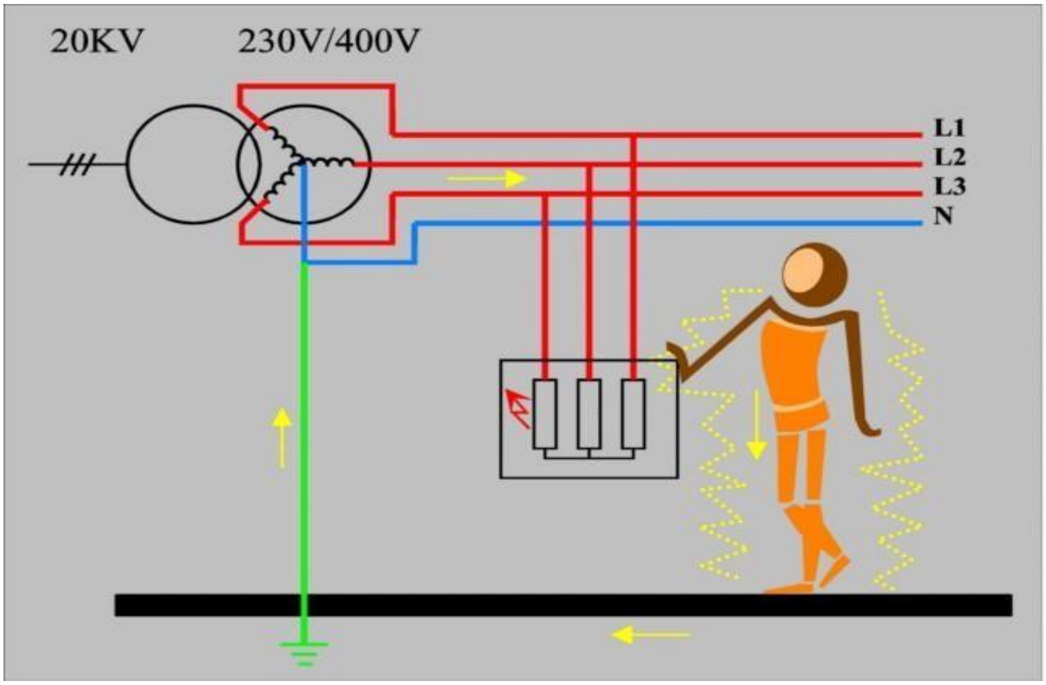

Fig 2.16 Contact with a mass accidentally energized is relatively frequent

2.32.3.4 Bipolar indirect contact

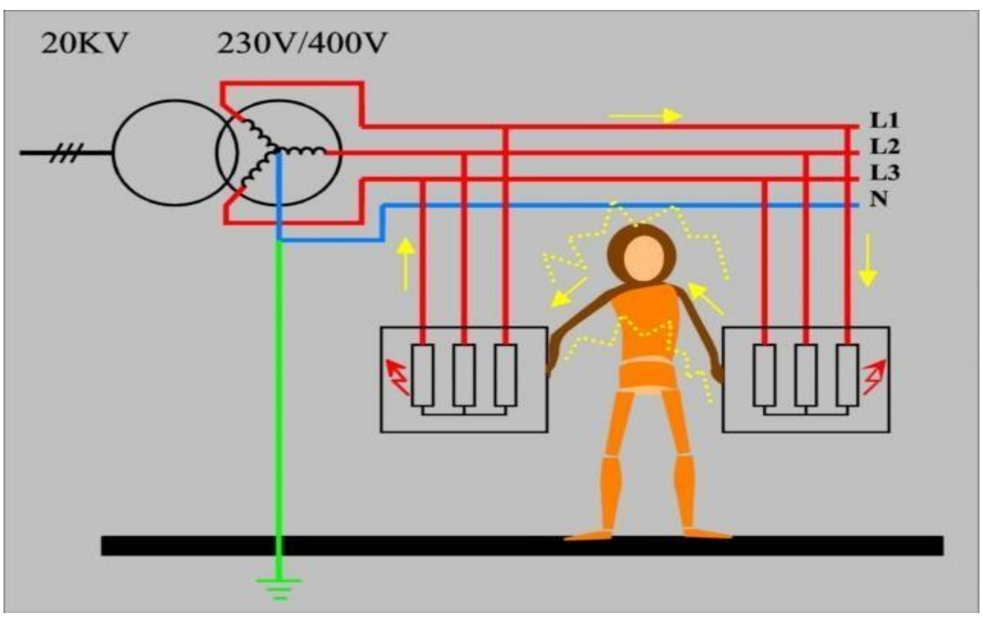

Fig 2.17 Contact with one energized mass and another mass accidentally energized, very rare

2.32.3.5 Short circuit

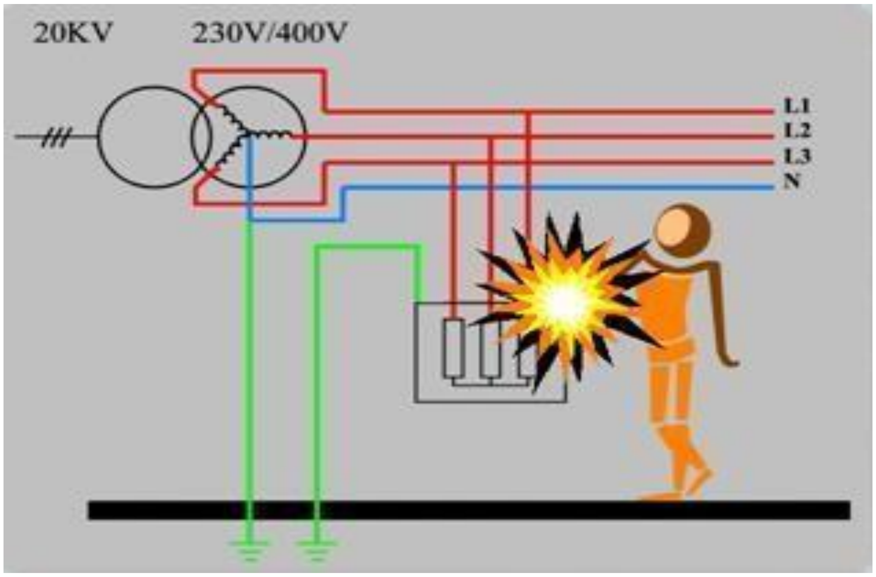

Fig 2.18 Contact made by a metallic object between a mass and an active part or between two active parts, frequent

2.33 Factors influencing the risk of electrocution

The danger of different electrical risks depends on the following factors:

- ✓ The current intensity and the resistance of the human body
- ✓ The frequency of the current
- ✓ Humidity
- ✓ The duration of current flow
- ✓ The path of the current through the body (pathways)
- ✓ The physiological state of the person.

2.33.1 Role of voltage

The onset of the electrification process is only perceptible above a certain voltage threshold. A contact between two terminals of a car battery (12 or 24 V) causes no sensation in the human body. However, the same contact with the terminals of a power outlet (240 V) will result in a painful sensation, or even unconsciousness.

In fact, our body is protected by the skin, which acts as a physiological barrier against electric sensations. Increasing the voltage applied to the skin leads to its perforation.

Conventional contact limit voltage: The maximum value of the contact voltage that it is permissible to maintain indefinitely under specified conditions of external influences. [2]

Condition BB1: Conventionnel contact limite voltage: 50 V

Condition BB2: Conventionnel contact limite voltage: 25 V

Condition BB3: The conventional contact limit voltage is not defined. The installation is powered by SELV (12 V).

The effects of electrification depending on the supplied voltage are as follow:

In alternating current

- Below 50 V: absence of fatal accidents;
- Between 50 and 500 V, the highest percentage of cardiac fibrillation is observed;
- For voltages ranging from 500 to 1,000 V, there is mainly respiratory syncope and burns;
- From around 1,000 V, internal hemorrhagic burns occur with release of myoglobin (kidney blockage).

Voltage range All the various aspects of electrical risk and the resulting severities have led the legislator to create voltage ranges in order to define the prevention measures to be implemented [13,14].

2.33.2 Impedance of the human body

The tissues of the human body can be represented by a series of resistances R and reactances X, all of which constitute an impedance Z:

$$\textbf{impédance : } Z_h = R_h + X_h$$

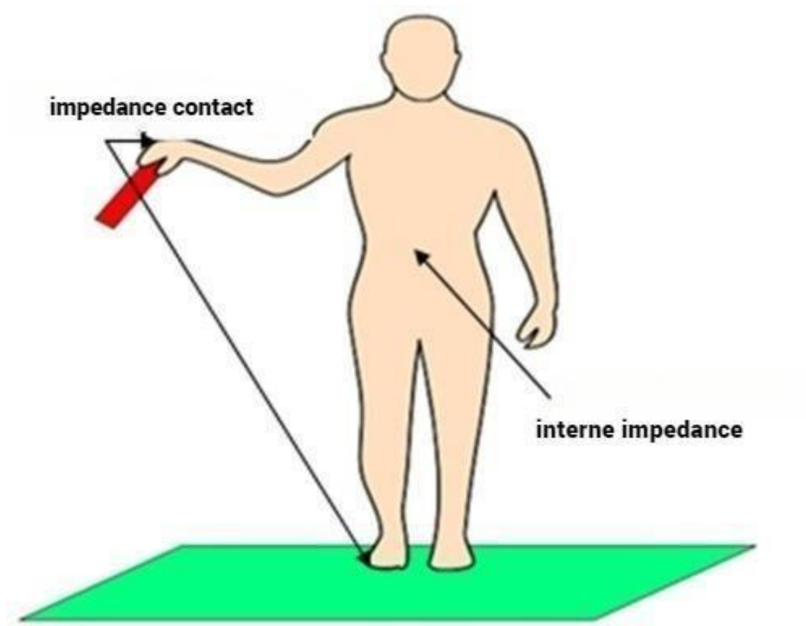

Fig 2.19 Deference between impedance contact and interne impedance

The impedance of the human body Z results from the geometric sum of the impedances of the skin or mucous membrane at the contact points Zp1 and Zp2 and the internal tissue impedance Zi. [2]

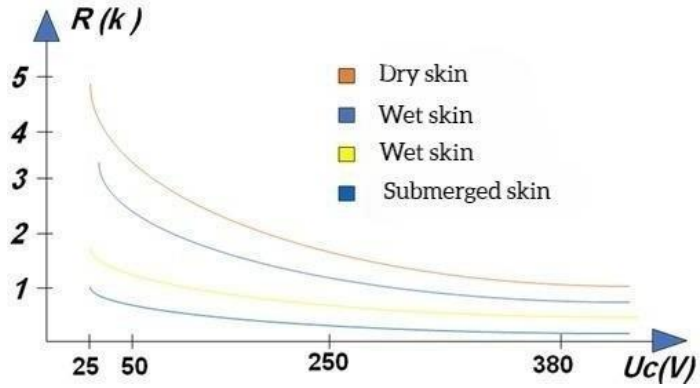

Fig 2.20 Variation in the resistance of the human body depending on the contact voltage and the condition of the skin

2.33.3 Effects of current intensity

The effects of the current intensity are determined by the voltage and the impedance of the human body.

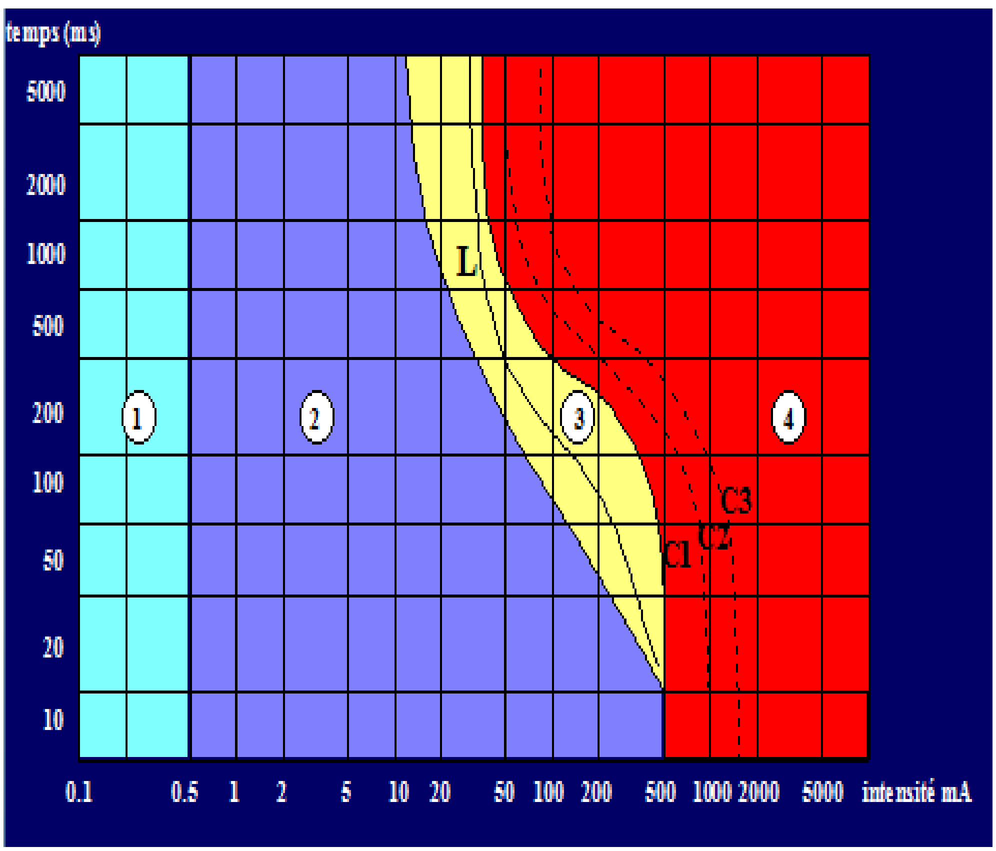

Fig 2.22 Time/current zone cycle of the effects of alternating current

- Physical effects (burns)
- Effects on muscles
- Effects on the heart
- Effects on the lungs
- Effects on the nervous system
- Ventricular fibrillation is considered the main cause of death from electric shock. There are also causes the death from asphyxia or cardiac arrest.

The following table shows the effects of the passage alternating current to the human body :

Tab 2.2 The effects of the passage of alternating current 50/60 Hz [2]

Intensity	Perception of effect	Time
0.5 to 1 mA	**Perception threshold depending on the condition of the skin**	**/**
8 mA	**Shock to touch, violent reactions**	**/**
10 mA	**Contraction of limb muscles lasting tensions**	**4 mm 30**
20 mA	**Beginning of totalization of the rib cage**	**60 sec**
30 mA	**Ventilator paralysis**	**30 sec**
40 mA	**Ventricular fibrillation**	**3 sec**
75 mA	**Ventricular fibrillation**	**1 sec**
300 mA	**Ventilator paralysis**	**110 ms**
500 mA	**Ventricular fibrillation**	**100 ms**
1000 mA	**Cardiac arrest**	**25 ms**
2000 mA	**Nerve centers affected**	**instante**

a) Physical effects: Arc burns

Arc burns are caused by the intense heat generated by the Joule effect during the production of the electric arc, as well as by the projections of molten metal particles. They are the most common, both in low and high voltage situations. In low voltage, they are localized to exposed parts (hands and faces). Arcs can also lead to conjunctivitis and corneal burns [14].

b) Electro-thermal burns

Electro-thermal burns are caused by the energy dissipated by the Joule ($Q=RI^2.t$; j) effect along the current path. These burns are always more extensive than they appear upon initial examination because superficial burns are associated with deep burns along the current path, especially in the muscle masses [11-14]

In the hours following this type of burn, temporary kidney failure (sometimes fatal) may occur due to the release of myoglobin into the blood, a release caused by the burning of internal muscle tissues.

c) Effects on the muscles

The intensity is determined by the value of the contact voltage and the impedance of the human body. In this context, we distinguish within the human body:

- Motor muscles controlled by the brain (such as muscles of the limbs)
- Autonomic muscles that function automatically, such as the lungs and the heart.

Motor muscles: Muscles, through their contractility and elasticity, enable body movements. Antagonistic muscles, through their opposing actions, allow for the flexion and extension of limbs. This is the case with the biceps and triceps of the arm. When muscles are traversed by an electric current, the brain no longer controls them, resulting in violent contractions. These conditions, generating involuntary movements, may lead to either not releasing the contacted object or repulsion, depending on the nature of the muscle involved (flexor or extensor).

Thoracic cage muscles: The thoracic cage operates automatically under the control of the cerebellum, which commands the numerous muscles involved in respiratory function (especially the diaphragm). Respiratory asphyxia can therefore be due to the action of electric current on the thoracic muscles, causing tetanus of the cerebellum and leading to respiratory arrest. Pulmonary involvement is rare in electrical burns compared to thermal burns, but it can occur when the current path crosses the thoracic wall, resulting in pleural effusion, hemothorax, and pneumopathy [14,15].

d) Effects on the heart

Cardiac cycle and fibrillation:

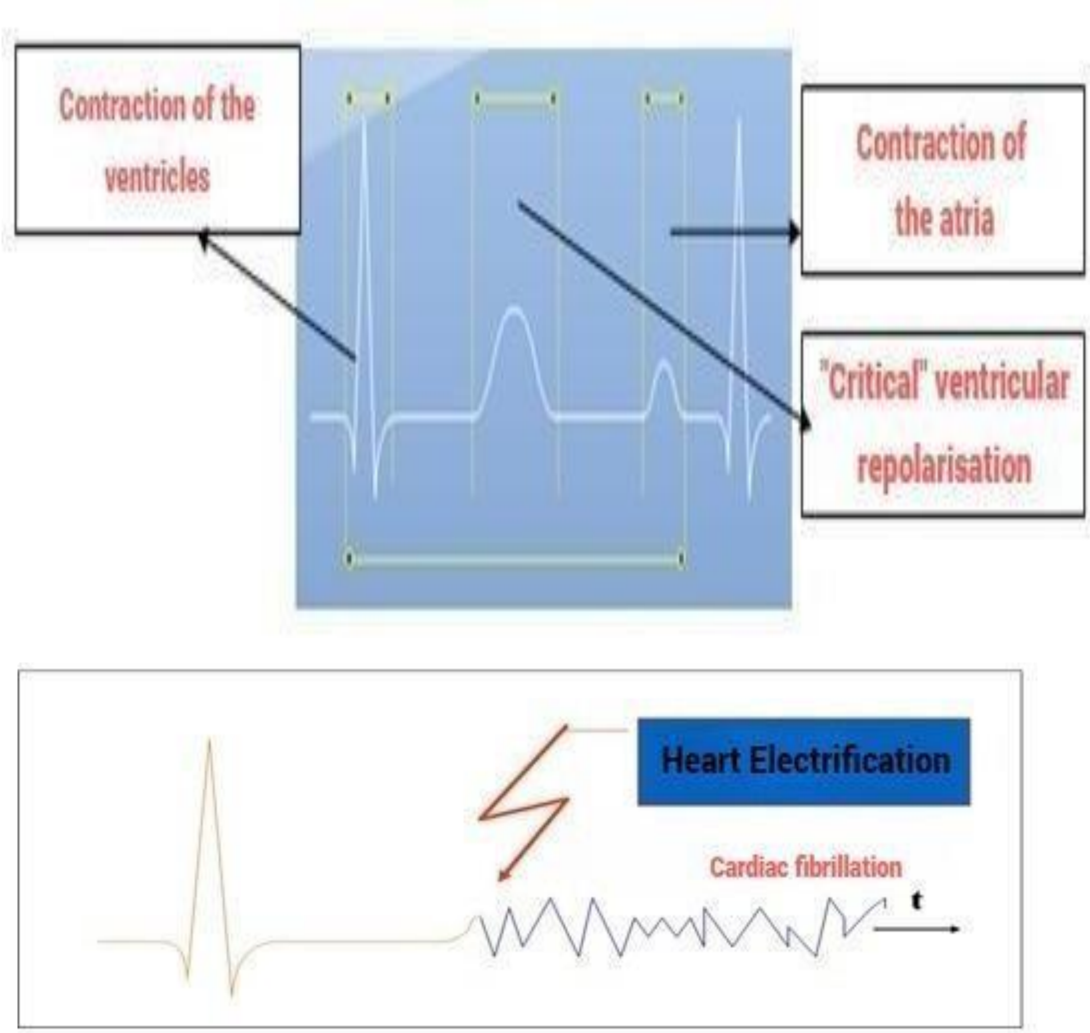

Fig 2.21 cardiac cycle and heart electrification

The heart has its own automatic control systems. It is during the ventricular repolarization phase that the heart is most vulnerable. The threshold for ventricular fibrillation depends on:

- Physiological parameters (body anatomy, cardiac condition, etc.)
- Electrical parameters (duration and path of current, current waveform, etc.)

In alternating current (50 or 60 Hz), the threshold for fibrillation decreases considerably if the current passage duration is prolonged beyond one cardiac cycle [14,15]

2.33.4 Effects of the current frequency

a) Skin impedance for frequencies higher than 100 Hz:

- ➢ The skin impedance is practically inversely proportional to the frequency for contact voltages of a few tens of volts.

- It is evaluated that at 500 Hz, the skin impedance is approximately one-tenth of that at 50 Hz, so it can be neglected in many cases.
- The total impedance of the human body can be assimilated to its internal impedance Zi.

b) Effects of alternating current passing through the human body for frequencies higher than 100 Hz

- Electrical energy in the form of alternating current with frequencies higher than 50/60 Hz is increasingly used in modern electrical equipment:
- Aviation (400 Hz),
- Portable tools and electric welding (100, 200, 300 Hz, and up to 450 Hz),
- Electrotherapy (several kHz),
- Power supplies from 20 kHz to 1 GHz.

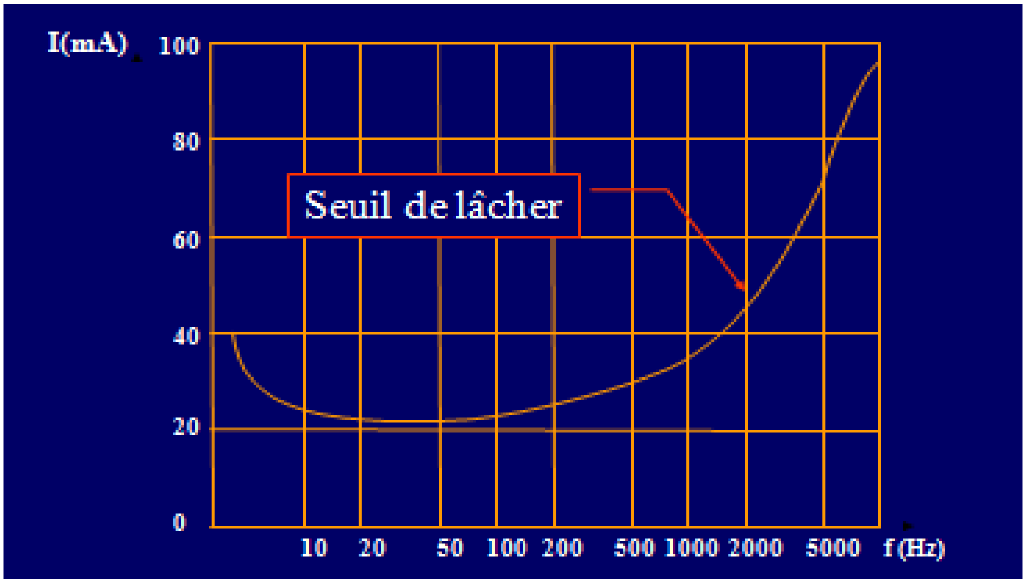

Fig 2.23 Release threshold based on current intensity and frequency

For frequencies higher than 50 Hz, currents become less dangerous, which does not mean that the danger disappears (less risk of fibrillation, but more risk of deep burns).

c) Other effects of current for frequencies higher than 10,000 Hz.

- For frequencies between 10 kHz and 100 kHz, the perception threshold increases approximately from 10 mA to 100 mA.
- At frequencies higher than 100 kHz, a sensation of warmth instead of tingling characterizes the perception threshold for currents of several

hundred milliamperes. With currents of a few amperes, the occurrence of burns is likely depending on the duration of the current flow [15].

2.34 Intervention plan

In the event of an accident, the intervention plan depends on the state of the human body and the damage caused. The figure below illustrates the different states of the individual subject to the accident and the options available to the rescuer according to which he chooses his intervention. Images are more expressive than words, which is why the following intervention plan is more expressive in images and everybody should read it [11].

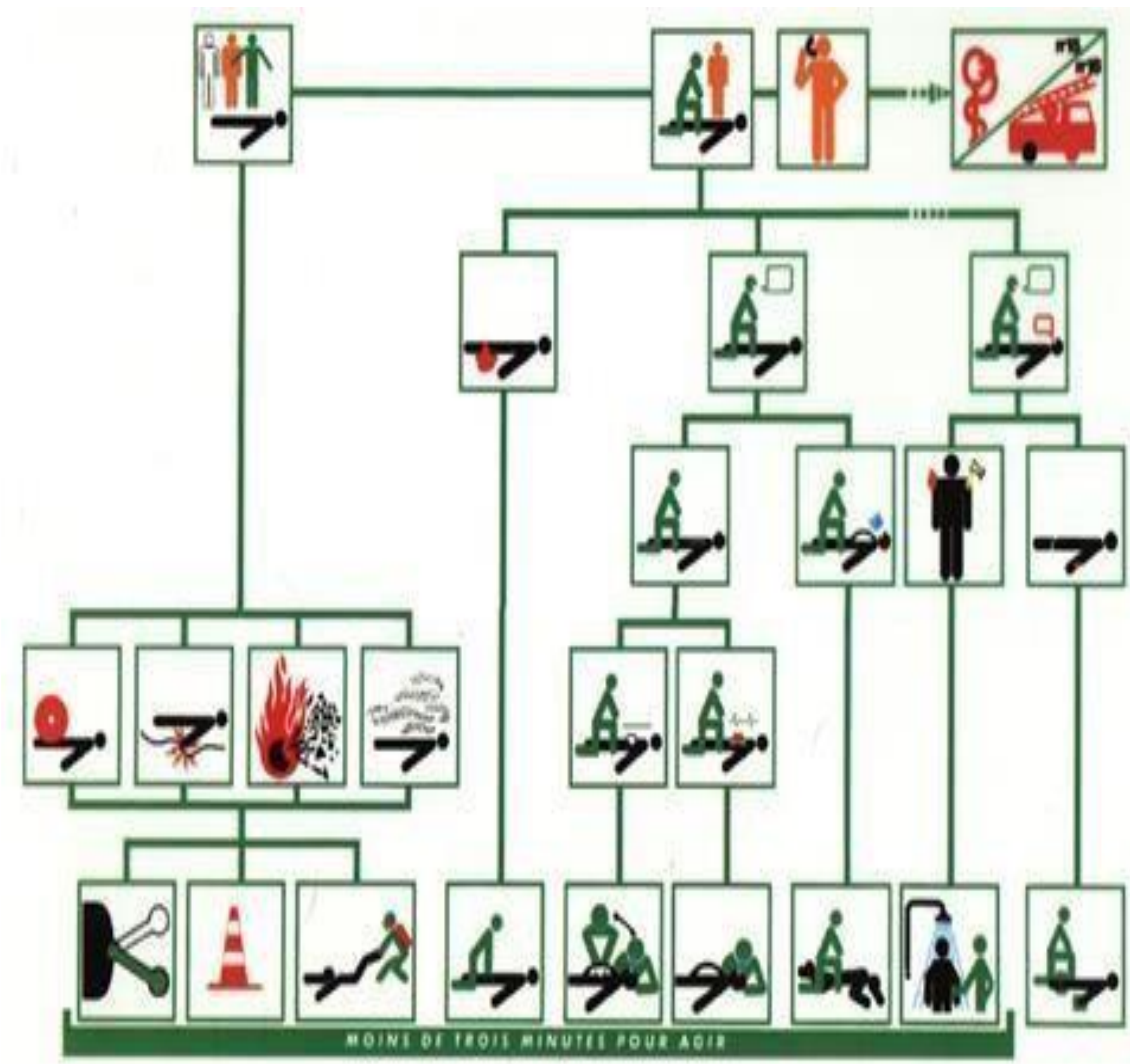

Fig 2.24 First Aid and Rescue Intervention Plan

2.35 Grounding connection diagrams

The universal standard C15.100 defines the three well-known neutral regimes, which are characterized by two letters:

- -The first letter indicates the situation of the grounding of the power transformer. (T) indicates the direct grounding, and (I) indicates isolation of conductors or electrical cores.
- -The second letter indicates the situation of the equipment's masses relative to the ground. (T) means that the equipment's masses are directly connected to the ground, (N) means that the masses are connected to the installation's neutral.
- We will particularly distinguish the following three regimes: TT, TN, and IT.[2]

TT System:

The TT distribution system is the system used by EDF for all low-voltage public energy distribution.

The principle of the connection involves connecting the neutral to the ground at the head of the low-voltage installation as well as all masses directly to the local ground.

Thus, as soon as an insulation fault occurs, it is characterized by a Phase-Earth short circuit that must be interrupted; this is referred to as "first-fault disconnection. [2]

TT Diagram:

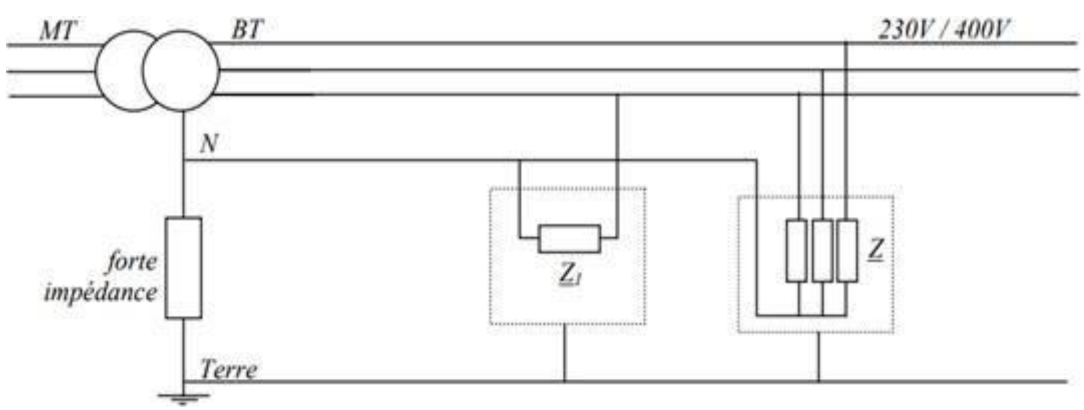

Fig 2.25 Diagram of TT system

TN System:

The TN distribution system is employed when grounding the equipment masses poses a problem. In this case, the masses are connected to the neutral conductor, which is connected to the ground at the head of the installation.

Thus, when an insulation fault occurs, it is characterised by a Phase-Neutral short circuit that must be interrupted; this is also referred to as first-fault disconnection.[2]

TN Diagram :

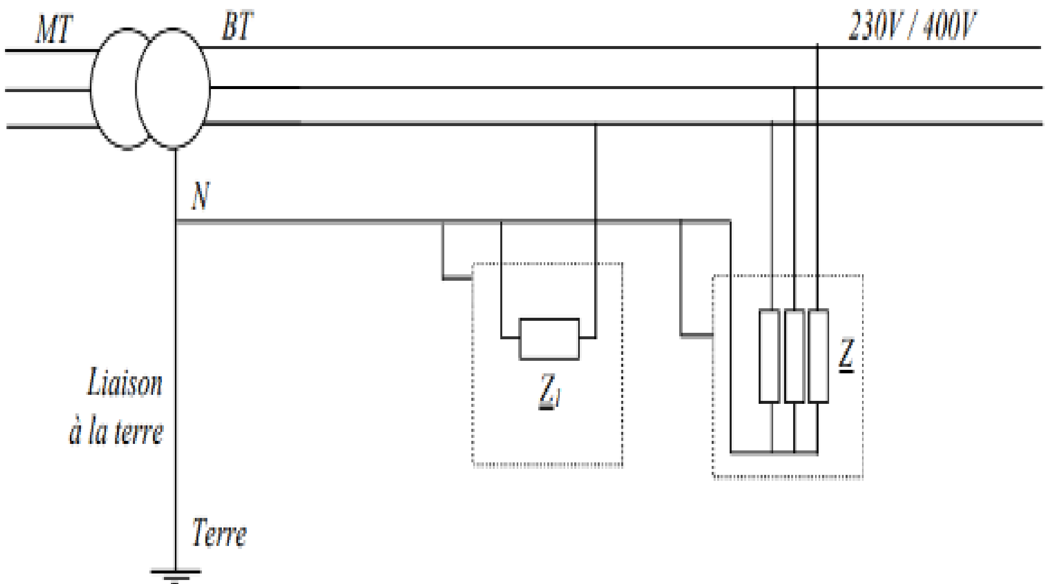

Fig 2.26 Diagram of TN system

IT System:

The IT distribution system is employed when insulation faults need to be detected without causing disconnection (for example, in hospitals). The neutral is not connected to the ground or is connected through a high-value impedance (1500 to 2200Ω). However, equipment masses are connected to the ground.

Thus, when an insulation fault occurs, it does not present a dangerous voltage or significant current to the ground. Detecting the current in the impedance allows for fault detection. However, if a second fault occurs, it represents a short circuit between phases or between phase and neutral, which must be eliminated; this is referred to as "second-fault disconnection.[2]

IT Diagram:

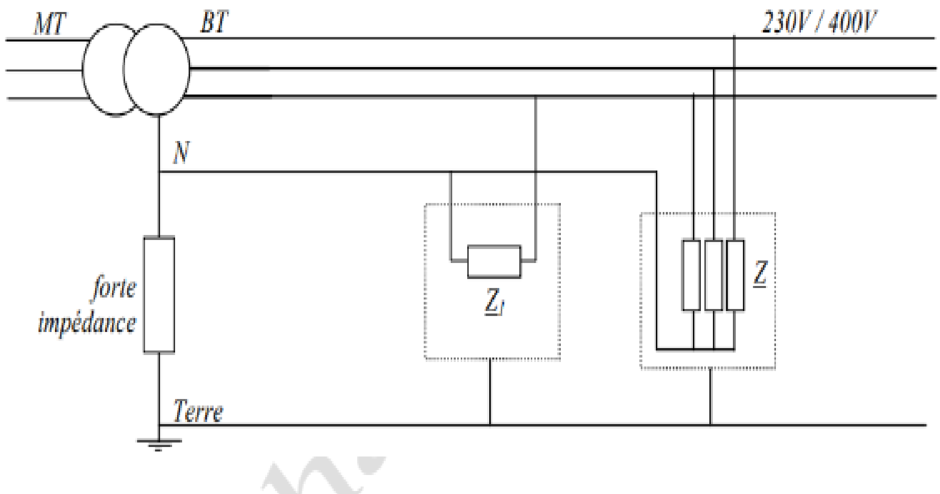

Fig 2.27 Diagram of IT system

2.36 Differential disjuncture device

The role of a residual current device in alternating current:

- Opens the electrical circuit in case of leakage exceeding the set value;

Id: Fault current

Ir: Residual current device setting Id > Ir

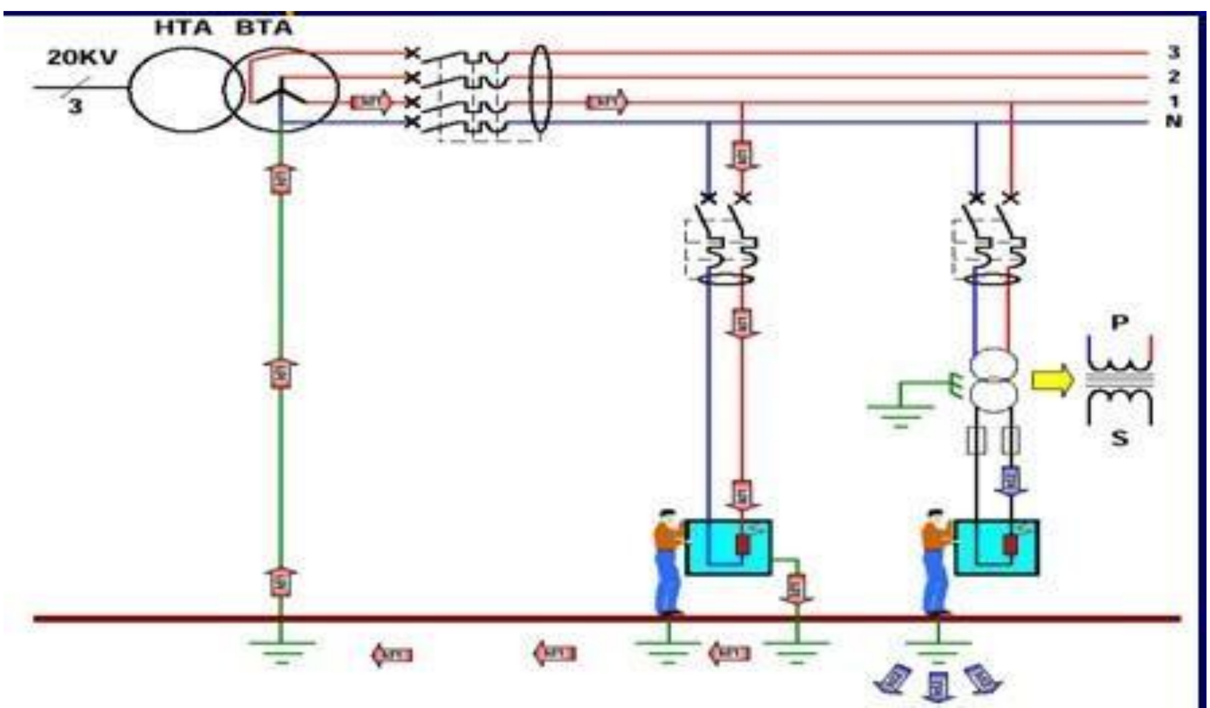

Fig 2.28 Disjuncture plan [2]

2.37 Conclusion

Effective protection against dust is essential for maintaining health and safety in both industrial and daily environments. By utilizing personal protective equipment (PPE), implementing engineering and administrative controls, and employing environmental dust suppression techniques, individuals and organizations can significantly reduce dust exposure. These combined efforts not only protect respiratory health and prevent skin irritation but also contribute to overall well-being and productivity. Prioritizing dust protection is a proactive step toward ensuring a safer and healthier environment for everyone. Electrical danger is the most died liest among all the other risks in industrial manufactories, moreover in mining exploitations. In this part of our study, we have highlight the different protocols and procedures for fixing them.

Chapter 3

The security department and electrical lighting of the underground areas

Electrical lighting in underground areas is essential for ensuring safety, functionality, and comfort. These areas, which include basements, tunnels, mines, and underground parking facilities, lack natural light and require artificial illumination to be navigable and usable. Proper lighting design in underground environments enhances visibility, prevents accidents, and supports the efficient performance of tasks. It involves selecting the right types of light fixtures, ensuring adequate light levels, and implementing energy-efficient solutions. Effective underground lighting not only improves operational safety but also contributes to the overall efficiency and usability of these spaces.

3.1 Introduction

Mines present numerous and deadly dangers. Many have met their fate in this field, as statistics and history confirm. As a result, a new branch within this domain has been created, becoming both a specialty and a concern. In this section, we will discuss the following points:

Given that the security service of Boukhadra unit is still young and lacksmuch in terms of organization, equipment, and personnel, it does not meet the unit'sneeds. We found it necessary to highlight what is missing in terms of equipment, the maneuvers performed, and training.

Considering the significant risks of electrocution, a brief overview of the factors determining electrocution risks will be provided. The conditions of electrocution and the main protection and first aid measures will be mentioned before starting the third part.

The third part includes a proposal for installing an isolated neutral regime after a modest investigation into the insulation status of mining cables. In this research, we will establish the difference between operating a network with an isolated neutral and a network with a grounded neutral. The nature of the danger presented by each will be discussed, highlighting the influence of the insulation state on electrical safety.

Finally, we will propose an appropriate method for monitoring the insulation state after comparing several methods.

3.2 Security Service at Boukhadra Unit

Before discussing the risks and consequences, and conducting a study on cable insulation (particularly systems with isolated neutral networks), we would like to mention the current state of the security service at Boukhadra unit. This willallow for a constructive critique and provide suggestions on what actions the securityservice should undertake.

The current staff of the security service includes 1 assistant, 4 agents, 3 drivers, and 12 guards. This number is insufficient due to the numerous tasks it handles. A security team comprising 20 to 22 people would be much more appropriate, including a team of 4 agents led by a supervisor. The material resources are also not satisfactory. The needs of the service are as follows:

- One reserve ambulance,
- One fire truck,
- Motor pump,
- Stretchers,
- Shovels,
- Pickaxes,
- Forks,
- Axes,
- Alarm systems,
- Electric torches,
- Gas helmets,
- Noise protection helmets, and
- Various pharmaceutical products.

The actions to address these problems should include ensuring that security agents and rescuers are trained to respond to any potential situation.

Awareness campaigns can be conducted, and true team work will be organized, bringing together security services and the hygiene commission to educate workers about the risks inherent to their jobs.

Notices and service notes with explanations should be posted. A rigorous control of the application of instructions will be established continuously, jointly with the training section.

It is important to properly train auxiliary intervention agents. The work plan will aim to:

- Ensure the locking of electrical panels,

- Equip all electrical posts with insulating materials (stools, gloves, poles, etc.),

- Address and repair defective protections in electrical installations, damaged roofs, walls, and cracked ceilings,

- Increase the number of signage panels to provide appropriate equipment for each type of hazard,

- Study occupational health issues, and

- Give priority to hygiene within the unit.

In conclusion, it is important to note that many dangers may arise, which will need to be addressed as they appear.

3.3 General Information

Work safety is a paramount issue, as it is crucial to inform workers about safety techniques in order to reduce the number of workplace accidents and combat occupational diseases, such as trauma and dust-related illnesses, which are common. This aspect plays a very important role in the mining industry, aiming to increase production while simultaneously ensuring the safety of workers in their workplaces.

The task of work protection involves improving and perfecting production processes and creating better and safer conditions. At Boukhadra mine, likein any company, there is a security service whose purpose is to monitor the implementation of safety instructions and distribute work equipment that can prevent and protect individuals from all accident risks.

This equipment includes:

- Helmets,

- Goggles,

- Safety shoes,

- Noise protection devices,

- Dust masks, etc.

Each department is equipped with one or more foam extinguishers for potential fire-fighting needs. In past years, the company has experienced numerous workplace accidents, resulting in fatalities, injuries, and an increase in number of lost workdays, which negatively impacts mining production. The statistics on workplace accidentsare shown in Table bellow.[3]

Tab 3.1 Statistics of the number of work accidents per precedent years

YEARS	*89*	*90*	*91*	*92*	*93*	*94*	*95*
NWA	*47*	*61*	*77*	*71*	*66*	*81*	*60*

3.4 Organizational configuration

To monitor safety, the previous table shows that the number of workplace accidents is not consistently recorded because regulations change from year to year along with the deterioration of safety measures and changes in working conditions. This fluctuation is evident.

The organizational chart is configured to reflect these issues and track safety performance, ensuring that all safety protocols are observed and updated regularly to adapt to new regulations and working conditions.

3.5 Electrification of the underground mine of Boukhadra

3.5.1 Introduction

Electrification in the mining industry is considered one of the primary foundations for enhancing dynamism and automation in mining operations.

It also focuses on the rational supply of electrical energy to mines and the challenges associated with its utilization, not to mention ensuring the safety of its operation.

Boukhadra mine is an extension of quarrying operations, requiring theinstallation of an electrical network to supply various consumers. Electrification of the underground mine is still a project under development in the company's methods office.

The technical characteristics of the equipment used in our calculations are largely available in the mine, but they have not yet been connected for service. It's worth noting that geographical and climatic conditions have been taken into consideration.

The initial focus lies on the power supply mode, with particular attention given to preventing any unacceptable overheating.

From a safety standpoint, the risks of electrocution have long been significant causes of both human and material losses [11,14].

3.5.2Power supply underground with electrical energy

The choice of underground work power supply scheme depend on the global consumers of energy and the mode of electrical energy distribution in the open pit and underground mine.

a) Choice of power supply mode

Theoretically, there are three main types of power supply schemes.

- Power supply through mine shafts using quarry substations (SSC).

- Power supply through boreholes from neighborhood substations at surface low voltage.

- Power supply through boreholes at voltages higher than 1000 V using underground substations. The latter scheme cannot be recommended for Algerian mines; it's advantageous for neighborhoods with significant capacity if they are distant from mine shafts.

The second scheme is more preferable. The absence of high-voltage cable networks and oil-filled equipment underground is essential for the power supply scheme from the neighborhood substations through boreholes from the surface.

However, these schemes are not recommended for maintaining the high-voltage distribution network. The scheme involving power supply through mine shafts is the most common. Despite being a classic scheme, it cannot be adopted without considering the rational application of such a tool each time.

The power supply scheme under the given conditions must be resolved based on economic calculations. Generally, the choice of a particular process is made based on its ability to provide electrical energy. The transport depth for boreholes is determined by the maximum allowable length, which is explained by voltage losses.

b) Choice of power supply scheme for Boukhadra underground work

The power supply scheme for Boukhadra mine deviates from what has been previously mentioned due to its geographical condition. The different levels are powered from a main substation installed at the surface, at the mountain threshold. Cables ascend the mountain walls to then enter the galleries of levels 1285, 1255, 1165, 1225, and the haulage gallery at 1105.

These locations were chosen because the underground work is continuous (at least for the moment). The network in the galleries consists of sections of 350m, 400m, 500m, 250m covering the distances between levels and connections.

It should be noted that when installing overhead lines along the mountain flank, the height of the cable suspension poles at road intersections must exceed that of the tallest truck, as electrical supply lines sometimes intersect these roads. Additionally, there currently exists a station that only powers compressors.

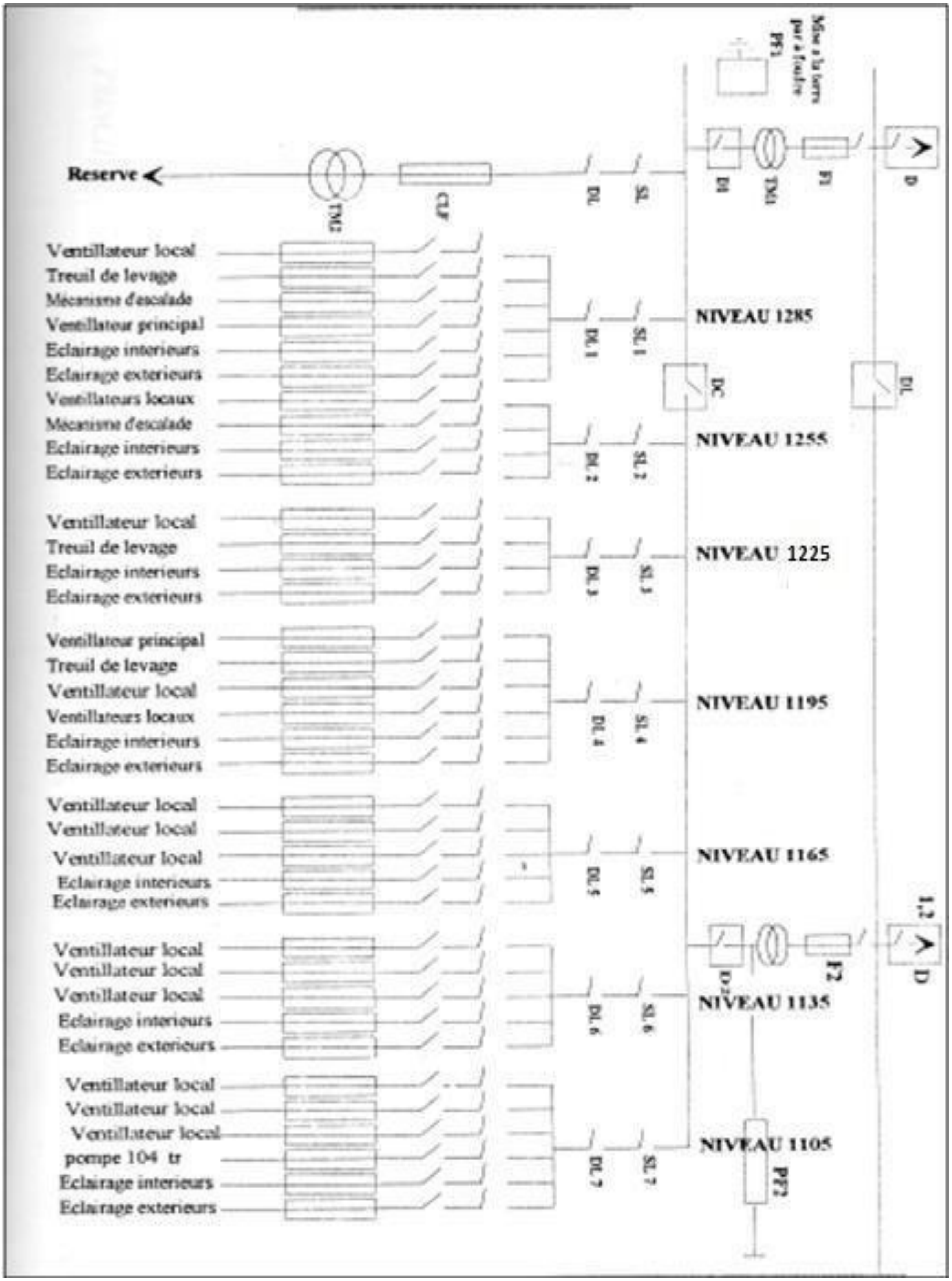

Fig 3.1Electrical distribution diagram [3]

Power supply diagram according to the mine configuration

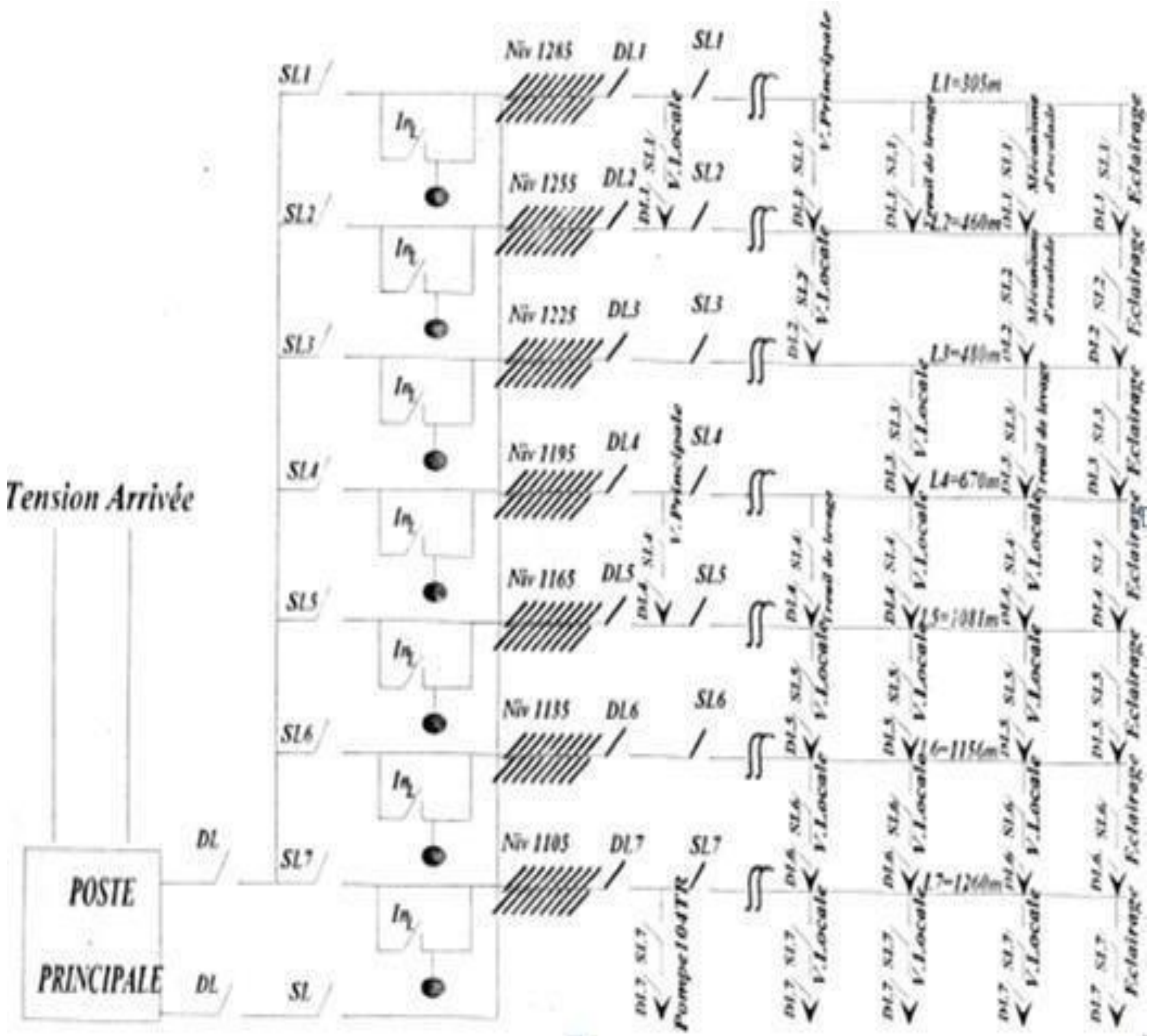

Fig 3.2 Power supply diagram for underground pit [3]

3.6The electrical lighting of mining area

The tight dimensions of the galleries and the specificities of mining works are such that it is impossible to fully meet the requirements and especially to achieve optimal illumination of the surfaces. This is why, currently, the minimum acceptable lighting standards for mining conditions are taken into account.

The minimum acceptable illumination (E_{min}) is the smallest hygienic standard of illumination that can ensure the proper functioning of personnel. This standard is based on the eye's ability to distinguish the details of machine parts. It also depends on the importance of the technological process, the type of work and the complexity of the mining operations.

The minimum standards has been developed through scientific research and have been refined by practical experiences under different conditions. Thus, for mining conditions, the values of the minimum acceptable illumination (E_{min}) are presented in the table below [5].

Tab 3.2 Minimal lighting of workspaces according to illuminated areas

Workplace	Illuminated Surface	E_{min}
- Size of preparatory excavation	- Horizontal on the floor / Vertical on the face	10/10
- Conveyor loading point	- Horizontal on the conveyor	10
- Haulage galleries	- Horizontal on the floor	1/3
- Shaft landing	- Horizontal on the floor	10
- Shaft tipping	- Horizontal at 0.8 m from the floor	10
- Hoist chamber	- Horizontal at 0.5 m from the floor	7
- Declines, inclines	- Horizontal on the floor	1
- Main underground substations, main dewatering chamber	- Horizontal at 0.8 m from the floor	10
- Locomotive depot	- Horizontal at 0.8 m from the floor	10
- Production excavations	- Vertical on the face	5

Evidently, with the development of lighting technology, the standards , E_{min} must be revised to refine them.

The purpose of lighting calculation is to determine the number and power of lighting devices, ensuring sufficient illumination of work surfaces. We distinguish the following lighting calculation methods:

- Point-by-point method
- Utilization lighting flux factor method [11]

3.8 Point-by-point method

The purpose of this method is, to calculate the lighting of places where the reflection factor is much small close to be negligible (haulage galleries, personnel walkways, stopping areas, etc.).This method, based on the use of the light intensity distribution curve of the lump; examines the relationship between the illumination (lightening) E of a given point of the proposed illuminating area and the light intensity of the lump.

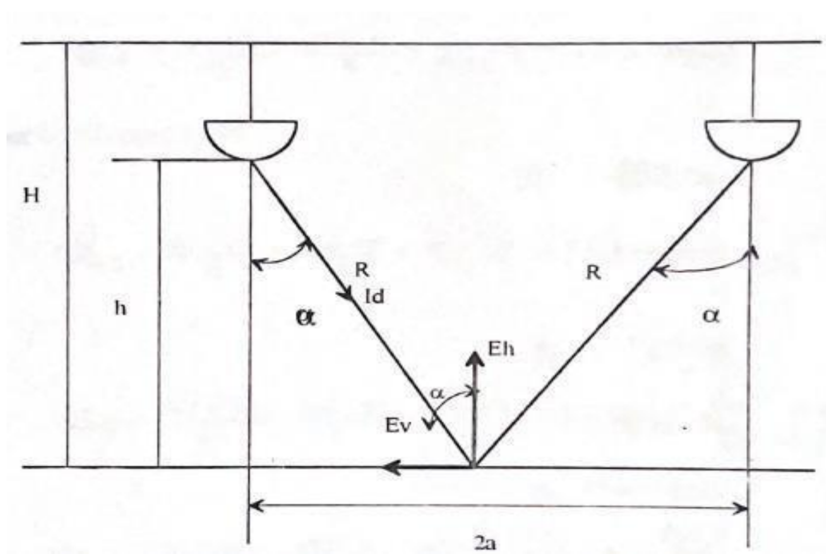

Fig 3.3 Scheme showing the point-by-point method

The horizontal and vertical illumination at point K from each lighting source S_1 or S_2, which are similar, depends on the luminous intensity (I_x) of the sources in that direction and the distance R . Both are determined by the following formulas:

$$E_h = la. \text{Cos}\alpha / R^2; (Lx) \qquad (1)$$

$$E_v = la. \text{Sin } \alpha / R^2; (Lx) \qquad (2)$$

We can transform the previous formulas as follows:

$$Eh = la \, . \, cos^3 a / h^2; (Lx) \qquad and \qquad Ev = Eh \, . \, t \, ; (Lx) \qquad (3)$$

We notice that for the calculation of illumination ; it is necessary to know the value of luminous intensity I_x of the lamp in this direction. This intensity is determined from the light intensity distribution curve. Basically, each lighting fixtures is characterized by several curves. It is depends on the number of lamps that can be installed in the lighting fixture. But for convenience, a single curve characterizes each lighting fixture; assuming the equipped with a conventional lamp who's specified by a luminous flux (F_o) equal to 1000 lumen (lm). Therefore, the characteristics of the luminous intensity distribution of different lighting fixtures with the conventional lamp are given in handbooks as curves or tables.

To determine the luminous intensity with the real lamp, the luminous intensity (I) given by a table or a catalog, must be multiplied by the correction coefficient (C), which is equal to the ratio of the luminous flux of the real lamp (F_i) to the luminous flux of the conventional lamp (F_o) [12].

$$C= F_i/ F_o = F_i/1000 \quad (4)$$

As lamps age and lighting fixtures get dirty with dust, it is necessary to introduce the depreciation factor (f_a). The final formula for the practical calculation of the horizontal illumination from lighting fixtures is:

$$Eh = \frac{2\times la\times C\times cos^3 a}{h^2\times h_d} \quad (5)$$

The calculation itself consists on the following steps:

1. Choose the value of E_{min}.

2. Choose the type of lighting fixtures and the type of lamp from a catalog.

3. Propose the distance between the lighting fixtures.

4. Propose the suspension height of the lamps H - h = 0.3 m

5. Find the value I_a of the lighting fixture from the table or handbook and calculate the correction coefficient C .

6. Calculate the illumination E_h.

7. Compare this value E_h with the value E_{min}. If the calculated value E_h is less than E_{min} .it is necessary to change either the arrangement of the lighting fixtures or the lighting fixture themselves and recalculate.

The necessary number of lighting fixtures is determined according to the following formula:

$$N = \frac{(L-2a)}{2a} \quad (6)$$

Where L is the length of the gallery concerned by illuminating the project (m).

2a is the distance between lighting fixtures (m).

3.9 Method of using luminous flux

If the influence of reflection flux on the total illumination is significant, the technicians use often this method for indoor lighting calculations in various premises (substation, workshops, etc.).The essence of the method consists of the commonly called "the useful luminous flux (F_u)"; witch is definite as only certain part of the total luminous flux F_t of the lighting installation used to ensure the illumination of the concerned area. The luminous flux utilization factor is:

$$n = fu/ft \quad (7)$$

The value of the utilization factor depends on:

The reflection wallsfactors ,ceilings ,and work areas

- The type of lighting fixture
- The index of the room "i"

The reflection coefficients of the surfaces depend on their colors:

- For gray surfaces: 10 to 30%
- For bright surfaces: 50%
- For white surfaces: 70%

The room index is a factor that depends on the geometric dimensions of the room and the hanging height of the lighting fixtures. [11,12]

$$i = A.B/(h.(A + B)) \quad (8)$$

A: Width of the room; meters

B: Length of the room; meters

H: Height of lighting fixture suspension; meters

The utilization factors for different types of underground lighting installations are represented in a reference guide or table. When making approximate calculations, it is common to use an utilization value of 0.3 to 0.4.

By using the utilization factor t, it is possible to calculate the total luminous flux F_t necessary to ensure the minimum permissible illumination E_{min} in the local area.

$Ft = (Fd.Emin.S)/(r * z)$ (9)E_{min}:

Minimum acceptable illumination;

F_d: 1.2/2 depreciation factor;

S: Illuminated area;^{2}.Z:

Utilization factor;

T: Minimum illumination factor depending on the type of lighting fixture, their spacing, and suspension height. For mines, Z: 0.8.

Given the total luminous flux Ft, one can calculate the required number of the lighting fixtures.

$$n = F_t / F_l \qquad (10)$$

F_l: Luminous flux of the chosen lighting fixtures.

The calculation steps are as follows:

1. Choose the type of lighting fixtures (from a catalog or table).
2. Calculate the room index I.
3. Find the utilization factor (from a table).
4. Calculate the total luminous flux F_t.
5. Calculate the number of lamps.
6. Calculate the total power of the lighting installation.

3.10 The electrical lighting of the district

It is impossible to meet the exact requirements and, especially, achieve optimal lighting of surfaces because of the tight dimensions of the galleries and the specifics of mining works.[4]

The minimum admissible lighting E_{min} is the smallest hygienic standard of lighting that can ensure the functioning of the personnel. This standard is based on the eye's ability to distinguish details machine parts. They also depend on the importance of the technological process, the type of work, and the complexity of the operations.[4]

Researchers developed the minimum standards through scientific research and refined them through practical experiences for different conditions. Thus, for mining conditions, the values of the minimum admissible lighting E_{min} are represented in the following table.

Tab 3.3 Illuminated surface according to workplace [4]

Workplace	**Illuminated Surface**	**E_{min}**
- Size of preparatory	- Horizontal on the floor / Vertical on the face	10/10
- Conveyor loading point	- Horizontal on the conveyor	10
- Haulage galleries	- Horizontal on the floor	1/3
- Shaft landing	- Horizontal on the floor	10
- Shaft tipping	- Horizontal at 0.8 m from the floor	10
- Hoist chamber	- Horizontal at 0.5 m from the floor	7
- Declines, inclines	- Horizontal on the floor	1
- Main underground	- Horizontal at 0.8 m from the floor	10
- Locomotive depot	- Horizontal at 0.8 m from the floor	10
- Production excavations	- Vertical on the face	5

3.11 Calculation of district lighting

Rational lighting must ensure:

- Sufficient illumination of the work surface,
- Illumination uniformity,
- Limitation of uncomfortable glare from light sources.

Practically, for the calculation ofthe illumination, we use the following expressions:

$$E_h = \frac{2C \times Id \times Cos^3\varphi}{Fd \times h^2} \quad (11)$$

$$E_v = E_h \times t \,; Lx \quad (12)$$

Where $E_v$is the vertical illumination,

E_h:horizontal illumination,

h: Height of the suspension of the lighting fixture (h = H - 0.5 = 3)

F_d: Depreciation factor, which for mining conditions is equal to 1.2 ÷ 2.

I_d: Light intensity according to the direction of the lighting fixture.

- L: Length of the illuminated gallery. [4]

$$C = \frac{F_1}{1000} \quad (13)$$

$$N = \frac{L-2a}{2a} \quad (14)$$

The luminous flux of the lamp (F_l) and the lighting fixtures (I_d) is a function of the angle. The calculation itself consists of the following steps:

-Propose the approximate distance between the lighting fixtures.

-The values of Id and Flare taken from the represented tables.

-Calculate the horizontal and vertical illumination (E_h, E_v).

-Determine the number of lighting fixtures using the following equation

Tab 3.4 Lighting intensity in the mining lighting fixtures in α direction

Aα (°)	Luminous intensity I_d C_d		Angle α	Luminous intensity I_d C_d	
	Longitudinalsurface	Transversalsurface		Longitudinalsurface	Transversalsurface
0	18	95	10	100	100
5	26	96	20	96	99
15	38	93	30	82	96
25	57	95	40	68	84
35	60	92	50	49	68
45	62	90	60	30	62
55	60	85	70	10	65
65	52	71	80	00	75
75	54	75	90	00	87
85	55	77	100	00	93
95	59	78	110	00	94
105115	59	80	120	10	92
125	60	84	130	20	91
135	47	81	140	27	93
145	15	83	150	38	85
155	00	85	160	46	70
165	00	83	170	49	55
	00	73	180	50	00

3.12 Lighting of the galleries by the point-by-point method

3.12.1 Calculation of horizontal lighting

$$Eh = \frac{2 \times C \times Id \times Cos^3\varphi}{Fd \times h^2} \qquad (15)$$

F_d : Depreciation factor F_d = 1,2 for mining conditions

$$C = \frac{F1}{1000} \text{ ; F1 = 1320 so C = 1.32} \qquad (16)$$

U = 220v 2a = 9 so a = 4,5

- h = H – 0,5 = 3,5 – 0.5 = 3m ; (H = 2 ÷ 5 m)

h : Suspension height of the lighting fixtures

$$tg\alpha = \frac{a}{h} \quad so \quad \alpha = arc\,tg\,\frac{a}{h} = arc\,tg\,\frac{4,5}{3} = arc\,1$$

$$\text{So : } Eh = 2,34\,L$$

Tab 3.5 The lengths of the different galleries at each level of the underground mine.

Level	1285	1255	1225	1195	1165	1135	1105
Length	305	460	480	670	1081	1156	1260

3.12.2 Calculation of vertical lighting

$$In\ terms\ of : \varphi = 56 \quad so \quad tg\,56 = 1,48$$

$$Ev = Eh \times tg\varphi = 2,34 \times 1,48 = 3,46\ (Lx)$$

$$Ev = 3,46\,L$$

Finally, we can conclude, the value of the standard for minimal illumination shows that the horizontal illuminance E_h approaches E_{min}.

$$Eh \geq Em \ ; \quad Emin = 2Lx \quad so\ 2,34 > 2$$

3.12.3 Calculation of the number of lighting fixtures

For the level 1285 $l_1 = 305\ m$

$$NL_1 = \frac{L_1 - 2}{2a} = \frac{305 - 9}{9} = 32{,}88 = 33\ Lamps$$

For the level 1255 $L_2 = 460\ m$

$$NL_2 = \frac{L_2 - 2a}{2a} = \frac{460 - 9}{9} = 50{,}11 = 51\ Lamps$$

For the level 1225 $L_3 = 480\ m$

$$NL_3 = \frac{L_3 - 2a}{2a} = \frac{480 - 9}{9} = 52{,}33 = 53\ Lamps$$

For the 1195th level $L_4 = 670\ m$

$$NL_4 = \frac{L_4 - 2a}{2a} = \frac{670 - 9}{9} = 73{,}44 = 74\ Lamps$$

For the 1165th level $L_5 = 1081\ m$

$$NL_5 = \frac{L_5 - 2a}{2a} = \frac{1081 - 9}{9} = 119{,}11 = 120\ Lamps$$

For the 1135th level $L_6 = 1156\ m$

$$Nl_6 = \frac{L_6 - 2a}{2a} = \frac{1156 - 9}{9} = 127{,}44 = 128\ Lamps$$

For the 1105th level $L_7 = 1105\ m$

$$Nl_7 = \frac{L_7 - 2a}{2a} = \frac{1105 - 9}{9} = 139\ Lamps$$

3.12.4 Calculation of total power of the lamps in the galleries for each level

$$\sum Pi = PL \times NL_i \dots\dots\dots\dots\dots\dots\dots\dots..(Kw) \qquad (18)$$

- Level 1285 : $\sum P_1 = 100 \times 33 = 3300\ w = 3{,}3\ Kw$
- Level 1255 : $\sum P_2 = 100 \times 51 = 5100\ w = 5{,}1\ Kw$
- Level 1225 : $\sum P_3 = 100 \times 53 = 5300\ w = 5{,}3\ Kw$
- Level 1195 : $\sum P_4 = 100 \times 74 = 7400\ w = 7{,}4\ Kw$
- Level 1165 : $\sum P_5 = 100 \times 120 = 12000\ w = 12\ Kw$
- Level 1135 : $\sum P_6 = 100 \times 128 = 12800\ w = 12{,}8\ Kw$

- Level 1105 :$\sum P_7 = 100 \times 139 = 13900\ w = 13{,}9\ Kw$

3.14.1 Calculation of exterior lighting

Of each gallery of these levels with a lamp of power P_L = 200W for the night shift, therefore: N_L = 7 lamp

$$\sum PL = \times NL = \quad 200 \times 7 = 1400$$

$$\sum PL = 1{,}4\ Kw$$

3.14.2 Calculation of lighting power

a- Calculation of the total power of the lighting installations:

$$S_t = \frac{\sum PL}{n_r \times n_l \times \cos \varphi} \qquad (19)$$

Where:

- $\sum PL$: Total power of the lighting fixture in (kW)
- n_r: Efficiency of the lighting network, $n_r = 0{,}9$
- n_l: lighting fixture efficiency, $n_{l=1}$
- $cos\varphi l$: Power factor of the lighting fixture,$cos\varphi l = 1$

$$S_t = \frac{3{,}3 + 5{,}1 + 5{,}3 + 7{,}4 + 12 + 12{,}8 + 13{,}9}{0{,}95 + 1 + 1} = \frac{61{,}2}{0{,}95} = 64{,}42\ Kw$$

$$S_t = 64{,}42\ Kw$$

With the reserve coefficient equal to $K_r = 1{,}2$

$$S_t = 1{,}2 \times 64{,}42 = 77{,}3\ Kw$$

$$S_t = 77{,}3\ Kw$$

3.15.1 Lighting network calculation

3.15.2 Calculation of conductor section

We must check the conductor sections according to several factors:

- Mechanical strength and economic density
- Permissible voltage drop
- According to the order of unacceptable heating,

We perform a check on the current of a branch of the lighting network as follows:

$$Ibr = \frac{\sum p \times 1000}{Unom \times cos\varphi_L} ;(A) \qquad (20)$$

Tab 3.5 Summary table of lighting calculation results

Location of gallery lighting	Type of light fixture	F_L (Lm)	N_L	2a	P_n (w)	P_L (Kw)	L_g (m)
Lv . 1285	PH 100	1320	33	9	100	3,3	305
Lv . 1255	PH 100	1320	51	9	100	5,1	460
Lv . 1225	PH 100	1320	53	9	100	5,3	480
Lv . 1195	PH 100	1320	74	9	100	7,4	670
Lv . 1165	PH 100	1320	120	9	100	12	1081
Lv . 1135	PH 100	1320	128	9	100	12,8	1156
Lv . 1105	PH 100	1320	139	9	100	13,9	1260
E.exterior	PH 200		7		200	1,4	

P: Total power of lighting fixtures interconnected in this branch

cos ; n_L ; Power factor and lighting fixture efficiency

$$cos\varphi_L = n_L = 1$$

Sowe calculate the conductor section of a branch of the network according to the following expression:

$$S = \frac{Ibr \times L \times cos\varphi_L}{\gamma \times Uadm} \qquad (21)$$

Where:

- U_{adm}: Admissible voltage , U_{adm} = 220 V

- γ: Conductivity of the lighting cable for copper γ = 50
- According to the calculated section, we choose the standardized section, which is verified based on normal service heating.
- The current intensity passing through the cable must be lower than the permissible value for this cable section.
- **Example:**

Calculation of the lighting network for a gallery:
- The branch current of the gallery (100 W): according to the following formula, we calculate the current for all levels.

$$Ibr = \frac{\sum p \times 1000}{Unom \times cos\varphi_L}; (A)$$

- Level 1285 $Ibr = \frac{(0,2+3,3) \times 1000}{220 \times 1 \times 1} = 15,9\ A$
- Level 1255 $Ibr = \frac{(0,2+5,1) \times 1000}{220 \times 1 \times 1} = 24,09\ A$
- Level 1225 $Ibr = \frac{(0,2+5,3) \times 1000}{220 \times 1 \times 1} = 25\ A$
- Level 1195 $Ibr = \frac{(0,2+7,4) \times 1000}{220 \times 1 \times 1} = 34,45\ A$
- Level 1165 $Ibr = \frac{(0,2+12) \times 1000}{220 \times 1 \times 1} = 55,45\ A$
- Level 1135 $Ibr = \frac{(0,2+12,8) \times 1000}{220 \times 1 \times 1} = 59,09\ A$
- Level 1105 $Ibr = \frac{(0,2+13,9) \times 1000}{220 \times 1 \times 1} = 64,08\ A$

Then we calculate the section of the lighting network for the gallery according to the following formula :

$$S = \frac{Ibr \times L \times cos\varphi_L}{\gamma \times Uadm} \quad ; (mm^2)$$

L: Length of the gallery (m)
γ: Conductivity of the lighting cable for copper (γ = 50 m/mm²)
(U_{adm}): Admissible voltage (U_{adm} = 220V)

- For the 7 levels, we have the section as follows:

- Level 1285 $S_1 = \frac{15,9 \times 305 \times 1}{50 \times 220} = 0,44 \approx 1,5\ mm^2$
- Level 1255 $S_2 = \frac{24,09 \times 450 \times 1}{50 \times 220} = 1 \approx 1,5\ mm^2$
- Level 1225 $S = 1,09 \approx 1,5\ mm^2$
- Level 1105 $S_7 = \frac{64,09 \times 1260 \times 1}{50 \times 220} = 7,34 \approx 8\ mm^2$

Tab 3.7 Lighting network calculation table

Gallery level	P (W)	L (m)	I_{br} (A)	S_{cal} (mm^2)
Lv . 1285	3300	305	15,09	0,44
Lv . 1255	5100	460	24,09	1,00
Lv . 1225	5300	480	25	1,09
Lv . 1195	7400	670	34,45	2,00
Lv . 1165	12000	1081	55,45	5,5
Lv . 1135	12800	1156	59,09	6,00
Lv .1105	13900	1260	64,09	7,34

Choice of standardized section for the gallery must satisfy the following requirement after calculations. The branch current must be less than or equal to the section standardized:

$$Ibr \leq I_{Str} \qquad (22)$$

Tab 3.8 Representation of the standardized section

Level	L (m)	Ibr (A)	Scal (mm^2)	S_{stand} (mm^2)
Lv . 1285	305	15,09	0,44	1,5
Lv . 1255	460	24,09	1,00	1,5
Lv . 1225	480	25	1,09	1,5
Lv . 1195	670	34,45	2,00	2
Lv . 1165	1081	55,45	5,5	6
Lv . 1135	1156	59,09	6,00	6
Lv . 1105	1260	64,09	7,34	8

3.16.1 Energy study of lighting system with proposal of motion detection system

3.16.2 Definition

A lighting system consists of a network of lights and connected elements that are meant to provide light in settings, like houses, workplaces or outdoor areas. It usually includes fixtures, bulbs, switches, sensors and systems for control.

Motion detection is a feature found in lighting systems to improve efficiency and security. This entails using sensors to recognize movement within an area. When movement is detected the system activates the lights automatically to provide light where and when its needed. This not saves energy by turning on lights when required but also boosts safety by illuminating spaces when people are present.

When proposing a lighting system with motion detection the design should take into account aspects such as;

1. Sensor Placement; Placing motion sensors in areas where movement is expected like corridors, entrances or outdoor walkways.

2. Sensitivity Settings; Adjusting the sensitivity of the motion sensors to reduce triggers caused by factors like pets or moving plants.

3. Integration with Control Systems; Linking the motion detection function with control systems such as home platforms or building management systems, for centralized supervision and operation.

4. Users can customize how long the lights stay on after detecting motion striking a balance, between saving energy and ensuring lighting.

5. By incorporating dimming features, alongside motion detection users can enjoy levels of brightness depending on the surrounding light or personal preferences.

Fig 3.4 light detection system

3.16.3 Known issue

In general addition in Boukhadra mining there is wasting of energy in all the galleries as we find out in the waste of 64,42 Kw monthly , so we propose an light system with a motion detection tracking a human in galleries that help us to reduce more energy and give more efficiency to the mine .

3.16.4 System usage

The system work in phase , there is a motion capture that tracking human , so when the sensor detects human presence it triggers the light in the phase 1 , and when he leave the area sensor turn of the light in phase 1 and turn it on the second phase.

3.16.5 Calculation of the number of lighting fixtures with a motion tracking system

We tack the first gallery like an example, to provide the idea:

- In normal addition:

For the 1285thlevel $l_1 = 305\ m$

$$NL_1 = \frac{L_1 - 2}{2a} = \frac{305 - 9}{9} = 32{,}88 = 33\ Lamps$$

- In motion tracking system:

Where: 2a = 30 m

So: for the 1285th level $l_1 = 305\ m$

$$NL_a = \frac{L_1 - 2}{2a} = \frac{305 - 30}{30} = 9{,}11 = 10\ Lamps$$

3.16.6 Calculation of total power of the lamps in the galleries for each level with motion tracking system

- In normal addition:

$$\sum Pi = PL \times NL_i \dots\dots\dots\dots\dots\dots\dots\dots\ (Kw)$$

- Level 1285 :

$$\sum P_1 = 100 \times 33 = 3300\ w = 3{,}3\ Kw$$

- With motion of tracking system :

$$\sum Pi = PL \times NL_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(Kw)$$

- Level 1285 :

$$\sum P_a = 100 \times 10 = 1000\ w = 1\ Kw$$

- So as we can deduce that :

$$\boldsymbol{NL_1 > NL_a}$$

$$\mathbf{33 > 10}$$

- For the energy:

$$\sum \boldsymbol{P_1} > \sum \boldsymbol{P_a}$$

$$\mathbf{3{,}3}\ \boldsymbol{Kw} > \mathbf{1}\ \boldsymbol{Kw}$$

3.17 Signage and alarm

3.17.1 Generality

The basic protection at the level of company blocks, especially electrical supply blocks, relies on warning systems to continuously alert personnel against all kinds of explosion and fire risks. This foresight involves a protection installation chain composed of signaling and alarms to ensure the continuity of protection system [6]

3.17.2 Known problems

Under the usual conditions at Boukhadra, the warning to workers about blast schedules (explosions) is given within a time interval. However, in certain cases, due to a lack of transportation means and irregular management of blasting operations, the warning period extends into waiting times of several minutes and hours, affecting production continuity[6].

3.17.3 Problem handling and proposal

To manage the organization of protection safety, it is necessary to adhere to a chain for signaling the schedules or periods when site evacuation is required. Our proposed solution is an electrical installation based on a chain of signaling and alarms to manage the control of protection.[6]

3.17.4 System description

This system involves the installation of red lamps and bells to signal dangers and also to declare alarms against risks.[6]

3.17.5 System Usage

Signaling is performed using 100W red lamps connected in series, with one red lamp placed between every three white lighting lamps.

Additionally, the alarm is produced using powerful 200W bells placed between every nine white lamps (three red lamps). Thus, this installation is powered by the lighting cable.[6]

3.17.6 Calculation of total power of red lamps in the galleries for each level

- Level 1285 $\sum P_1 = 100\ x11 = 110$ $\sum P_1 = 1100 = 1{,}1\ K$
- Level 1255 $\sum P_2 = 100\ x17 = 170$ $\sum P_1 = 1700 = 1{,}7\ K$
- Level 1225 $\sum P_3 = 100\ x18 = 180$ $\sum P_1 = 1800 = 1{,}8\ K$
- Level 1195 $\sum P_4 = 100\ x25 = 250$ $\sum P_1 = 2500 = 2{,}5\ K$
- Level 1165 $\sum P_5 = 100\ x40 = 400$ $\sum P_1 = 4000 = 4\ K$
- Level 1135 $\sum P_6 = 100\ x\ 43 = 430$ $\sum P_1 = 4300 = 4{,}3\ K$
- Level 1105 $\sum P_7 = 100\ x\ 47 = 470$ $\sum P_1 = 4700 = 4{,}7\ K$

3.17.7 Calculation of power of audible alarms in the galleries for each level

- Level 1285 $\sum P_1 = 200\ x4 = 800\ w = 0{,}8k$ $\sum P_1 = 0{,}8\ K$
- Level 1255 $\sum P_2 = 200\ x6 = 1200\ w = 1{,}2\ \ K$ $\sum P_2 = 1{,}2$ k
- Level 1225 $\sum P_3 = 200\ x6 = 1200\ w = 1{,}2\ k$ $\sum P_3 = 1{,}2\ k$
- Level 1195 $\sum P_4 = 200\ x9 = 1800\ w = 1{,}8\ k$ $\sum P_4 = 1{,}8\ k$
- Level 1165 $\sum P_5 = 200\ x14 = 2800\ w = 2{,}8\ k$ $\sum P_5 = 2{,}8\ k$
- Level 1135 $\sum P_6 = 200\ x\ 15 = 3000\ w = 3k$ $\sum P_6 = 3k$
- Level 1105 $\sum P_7 = 200\ x\ 16 = 3200\ w\ = 3{,}2k$ $\sum P_7 = 3{,}2\ k$

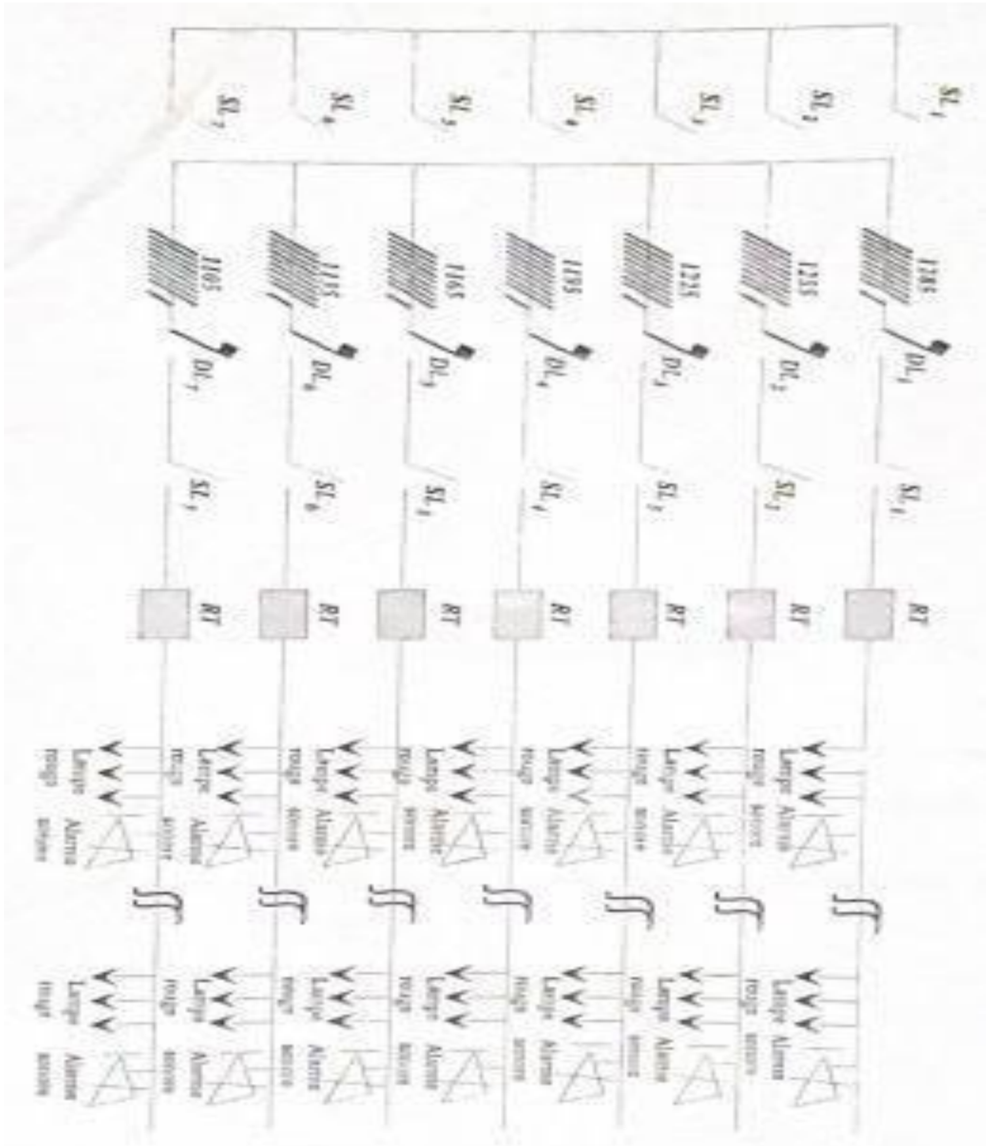

Fig 3.5 Alarm and signage diagram [5]

3.18 Conclusion

Effective electrical lighting in underground areas is vital for ensuring safety, visibility, and operational efficiency. By using two systems: the first one is to reduce the electric energy consumption and the second one is the proposition for emergency cases to help us to make the workplaces safer.

General Conclusion

After giving an overview of the Boukhadra mine, including its specific features and characteristics, as well as its mode of operation and production capacity, we have developed the mining safety, which nowadays is a very important topic.

The bibliographical research has been established to know the different knowledge of mining and electrical risks. It also allowed us to compare the electrocution conditions in the different systems of the isolated and the grounded neutral.

A dark workplace like the underground mine of Boukhadra, full of unforeseen events of varying severity ranging from a simple injury to the most fatal accidents; vision is essential, especially since workers rely solely on simple headlamps powered by batteries hung at belt.

In this work, sufficient and comfortable lighting (far from glare) was proposed, capable of viewing the fine parts and details of mining machines. We have used the method called point-by-point for calculating the different parts of the lighting project.

In addition, an intelligence motion of detection system to reduce the electrical energy consumption to more than 60 % of the total consume for electrical galleries lighting. The digital Study touched the essential organs of the galleries of the Boukhadra mine.

The present study has also developed the project, which consists to proposing a system warning composed of a signaling and alarm chain in the same network of lighting, to always to warn workers against the risks of shooting and explosion.

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