POLITECNICO DI TORINO

Master of Science
in Petroleum and Mining Engineering

Analysis of Accidents in Mining Industry

Supervisors: **Done by:**

Prof. Pierpaolo Oreste Ziad El Khechen

Prof. Micaela Demichela

October 2019

ABSTRACT

Working in the mining industry is considered a hazardous and risky business. Mining accidents and fatalities are still occurring around the world as regular occurrences. The reasons for these accidents are varied and different but analysing these accidents provide a better way to prevent similar accidents to reoccur in the future. Mine safety is an essential component that should be an ever-present concern. Accident investigation and other safety improvement methods such as risk assessment are the key aspects for reducing accidents in the mining industry in the future.

The point of this project is to build a database of major accidents for the last 15 years and to perform statistical analysis on it and then trying to find possible ways to act. It also includes databases for 3 countries, United States, Australia and China with their accident and fatalities in order to compare the safety aspects between them.

ACKNOWLEDGEMENTS

"Always at the end, there is an end, there is time to say goodbye." Ziad Al Rahbani

As this page of my life comes to an end, and before to start writing new pages, I would like to thank everyone who make it all possible. First, special thanks to my family for their unconditional love, who supported and motivated me through years passed and surely many years to come.

And I would like to express my deepest appreciation and sincere gratitude to my supervisors Prof. Pierpaolo Oreste and Prof Micaela Demichela for their support and guidance during the whole period of my project.

Special thanks to all my friends who really loved me and showed great support and motivation,

Thank you all for being there next to me.

ALL MY LOVE

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE: INTRODUCTION

1.1 MINING: Overview and Safety

Mining, the extraction of minerals, exists today in most countries. Mining operations can be gathered into five major categories in terms of their competent products: coal mining, metal mineral mining, non-metallic mineral mining and quarrying, oil and gas extraction, and support activities for mining. Mining is a prerequisite for industrial production. The four major mineral mining commodities that deliver most income is coal, copper, iron ore and gold in which coal contributes approximately 27% of the world total energy supply [1].

The phases of a mining project are [2]:

1- Exploration

2- Development

3- Active Mining

4- Disposal of overburden and waste rock

5- Ore extraction

6- Beneficiation

7- Tailings disposal

8- Site reclamation and closure

What is Safety?

Safety is "*the provision and control of work environment systems and human behaviour which, together, give relative freedom from those conditions and circumstances which can cause personal damage.*" [3]

Safety is a significant part in functioning of the mining industry. It must be present in all mining phases shown above. Safety is important for its employees and workers as well as for the environment and the nations. Specifically, coal industry is one of the most difficult industries in the area of safety, health and environment compared to other mining industries due to its complex operations and maintenance activities along a wide range of hazards associated with them [4].

Safety is one of the five fundamental aspects of Sustainable Mining Production: Economic, Environmentally Excellent, Socially Acceptable, Efficient, Safe [5].

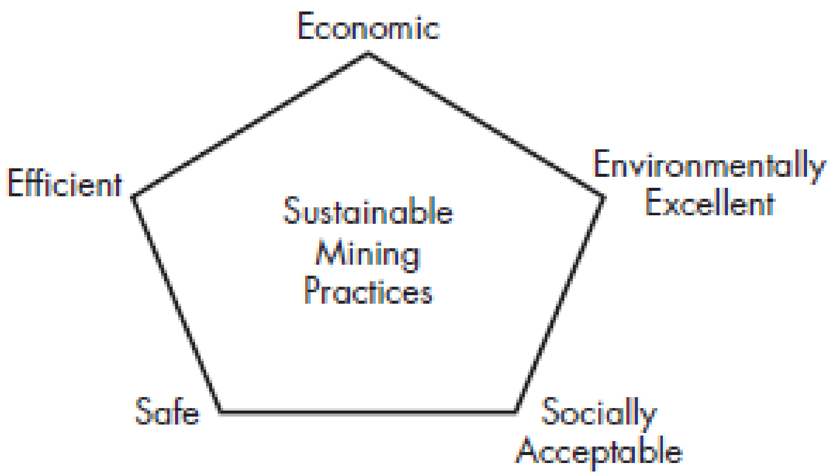


Figure 1.1 Sustainable Mining Practices [5]

Working in mining is a hazardous operation and a risky business. It consists of great health, environmental and safety risk to miners. Critical conditions in mines lead to several accidents that cause injuries to miners or loss of their lives, property damage, shortage in production, some environmental problems etc... [6] The existing hazards in mines may also occupational diseases (health illness or diseases), depending on the level of exposure and duration.

For this reason, accident analysis is needed.

What is Accident Analysis? What is its goal?

1.2 ACCIDENT ANALYSIS: Scope and Importance

Accident analysis is executed in order to mark the cause or causes of an accident or a series of accidents in order to prevent further accidents of the same kind [7]. It is a tool for effective prevention.

The objective of accident analysis is to identify accidents, the event sequence leading to these accidents, and the risk associated with these events [8]. This is done in order to prevent similar accidents in the future.

It is also clear to identify what are the end products of this analysis: a reasoned listing of several aspects in the operation that can or should be modified [9]. Thus, the analysis of any accident gives an overview on the different sequential causes in order to make the suitable adjustments and modifications to the target causer or sometimes, depending on the severity of the accident, to completely change it. In addition to that, some additional and strict safety measures should be taken based on the analysis done to prevent analogous accidents to reoccur.

1.3 POINT OF THE PROJECT

Mining accidents are still occurring around the world as regular occurrences every year. Although the reasons for these are various and different, a great analysis is needed in order to prevent commonly repeating same accidents in the future.

So, the point of this project is to build a database of major fatal accidents around the world (including Australia, United States of America, Russia, China, Turkey, …). This database focuses on the type of mine, type of accident with its causes and initial causes, and then the consequences on the operators, environment and assets. Then, a data analysis is to be performed on this database so that a discussion can be done about the results obtained and further to draw out conclusions and some recommendations.

The database encompasses accidents which happened in the last 15 years (since 2005).

In addition, the other point is to build small databases focusing on the three most countries related to mining safety (Australia – United States of America – China). These databases focus only on the number of fatalities based on the different accident types. This is done to have a comparative data analysis between these countries in the mining safety field. The database encompasses accidents which happened in the year of 2010. Which country has the best mining safety system? And which one has the worst one?

CHAPTER TWO: ACCIDENT ANALYSIS LITERATURE

Accident analysis forms an integral part of safety [10]. Accidents are the central focus of research in safety science [11] and they are caused by several reasons including unsafe acts and human errors.

An accident is an unplanned event that results in an injury or ill health of people [12], and/or damage to or loss of assets or the environment. When an accident occurs in a mine, it can be difficult to understand precisely what happened because many factors can be involved in [13]. To prevent these accidents, a first step of the analysis is to classify them based on type and cause.

2.1 TYPES OF MINE ACCIDENTS

The types of mine accidents based on the fatality [14]:

1- Fatal: is an accident that causes the loss of life

2- High Potential Lost Time: is an accident that results in a lost time injury (involving the loss of a complete shift) that resulted or had the potential in a considerable adverse effect on the safety of workers.

3- High Potential No Lost Time: is an accident that had the potential to cause injuries but does not actually result in that.

4- Lost Time: is an accident that results in a lost time (enforced absence from work for a period exceeding 24 hours) which does not cause any significant effect on the safety of workers.

The types of mine accidents based on the operations (with reference to the MSHA Accident/Illness Investigations Handbook 56…59) [15]:

1- Electrical:

Accidents in which electric current is the main cause of the accident.

Figure 2.1.1 Electrical mine accident [16]

2- Exploding Vessels Under Pressure:

Accidents resulted from explosion of air hoses, hydraulic hoses, air tanks, hydraulic line and other related exploding vessels accidents.

Figure 2.1.2 Exploding vessels under pressure mining accident [16]

3- Explosives and Breaking Agents:

Accidents caused by the detonation of explosives that can cause flying debris and/or fumes.

Figure 2.1.3 Explosive and Breaking agents' explosives [16].

4- Falling, Rolling, or Sliding Rock or Material of Any Kind:

Accidents directly caused by falling rock or material. In case the material was set in motion by machinery or hand tools and an accident occurred, charge the accident to that most directly resulted in the accident.

Figure 2.1.4 Falling of material mining accident [16]

5- Fall of Face, Rib, Side or Highwall:

Accidents involve falls of material from in-place while barring down or placing props. It also includes pressure bumps and bursts.

Figure 2.1.5-a Falling of rib mining accident [16]

Figure 2.1.5-b Falling of highwall mining accident [16]

6- Fall of Roof or Back:

Accidents in underground that include falls while barring down or placing props. It also includes pressure bumps and bursts.

Figure 2.1.6-a Fall of roof mining accident [16]

Figure 2.1.6-b Falling of back mining accident [16]

7- Fire:

Accidents involving unplanned fires in underground that are not extinguished within 10 minutes of discovery and unplanned fires in a surface mine that are not extinguished in 30 minutes. It also includes other shorter fires that are responsible of reportable injuries.

Figure 2.1.7 Fire mining accident [16]

8- Handling Material (lifting, pushing, pulling, shovelling material):

Accidents caused directly by handling material. The material can be in boxes or bags, or loose sand, rock, coal, timber, etc.

Figure 2.1.8 Handling material mining accident [16]

9- Powered Haulage:

Accidents caused by the motion of haulage units. Haulage includes motors and rail cars, belt feeders, conveyors, bucket elevators, self-loading scrapers, shuttle cars, vertical manlifts, front-end loaders, load-haul-dumps, etc.

Figure 2.1.9 Powered haulage mining accident [16]

10- Non-Powered Haulage:

Accidents caused by the motion of non-powered haulage equipment including manual pushed mine cars.

11- Hoisting:

Accidents result from the action or failure of the hoisting equipment or mechanism.

Figure 2.1.11 Hoisting mining accident [16]

12- Ignition or Explosion of Gas or Dust:

Accidents resulted from the ignition or explosion of gas or dust. It can be splitted into two categories:

12.1- Methane Ignition:

occurs when methane burns without having destructive effects. Its damage is limited to that caused by heat or flame. It can only affect workers in the vicinity of the ignition.

12.2- Methane Explosion:

occurs when methane is ignited and burns violently causing huge flames, heating the environment and causing destructive forces. It can affect workers, equipment, structures, etc.

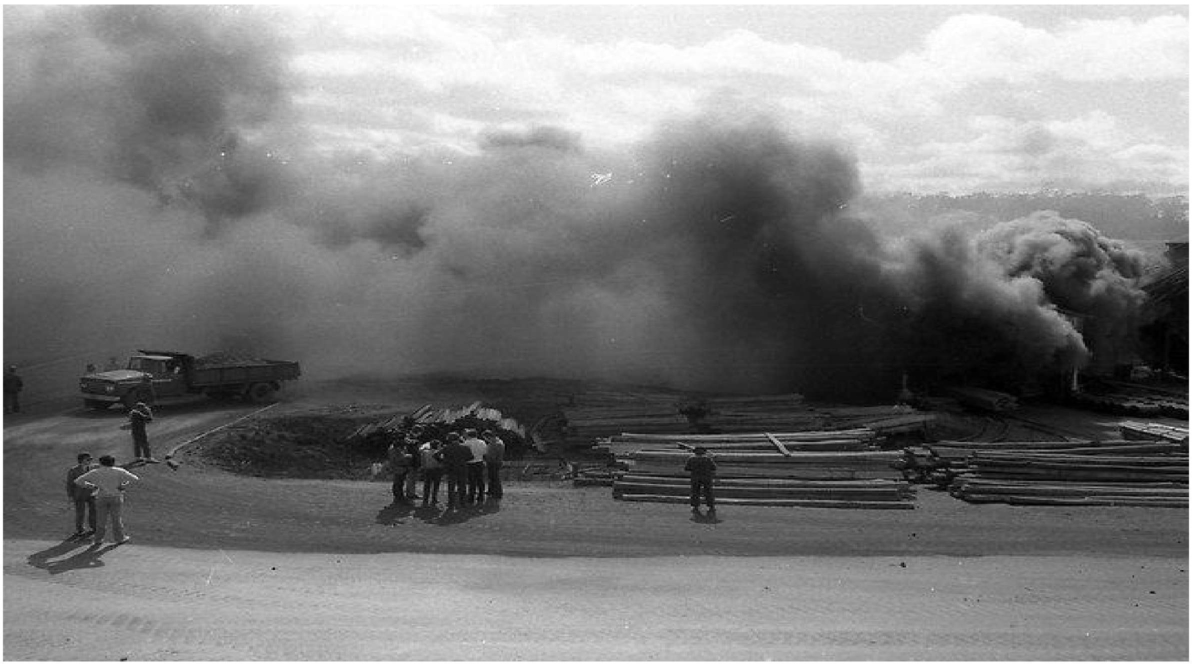


Figure 2.1.12 Gas and dust explosion mining accident [16]

13- Inundation:

Accidents caused by an unplanned inundation of a surface or an underground mine by a liquid or gas.

Figure 2.1.13-a Inundation by water mining accident [16]

Figure 2.1.13-b Inundation by waste clay and sand mining accident [16]

14- Machinery:

Accidents that caused by the action or motion of machinery or from failure of component parts. It includes all electric and air-powered tools and mining machinery such as draglines, drills, power shovels, loading machines, compressors, etc.

Figure 2.1.14-a Machinery (Dredge sank) mining accident [16]

Figure 2.1.14-b Machinery (Bulldozer travelled over the edge) mining accident [16]

15- Slip or Fall of Person:

Accidents occurred due to the slip or fall from a high position or at the same level while getting on or off machinery or haulage equipment. It also includes the slips and falls while repairing equipment or machinery. It includes stepping in a hole.

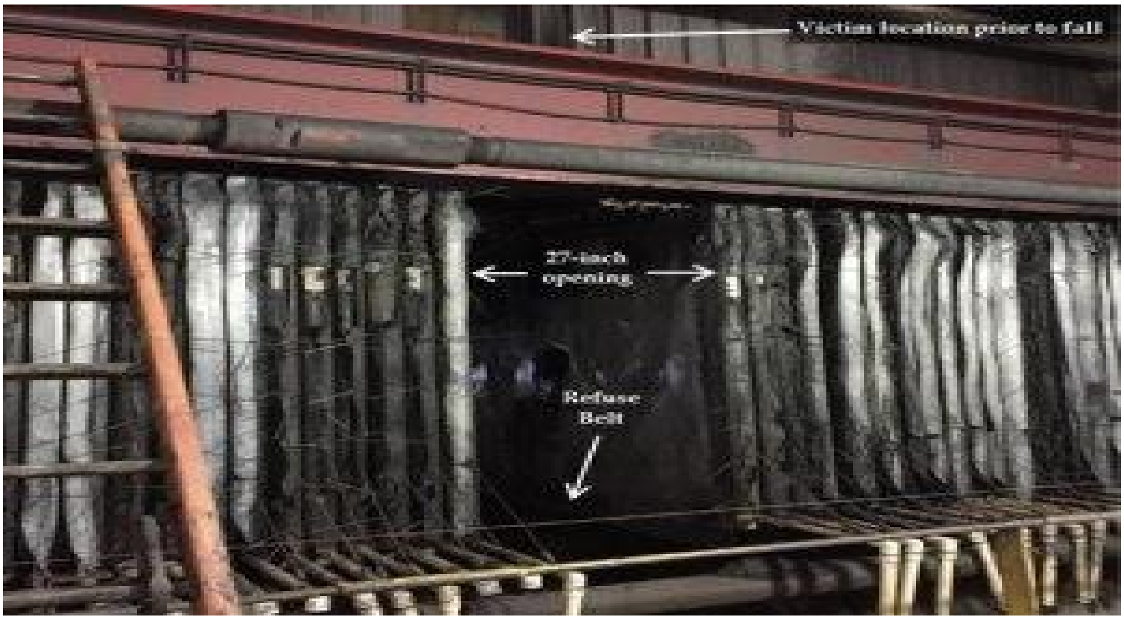


Figure 2.1.15 Slip or fall of person mining accident [16]

16- Stepping or Kneeling on Object:

Accidents caused directly by the stepping or kneeling on the object.

17- Striking or Bumping:

Accidents occurred in which an individual while moving about, strikes or bumps an object.

Figure 2.1.17 Striking mining accident [16]

18- Other:

Accidents that are not elsewhere classified.

In General, the main types of mining disasters are:

1- Methane gas and coal dust explosions:

Methane explosions are the result of the build-up of methane gas with the contact of a heat source in the absence of good ventilation to dilute the gas below its explosion point. While fine particles of coal dust with the correct concentration that contact a source of heat can also be explosive [17].

2- Fires with carbon monoxide production

These fires consist of fires occurred due to the increase of the coal temperature which triggers the phenomenon of coal-self heating and thus the fire hazard. This will lead to the characteristic emission of carbon monoxide gases in addition to other gases as ethylene, acetylene and propylene [18].

3- Floods of water and sludge inside the mine

This phenomenon occurs because of large amounts of water and sludge suddenly entering a mine. It has several sources of water and sludge. One of these sources is flash floods where heavy rainfall and rivers dumps huge amounts of water into a mine entrance trapping miner by blocking escape routes. Another source can be mining into an adjacent, abandoned mine that is flooded. Mines can also become flooded when left over mining wastes are not properly contained in an impoundment, if this impoundment fails, slurry can enter and quickly flood a mine. Another way a mine can become flooded is by mining under an aquifer, such as lake, when the ground above the mine is damaged by mining activity [19].

4- Blasting accident

Blasting accidents occur as the fragmented rock travels and propels beyond the limits of the blast area (considered as fly rock) and injures worker there. This can happen due to several causes such as insufficient burden, insufficient stemming, improper blasthole layout and loading, inadequate firing delays, etc… or can happen due to lack of blast area security such as the failure to evacuate the blast area by employees and visitors, taking shelter at an unsafe location, inadequate guarding of the access roads leading to the blast area, etc… [20].

5- Rock bursts, possibly triggered by an earthquake

Rock burst is a spontaneous, sudden and violent fracture of rock that can occur in deep underground mines. It is a serious hazard and the most dangerous event that can occur during mining works. It depends on the size of the excavation, the depth of excavation and the geological structures such as faults and joints. Sometimes, it is possibly triggered by natural earthquakes [21].

While the most recurring types of accidents are:

1- Movements and falls of rock or soil portions

2- Crushing or collision with dumpers or wagons or any other moving machine

3- Falls, trips or slips

4- Usage of explosives and other chemicals

5- Electric shocks or burns with high temperature elements

2.2 CAUSES OF MINE ACCIDENTS

Main Causes of Mine Accidents [22]:

1- Age Group:

Younger workers in most cases have great capabilities over older workers considering increased strength, speed and precision [23]. However, in some cases, they lack experience as the older ones have which may lead to some accidents. But after a certain time, even with experience, older workers have the highest probability to cause an accident as the age is splitted into two groups [22]:

1.1- <40 years: Energetic but not consistent

1.2- >50 years: Lethargic due to age

2- Timing Group:

2.1- Change of Shift / End of Shift: Quick escape

2.2- Night Shift: Sleeping tendency or poor light

2.3- Overtime Hours or Long Hours Without Rest: Fatigues

3- Change of Occupation:

3.1- Unauthorized Work

3.2- Unauthorized deployment

3.3- Lack of knowledge or skills

3.4- Lack of confidence

3.5- Lack of conception of work

4- Unsafe Act: Breach of commonly accepted procedures. Exposure to high risk man-made and undesirable causing accidents.

4.1- Act itself is risky

4.2- No correction

4.3- No safe workplace design

4.4- No safety guidance

4.5- No safety law observance

5- Unsafe Condition: Exposure to man-made and high-risk causing accidents.

5.1- Condition left uncorrected

5.2- Unsupported workplace

5.3- Unexamined machine

5.4- Unobserved safety standards

6- Stress or Mental Imbalance: Exposure to high risk man-made uncontrolled phenomenon that lead to force people to live in high stress level.

6.1- Work stress

6.2- Production stress

6.3- Behavioural stress

6.4- Overwork

6.5- Exhaustion

6.6- Influence of drug or drink

2.3 WORST ACCIDENTS IN MINING INDUSTRY

In this part, the worst 10 mining accidents in the history are shown below [24]:

1- Benxihu Colliery, Liaoning, China, 26 April 1942 (1,549 deaths)

An underground gas and coal dust explosion occurred involving several parts of the mine in succession causing fires afterward. It caused the death of 1,549 mostly due to suffocation resulting from the breathing of the carbon monoxide. It took about ten days to bring the dead bodies out from the coal mines where they had trapped and died. This accident occurred at a time when the invading Japanese Imperial Army had taken control over major parts of China.

In order to limit and reduce the fire underground, the Japanese shut off the ventilation and sealed the pit head.

2- Courrieres Coal Mine, Courrieres, France, 10 March 1906, (1,099 deaths)

A gas explosion occurred which triggers series of blasts through the entire mine and reaches an inhabited area situated above the shafts. The elevators there, were also blasted out of the mine and had a lot of dead miners within them as well. An elevator cage at shaft 3 was thrown to the surface, damaging the pithead, windows and roofs were blown out on the surface. The main cause of this accident was a gas explosion. It costed the death of 1,099 people where many children and women were among the dead. The primary cause of this disaster could not be determined because of the large damage and thus all witnesses to the accidents are gone. It was one of the odd mining accidents that occurred in Europe.

3- Laobaidong Colliery, Datong, China, 9 May 1960 (682 deaths)

A methane gas explosion took place involving most parts of the mine causing fires afterwards. This accident caused the death of 682 people and it has been listed as the second most tragic mining accident in the Chinese history. The information about this disaster was suppressed by the Chinese Government for more than three decades until it was revealed in 1992.

4- Sumitomo Besshi Bronze Mine, Shikoku, Japan, 1899 (512 deaths)

A debris and mud stream due to a landslide of a mining landfill flowed down the mine and trapping and killing everyone caught up in the flow. This occurred because the erosion control and ensuring structural support were often overlooked completely at that time there. It involved the death of 512 people. It is one of the most serious occupational disasters of any kind that rocked Japan.

5- Hawks Nest Tunnel Silica Mine, West Virginia, USA, 1931 (476 deaths)

The miners were asked to mine the silica deposits from the tunnel during its construction with no practically safety measures. The silica deposits started congesting the miners' lungs and caused breathing problems. These miners had affected then by silicosis which damaged their airways. This accident caused the death of 476 miners. This large number of losses was since the safety conditions of the miners were poor and neglected.

6- Mitsui Miike Coal Mine, Fukuoka, Japan, 9 November 1963 (458 deaths)

The accident occurred due to a coal dust explosion underground which led to a series of massive explosions that had broken the pillars and the entire set up that held the mine walls and roof and thus causing the collapse of the tunnel. This disaster involved the death of 458 people; however, many others were survived but with brain damage and other related issues for years later due to carbon monoxide poisoning. It is considered as one of the most infamous disasters in the mining history of Japan.

7- Senghenydd Colliery, Caerphilly, Wales, UK, 14 October 1913 (440 deaths)

A coal dust explosion occurred involving several parts of the mine causing fires in succession. A firedamp ignition produces sparks which soon turned out to be disastrous and fatal when a fire on the floor of the coal mine led to a massive inferno. In this accident 440 miners died due to the direct engulfment by the flames and due to the build-up of toxic carbon monoxide gases resulted from the fire. This event is considered as one of the most severe disasters to occur in a mine in United Kingdom.

8- Coalbrook Colliery, Clydesdale, South Africa, 21 January 1960 (435 deaths)

The accident occurred due to the failure and loosening of 900 underground pillars which fell apart and caused the loosening the very supports to the roof of mine. This caused the collapse of the mine which trapped several miners. Some of the miners had the chance of escaping through an incline shaft. This event caused the death of 435 miners making it one of the worst mining tragedies to ever happen in Africa.

9- Wankie Coal Mine, Hwange, Zimbabwe, 6 June 1972 (426 deaths)

The disaster is caused by several explosions in the underground coal mine. These explosions turned into blast which destroyed the main shaft. The first blast killed four miners who were on the surface near the mine entrance as well. Since the entire shaft was filled with gas, the miners became panic and they died due to suffocation. Also, few rescue workers died getting trapped with collapsed ground and methane gas. This disaster caused 426 deaths in which 36 were Europeans and 390 were Africans.

10- Chasnala Coal Mine, Dhanbad, India, 27 December 1975 (372 deaths)

A firedamp and coal dust explosion occurred in the mine causing the failure of the water tank above it that produced the flood to its shafts. So, in addition to the full blast of the of the coal dust, there was the other problem which is the mine becoming flooded and drowning the trapped miners in it. This accident killed 372 miners making it as the second most dangerous mining accident to have ever been recorded in India.

2.4 ACCIDENT CAUSATION MODEL

When an accident occurs, what should be looked at as the cause of that accident? For this reason, several models and theories have been proposed. Accident causation models were primarily developed in order to help people in investigating accidents, so that the investigation can be done in an effective way [25]. They are theoretical models that clarify how accidents occur in organizations [26].

This is useful in a proactive sense because understanding how accidents occur allows to discover what are the causes, errors and failures that lead to that accident, and so actions can be taken to address these failures before they can happen [25].

In this part, Reason’s Swiss Cheese Model and Heinrich’s Domino Theory are to be discussed.

2.4.1 SWISS CHEESE MODEL

James Reason suggested the "Swiss Cheese" image to clarify the occurrences of system failure. Based on this image, in a complex system, hazards are prevented from occurring and thus causing human losses and other environmental and production problems by a series of defences or barriers. These defences have unintended weaknesses or holes as the swiss cheese has [27]. The holes in the barrier represent local circumstances and active failures or latent conditions [5]. See *Figure 2.4.1.1*

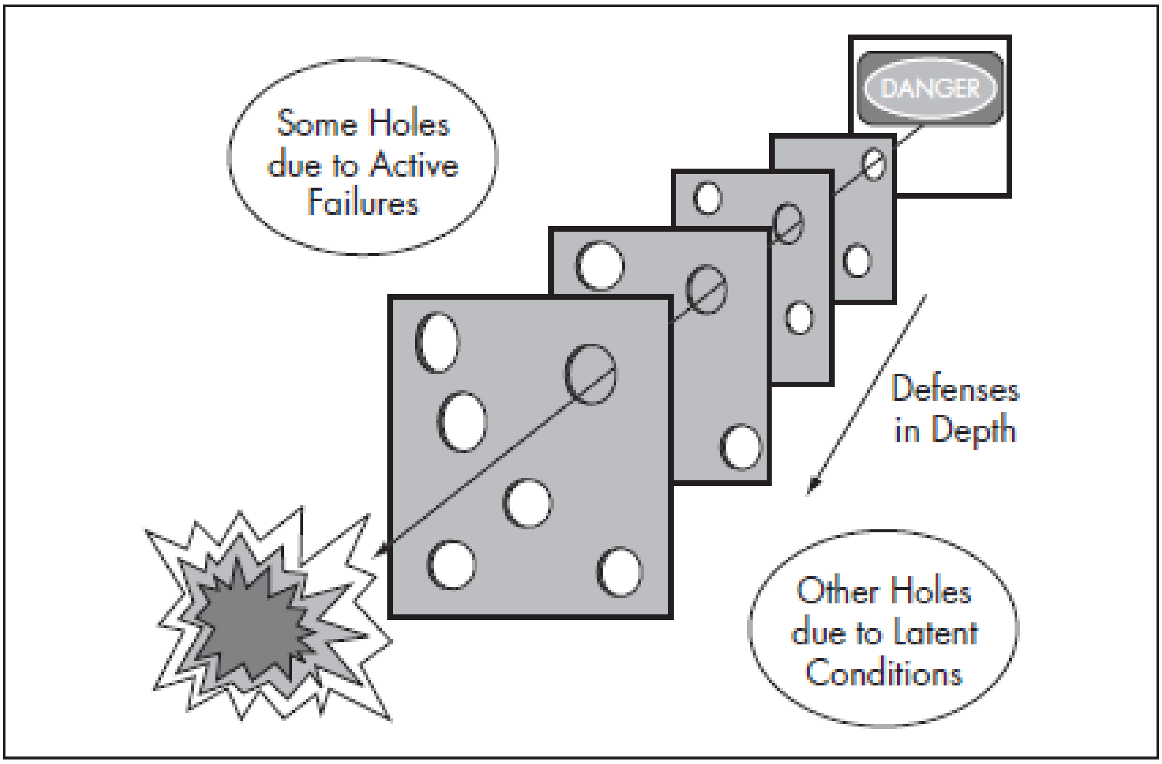


Figure 2.4.1.1 Reason's Swiss Cheese Model [5]

Active failures involve the unsafe acts that contribute directly to the accident. While latent conditions encompass contributory factors that may lie dormant for days, weeks and sometimes months before they contribute to the accident [28]. Examples on latent conditions include deficiency in design, supervision gaps, failures in maintenance, manufacturing defects, inadequate training concerning safety procedure and use of machines [5]. Those holes are changeful as they are open and closed randomly [27].

Thus, an accident occurs when there is a connecting set of the holes among successive barriers, causing an accident trajectory to occur. [5] This is shown in *Figure 2.4.1.2*.

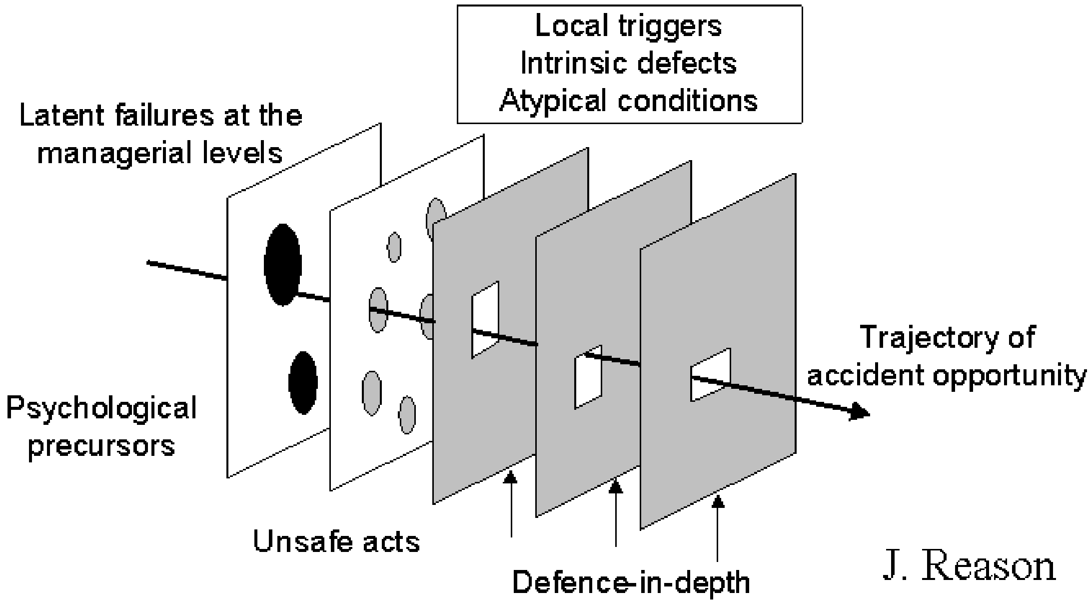


Figure 2.4.1.2 Reason Model published in 1990 [27]

The Swiss cheese model is frequently referred to. Although it is respected and considered to be a helpful method, it has been criticised because it is used in general without any interference with any other models [28].

2.4.2 HEINRICH'S DOMINO THEORY

Heinrich presented theories under the name of "the axioms of industrial safety". One of these axioms is about accident causation stating that *"the occurrence of an injury invariably results from a complicated sequence of factors, the last one of which being the accident itself"* [25].

Alongside, he proposed a model known as the "domino theory". His theory states that accidents result from a sequence of events, metaphorically like a chain of dominoes falling over. It is enough for one of the dominoes to fall to trigger the next one and etc… [29]. The sequence is:

1- Injury, caused by an;

2- Accident, due to an;

3- Unsafe act and/or mechanical or physical hazard; due to the

4- Fault of the person; caused by their,

5- Ancestry and Social Environment

as shown in *Figure 2.4.2.1* and *Figure 2.4.2.2* below:

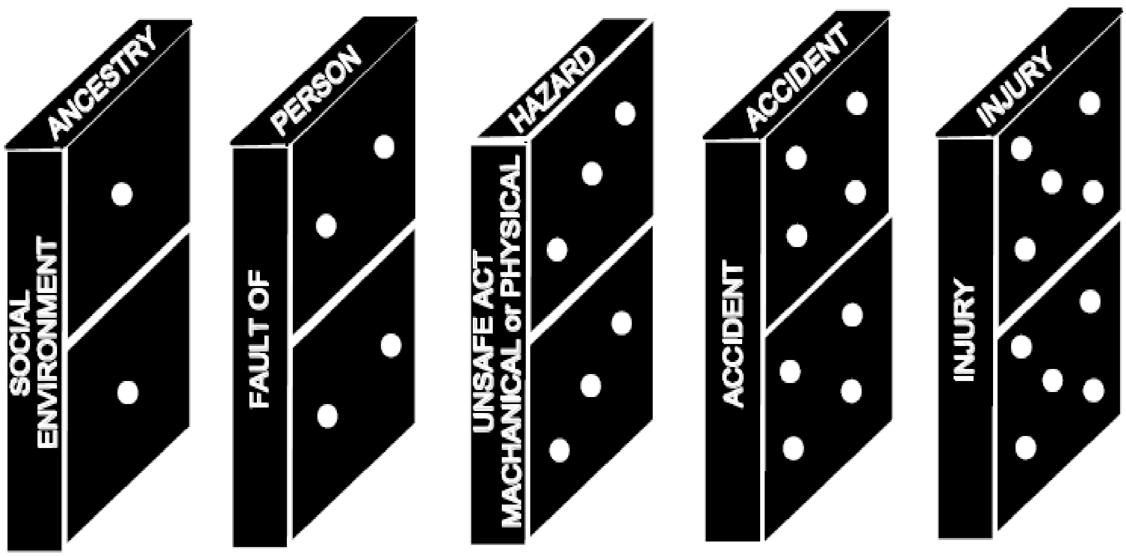


Figure 2.4.2.1 Domino Theory [25]

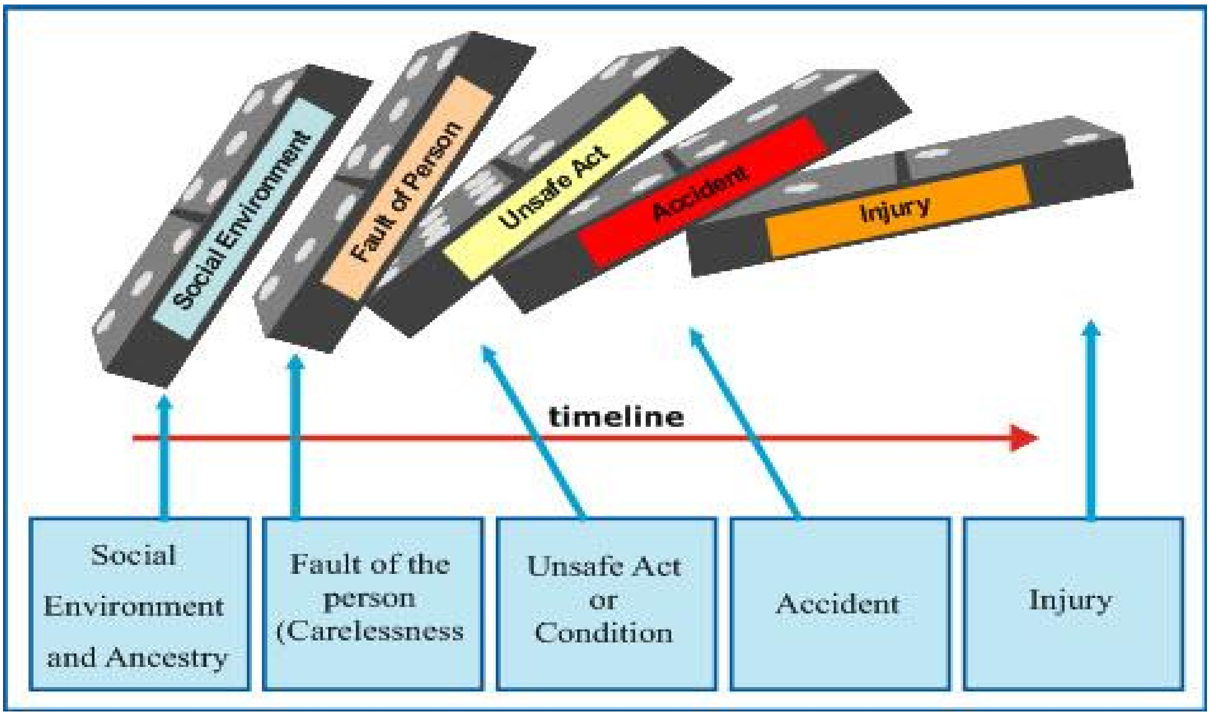


Figure 2.4.2.2 Heinrich's Domino Theory of Accident Causation [29]

The prevention of accident can be achieved by removing one of the dominoes, normally the key factor which is the middle one or unsafe acts [25].

2.5 ACCIDENT INVESTIGATION AND ROOT CAUSE ANALYSIS

2.5.1 WHY IS IT DONE?

When an accident occurs in a mine, a detailed investigation should be performed for many reasons based on [30]:

1- explore the causes of the accidents and to prevent similar accidents in the future

2- to determine the cost of the accident

3- to fulfil ant legal requirements

4- to determine compliance with applicable regulations (such as occupational health and safety)
5- to process workers' compensation claims

2.5.2 GOALS AND BENEFITS

Information and insights gained from an accident investigation as reported in [31]:
1- An understanding of how and why things went wrong

2- An understanding of the ways people can be exposed to substances or conditions that may affect their health

3- A true image of what really happens and how work is really done

4- Identifying deficiencies in the risk control management that will enable to improve the management of risk in the future and to learn lessons which can be applied to other parts in the organization

Benefits arising from an accident investigation as reported in [31]:
1- The prevention of further similar accidents

2- The prevention of business losses due to stoppage, disruption, lost orders etc …

3- An improvement of employee's attitude towards health and safety. Thus, employees will be more cooperative in implementing new safety precautions and they can see that problems are dealt with

4- The development of managerial skills that can be readily applied to other areas of the institution

An investigation is the first step in preventing future adverse accidents. A good investigation will enable to learn great lessons, which can be applied across the institution. The investigation should identify the factors that cause the existing risk control measures failed and what improvements or additional measures are needed. More general lessons on why the risk control measures were inadequate must also be learned [31].

The investigation should be concentrated on finding the root cause of the accidents. Root cause analysis (RCA) is a systematic process for identifying the root causes of an event or series of events leading to an accident and an approach for responding to them. The primary goal of using root cause analysis is to identify problems or accidents to identify: What happened? How it happened, why it happened? And then the Actions for preventing reoccurrence are developed [32].

Investigations that conclude that worker's error was the only cause and go no further are rarely acceptable and fail to find answers to most important questions as reported in [30]:
1- Was the worker distracted? If yes, why was the worker distracted?

2- Was a safe work procedure being followed? If not, why not?

3- Were safety devices in order? If not, why not?

4- Was the worker trained? If not, why not?

The objective is to discover not only how the adverse accidents occurred, but most importantly, what triggered it to happen [31].

2.5.3 WHO SHOULD CARRY OUT THE INVESTIGATION?

Generally, the investigation should be carried out by someone or group of people who have these qualifications as reported in [30]:

1- Experienced in incident causation models

2- Experienced in investigative techniques

3- Knowledgeable of any legal or organizational requirements

4- Knowledgeable in occupational health and safety fundamentals

5- Knowledgeable in the work processes, procedures, persons, and industrial relations environment for that situation

6- Able to use interview and other person-to-person techniques effectively

7- Knowledgeable of requirements for documents, records, and data collection

8- Able to analyse the data gathered to determine findings and reach recommendations.

2.5.4 ACCIDENT INVESTIGATION STEPS

A good investigation involves a systematic approach which consists of four main steps. Before proceeding with the main four steps in the investigation, pre-steps should take place which are divided into two categories [30] [31]:

1- Emergency Response:

1.1- Take rapid emergency action (Provide first aid and medical care to injured worker(s) and trying to avoid further injuries or damage)

1.2- Make the area safe (sometimes this should be the first step)

2- Initial Report:

2.1- Preserve the scene

2.2- Note the names of people and equipment involved as well as the names of the witnesses

2.3- Report the accident to a designated person within the organization responsible for health and safety

The four main steps are [30]:

1- Information Gathering (Data Collection)

This step should take place as soon as possible after the adverse event occurred. It involves talking to everyone who was close by when the accident occurred and finding out what happened and what actions influenced the adverse event.

It explores all reasonable lines of enquiry. It is timely and structured, setting out clearly what is known, what is unknown and records the investigative process.

It should include answers for these types of questions:
1.1- Where and when did the adverse event happen?

1.2- Who was injured or suffered an ill health or was involved with the adverse event?

1.3- How did the adverse event happen? Note any equipment involved
It involves the description of the chain of events leading up to the adverse event. It is possible to have several chance occurrences and coincidences combined to form the circumstance of the occurred adverse event. These should be reported as much as possible in chronological order.

In addition, plant and equipment involved in the adverse event must be identified clearly. Note all the details available including; the manufacturer, model type, model number, machine number and year of manufacture and any modifications made to the equipment.

1.4- What activities were being carried out at the time of incidence?
The work that was carried out at the time of incidence can give sight for what conditions and circumstances that caused something to go wrong. A good description should be provided including relevant details for example, the surrounding, the equipment and materials being used, the number of employees engaged in the different activities.

1.5- Was there anything unusual or different about the working conditions?
Adverse events often happen when something strange and different occurred. In this case, employees may find it difficult to adapt especially if they have not been adequately prepared to deal with new conditions.

1.6- Was there adequate safe working procedures and were they followed?
Adverse events usually occur when there is no safe working procedure or when these procedures are inadequate or are not followed.

1.7- What injuries or ill health effects, if any, were caused?
It is important to state what kind of injury has occurred and which part of the body it affected. In this part, precision is essential. Precise descriptions will enable to spot trends and take prompt remedial action. In addition, whether the injured person was given first aid or taken to hospital should be reported here.

1.8- If there was an injury, how did it occur and what caused it?
It involves the description of the mode of the injury and the way in which the injury was sustained.

1.9- Was the risk known? If so, why wasn't it controlled? If not, why not?
It is important to know if the source of the danger and its potential consequences were known, and whether this information was communicated to those who needed to know. The existence of a written risk assessment for the task or process which led to the adverse event should give information about what was known of the associated risks.

1.10- Did the organisation and arrangement of the work influence the adverse event?
The organizational arrangement provides the framework for which the work is done. Some examples explaining this: - standards of supervision and on-site monitoring of working practices may be less than adequate, - lack of skills or knowledge may mean that nobody intervenes in the event of procedural errors etc…

1.11- Was maintenance and cleaning enough? If not, explain why not?
Maintenance is important in every part of the work. Lack of maintenance and poor housekeeping are common causes of adverse events.

1.12- Were the people involved competent and suitable?
This is related to how enough are the instructions and trainings. Problems in this category can be summarized as misunderstandings, lack of instruction and training, lack of respect for the risks involved, problems due to the immaturity, etc …

1.13- Did the workplace layout influence the adverse event?
The physical layout and the circumstance of the workplace plays an important role in health and safety aspects. The workplace should be organised in such a way that safe practices are encouraged.

1.14- Did the nature or shape of the materials influence the adverse event?
Along the possibility of the material being intrinsically hazardous, materials can pose a hazard simply by its design, weight, quality, etc …

1.15- Did difficulties using the plant and equipment influence the adverse event?
Plant and equipment includes all the possible machinery and tools used to carry out the work. These items should be designed to suit the people using them. For example, if a machine that requires its operator to follow a complicated user manual can lead to a risk.

1.16- Was the safety equipment enough?
Safety equipment and safety procedure should be enough for all the conditions in which work takes place. Make a note whether these safety equipment was used, and if it was used correctly, whether or not it was in a good condition and was working properly, etc …

1.17- Did other conditions influence the adverse event?
It covers everything else not reported above which might have influenced the adverse event.

2- Information Analysis (Analyse the Data)

It involves checking all the facts, determining what happened and why. To understand what happened and why, first it requires to organise all the gathered information and then to follow a "Why question" procedure for each reason and set down the answers until the answers are no longer meaningful. It is done side by side with the information gathering as it requires sometimes additional information while it is progressing.
It is objective and unbiased. It identifies the sequence of conditions and events that result

in the negative event and thus it identifies the immediate causes. It also identifies underlying causes (actions done in the past that have allowed undetected unsafe practices) and root causes (i.e. organisational and management health and safety arrangements – supervision, monitoring, training, resources allocated to health and safety etc …)

What if the accident is caused by human errors?

Some accidents are the consequence of unsafe acts due to human errors. Human errors can be done in different forms and ways. They include unawareness of the rules, awareness of the rules but misunderstanding them, mistakenly applying the rules or sometimes ignoring them and risk taking. Instead other errors involve some communication failures, inability to recognize hazardous conditions, failure to recognize warning signs, poor judgement and lack of training or insufficient educational background [5].
In general, human errors can be divided into three categories and each type of error needs a special prevention action.

As *Figure 2.5.4.1* shows, the three general types of human errors are:

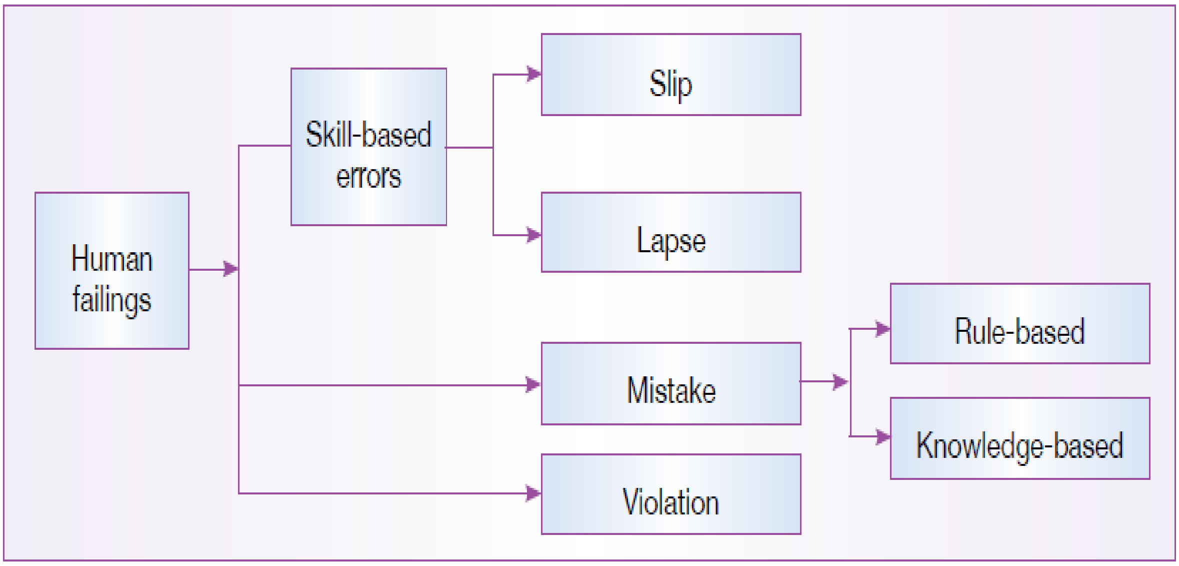


Figure 2.5.4.1 Human Failings Types [31]

1- Skill-based errors which can be divided into 2 subgroups:

1.1- Slips are the result of spontaneous error due to performing tasks automatically without thinking.

1.2- Lapses are the result of missing an action in a sequence or performing the task out of sequence.

2- Mistakes are errors of judgement which can be divided into 2 subgroups:

2.1- Rule-based mistakes are the result of applying wrong rules in certain situations instead of the correct ones.

2.2- Knowledge-based mistakes are the result of unfamiliar situations while the worker has no rules about it and tries to work based on his knowledge and comes with wrong conclusion.

3- Violations or Rule breaking

These errors are the result of deliberate breach of the rules to save time and effort and to increase production as workers believe that rules are too restrictive and can be ignored.

Blaming persons at fault is counter-productive [30] since the purpose is to remedy the situation not to discipline humans [29]. Also, blaming can make people in the next possible accident to not tell the truth. Human errors do not occur in isolation. Other factors can interfere to affect the human behaviour and can be classified in relation to [30]:

1- Job Factors:

1.1- Attention needed for completing the task (both too much and too low attention can lead to high error rates)

1.2- Inadequate procedures

1.3- Time available

2- Human Factors:

2.1- Physical ability (size and strength)

2.2- Competence (knowledge, skill, experience)

2.3- Fatigue, stress, moral, alcohols and drugs

3- Organizational Factors:

3.1- Work pressure, long hours

3.2- Supervision quality

3.3- Safety culture

4- Plant and Equipment Factors:

4.1- How easy to read the controls and understand them?

4.2- Is the workplace layout user-friendly?

4.3- Is the equipment designed to detect or prevent errors?

3- Risk Control Measures

It includes the identification of the risk control measures which were missing, inadequate or unused. It requires the comparison of conditions and practices required by current legal requirements, codes of practice and guidance with what they were. Then a list of alternative measures based on the priority should be done to prevent this adverse event or other possible events. Measures to be chosen should follow the following order:

3.1- Measures that eliminate the risk

3.2- Measures that resist the risk at source

3.3- Measures based on human behaviour to minimize the risk

The most trusted measures are those related to engineering risk control measures. This step also provides the identification of additional needed measures to classify the immediate, underlying and root causes. It gives meaningful recommendations which can be implemented but mysterious recommendations show that the investigation has not been studied deep enough for the findings of the root causes.
It should also consider if this event had occurred before and if yes why it recurred. And it should take into consideration if this same risk is possible to exist elsewhere. In this case, where this risk can exist and what steps can be taken to avoid it.

4- Action Plan and Implementation (Recommendations)

It provides an action plan with SMART objectives (Specific, Measurable, Agreed, Realistic and time-scaled). It should be ensured that the action plan deals effectively with all the immediate and underlying causes as well as the root causes. In addition, it should include lessons that can be applied to prevent other possible adverse events. And it must provide feedback to all related parties to ensure that the recommendations are correct, address the issues and are realistic.

It should communicate the results of the investigation and the proposed action plan to everyone who needs to know and include arrangements to ensure that the action plan is implemented, and progress monitored. Without these two steps, the investigation cannot be categorized as beneficial and nothing will change in the long term.

2.6 ACCIDENT CAUSATION CLASSIFICATION

The causes of any accident can be classified in five categories: Task, Material, Work Environment, Personnel, and Management. *Figure 2.6.1* with a simple model shows this.

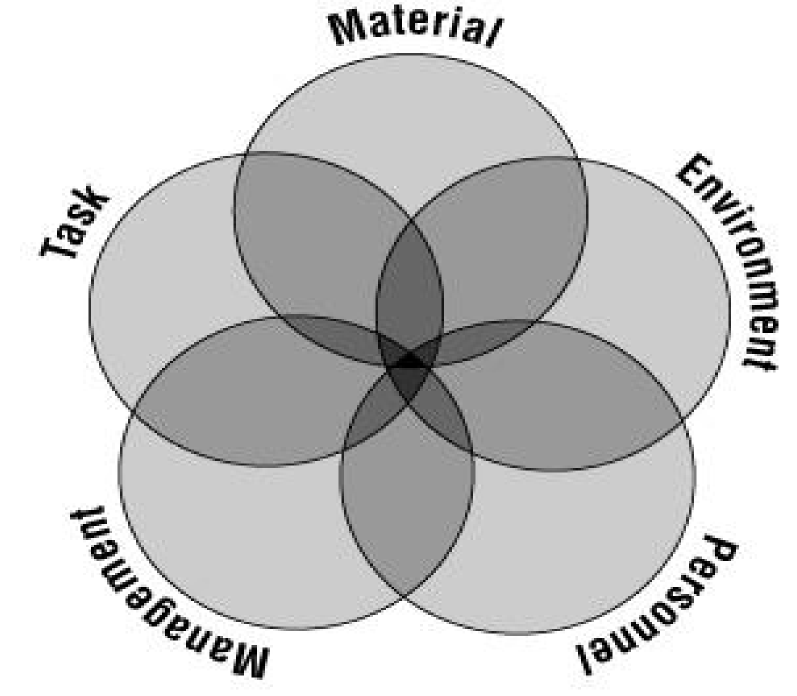


Figure 2.6.1 Accident Causation Classification [32]

These causes are investigated with simple questions as reported in [30]:

1- TASK:

In this part, the immediate work procedure being used at the instant of the accident is examined. Answers to these questions are needed by the members of the investigation team.
1.1- Was a safe work procedure adopted?

1.2- Had the condition modified to make the normal procedure safe?

1.3- Were the suitable tools and material available?

1.4- Were they used?

1.5- Were safety devices working properly? For most of these questions, an important following question is "**if not, why not**?"

2- MATERIAL:

In this part, questions related to the possible causes resulting from the equipment and materials used.
2.1- Was there an equipment failure?

2.2- What caused it to fail?

2.3- Was the machinery poorly designed?

2.4- Were the hazardous products involved?

2.5- Were they clearly identified?

2.6- Was a less hazardous alternative product possible and available?

2.7- Was the raw material substandard in some way?

2.8- Should personal protective equipment (PPE) have been used?

2.9- Were users of PPE properly educated and trained?

In case of unsafe condition answer, the investigator must ask **why** this situation could exist.

3- WORK ENVIRONMENT:

The physical work environment at the time of incident and especially sudden changes to that environment, are important factors that need to be identified not the “usual” conditions were. So, investigators wish to know:

3.1- What were the weather conditions?

3.2- Was poor housekeeping a problem?

3.3- Was it too hot or too cold?

3.4- Was noise a problem?

3.5- Was there adequate light?

3.6- Were toxic or hazardous gases, dusts, or fumes present?

4- PERSONNEL:

In this part, the physical and mental condition of those individuals in the accident event as well as psychosocial environment they were working within must be explored.

4.1- Did the worker follow the safe operating procedures?

4.2- Were workers experienced in the work being done?

4.3- Had they been adequately educated and trained?

4.4- Can they physically do the work?

4.5- What was the status of their health?

4.6- Were they tired?

4.7- Was fatigue or shift work an issue?

4.8- Were they under work or personal stress?

4.9- Was there pressure to complete tasks under a deadline, or to by-pass safety procedures? The goal of the investigation is not to establish blame against someone, but the enquiry required the personal characteristics to be completed.

5- MANAGEMENT:

Management holds the legal responsibility for the safety of the workplace. Thus, the role of supervisors and managers and the role or presence of management systems must always be considered in an accident investigation. These factors are also called organizational factors.

Failures of management are often considered as direct or indirect causes. Important questions for the investigations are:

5.1- Were safety rules or safe work procedures communicated to and understood by all employees?

5.2- Were written procedures and orientation available?

5.3- Were the safe work procedures being enforced?

5.4- Was there adequate supervision?

5.5- Were workers educated and trained to do the work?

5.6- Had hazards and risks been previously identified and assessed?

5.7- Were unsafe conditions corrected?

5.8- Was regular maintenance of equipment carried out?

5.9- Were regular inspections carried out?

5.10- Was action taken?

This model of accident investigation gives a guide for discovering all possible causes and reduces the chance of looking at facts in isolation.

CHAPTER THREE: SOURCES OF DATA

3.1 TAXONOMY

The taxonomy considers the major accidents occurred all over the world. The chosen accidents are due to the availability of data, number of fatalities and environmental effects. Most of the accidents have fatalities, others do not have, but their massive environmental consequences are the reason why they are included in this study.

However, the countries involved in this study include Australia, United States of America, Russia, China, Turkey, Ukraine, Canada, India, Indonesia, etc…

Most of the data included in this database are from news websites due to the complexity to find regular reports for each accident in most of the countries. This is due to the illegal work of some mines and in most cases due to poverty of mines' websites to mining accident data and reports. On the other hand, for the United States of America, all the data are extracted from the UNITED STATES DEPARTMENT OF LABOR, Mine Safety and Health Administration (MSHA).

The database (Taxonomy) in ANNEX 1 is referred to the last 15 years in the mining history starting from year 2005 till the mid-2019, including 76 accidents involving all types of mines: Underground/Surface, Coal/Non-coal mines. It consists of the various types of accidents with their different causal factors and the corresponding consequence on operators, environment and assets. The total number of fatalities in this database is 3523 fatality with numbers of non-fatal injuries. These are associated with major environmental problems.

The sources of the data included in the taxonomy (ANNEX 1) are listed in the bibliography as: [1.1 … 1.76]

China	India
United States	Chile
Mexico	Australia
Canada	Poland
Russia	Ukraine
Romania	South Africa
Slovakia	Ghana
Turkey	Nigeria
Ecuador	New Zealand
United Kingdom	Central African Republic
Indonesia	Bosnia & Herzegovina
Tanzania	Myanmar
Brazil	Pakistan
Iran	

Table 3.1.1 Countries Involved in the Taxonomy

Number of Accidents	**Number of Fatalities**
76	3523

Table 3.1.2 Number of accidents and fatalities in the Taxonomy

3.2 THE COMPARISON

For the second part, small databases are constructed for United States of America and China and Australia. In this part, the data involved in are taken from different websites and MSHA, but it is limited just to the types of mines with the different types of accidents and the number of fatalities in the year of 2010.

For the United States of America and Australia, every single accident is taken into consideration while for China only the accidents occurred only in the first three months (January - February – March) are considered. This part is performed for the comparison in the safety issues of these countries.

United States	Australia	China

Table 3.2.1 Countries involved in the comparison

Country	**Number of Accidents**	**Number of Fatalities**
United States	41	69
Australia	5	5
China	41	363
TOTAL	87	437

Table 3.2.2 Number of accidents and fatalities in United States, Australia and China in 2010

The sources of the data included in this part are listed in the bibliography as [1.77 … 121]

CHAPTER FOUR: DATA ANALYSIS

4.1 TAXONOMY

Based on the taxonomy built in ANNEX 1, a statistical analysis is performed. Accident statistics and fatality statistics are performed on different mine types as shown in *Table 4.1.1*, followed by graphical representation as shown in *Figures 4.1.1 and 4.1.2* and *Figures 4.1.3 and 4.1.4* respectively.

Accident and fatality statistics for coal and non-coal mines are shown in Table 4.1.2 with their representative graphs showed in *Figures 4.1.5 and 4.1.6* and *Figures 4.1.7 and 4.1.8* respectively.

Among the underground mines, an accident and fatalities statistics on coal and non-coal mines and the results are showed in *Table 4.1.3* with the graphical representations in *Figures 4.1.9 and 4.1.10.*

As a separate study for the non-coal mines, the number of accident and fatalities are shown in *Table 4.1.4* followed by their graphical representations in *Figures 4.1.11 and 4.1.12* and *Figures 4.1.13 and 4.1.14* respectively.

For the different accident types involved in the taxonomy, the relative number of accidents and fatalities are shown in *Table 4.1.5*. Their respective graphical representations are shown in *Figures 4.1.15 and 4.1.16* and *Figures 4.1.17 and 4.1.18* respectively.

A detailed accident and fatality statistical analysis for coal and non-coal mines is performed. The associated accident types with respect to the number of accidents and number of fatalities for coal and non-coal mines are shown in *Table 4.1.6* and *Table 4.1.7* respectively. Their graphical representations are shown in *Figures 4.1.19, 4.1.20, 4.1.21 and 4.1.22* and *Figures 4.1.23, 4.1.24, 4.1.25 and 4.1.26* respectively.

Mine Type	Number of Accidents	Number of Fatalities
Surface	23	1153
Underground	50	1993
Unknown	3	377
TOTAL	76	3523

Table 4.1.1 Number of accidents and fatalities in different types of mines

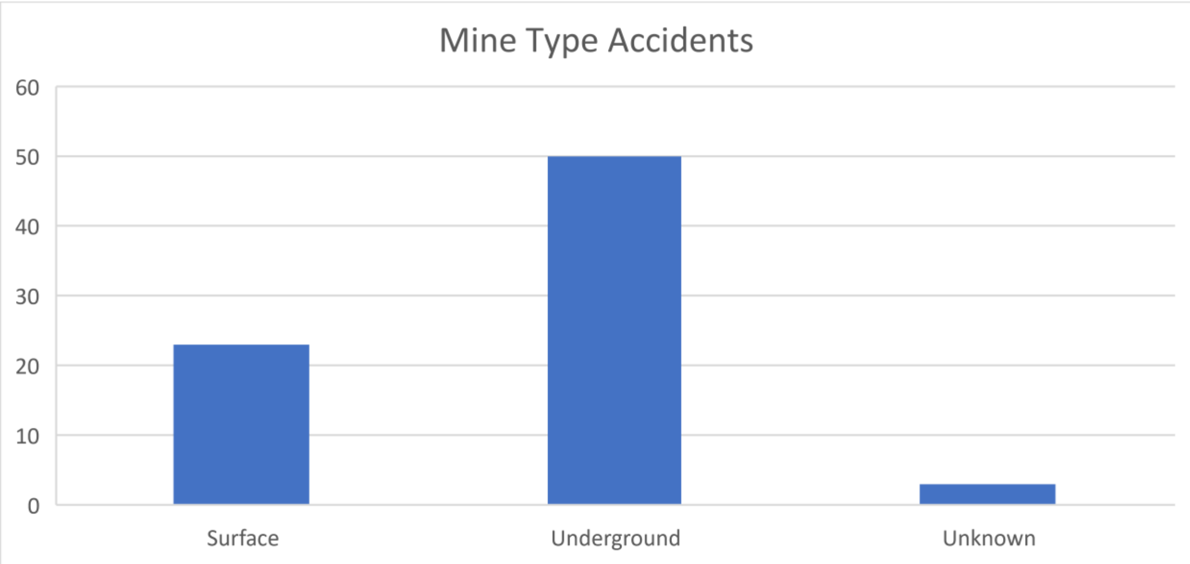


Figure 4.1.1 Number of accidents in different types of mines

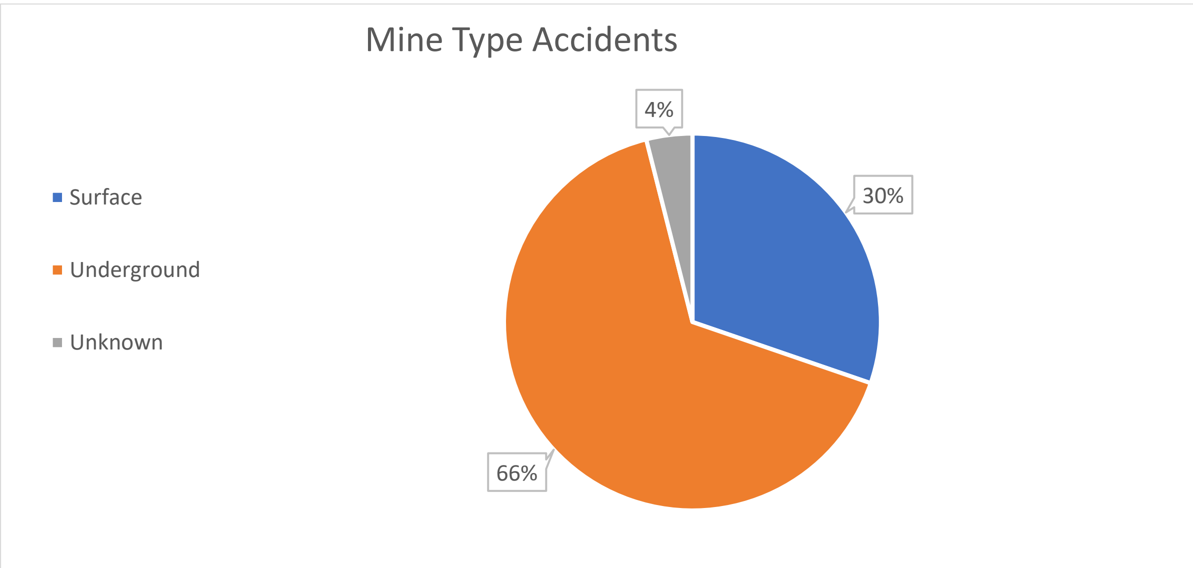


Figure 4.1.2 Pi Chart representation of number of accidents in different types of mines

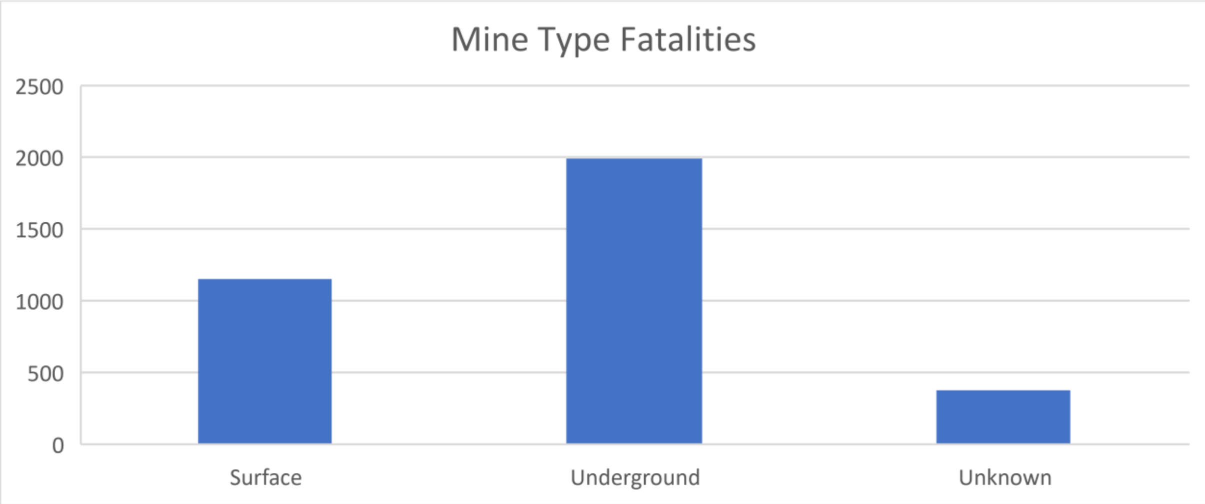


Figure 4.1.3 Number of fatalities in different types of mines

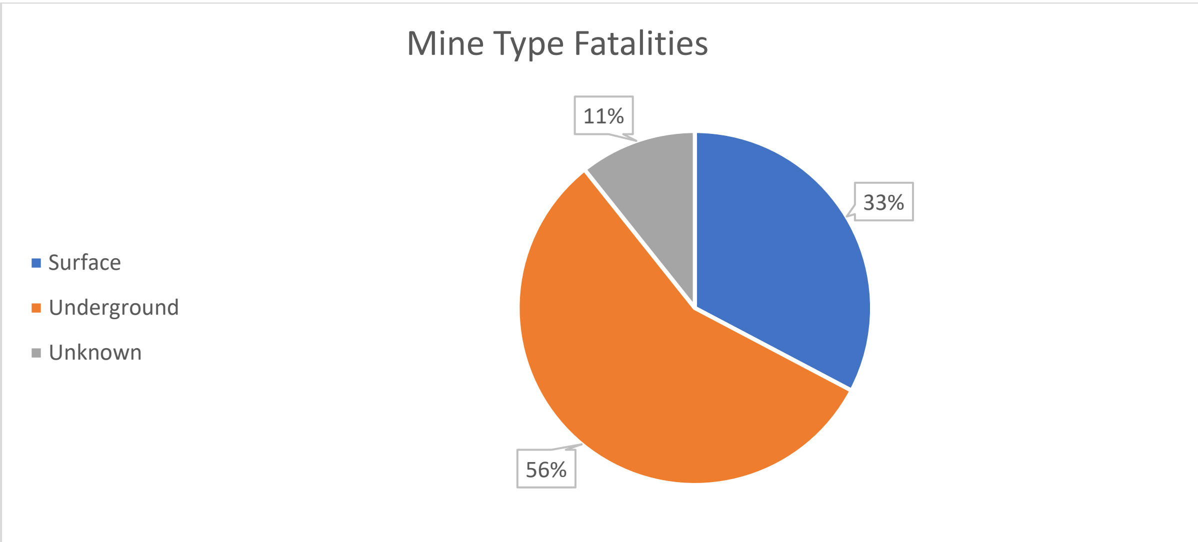


Figure 4.1.4 Pi Chart representation of number of fatalities in different types of mines

It can be seen from *Table 4.1.1* and *Figures 4.1.1 and 4.1.2* and *Figures 4.1.3 and 4.1.4* that underground mines account for the largest number of accidents, 50 accidents (about 66% of all the accidents) and the largest number of fatalities, 1993 fatalities (about 56% of all the fatalities) respectively. While the surface mine accidents are approximately 30%, instead the remaining 4% are unknown types of mines. On the other hand, the number of fatalities occurred in the surface mines are 1153 fatalities which corresponds to 33%, instead the unknown types of mines account for 11% of fatalities.

Operation Type	Number of Accidents	Number of Fatalities
Coal	53	2363
Non-Coal	23	1160
TOTAL	76	3523

Table 4.1.2 Number of accidents and fatalities in coal and non-coal mines

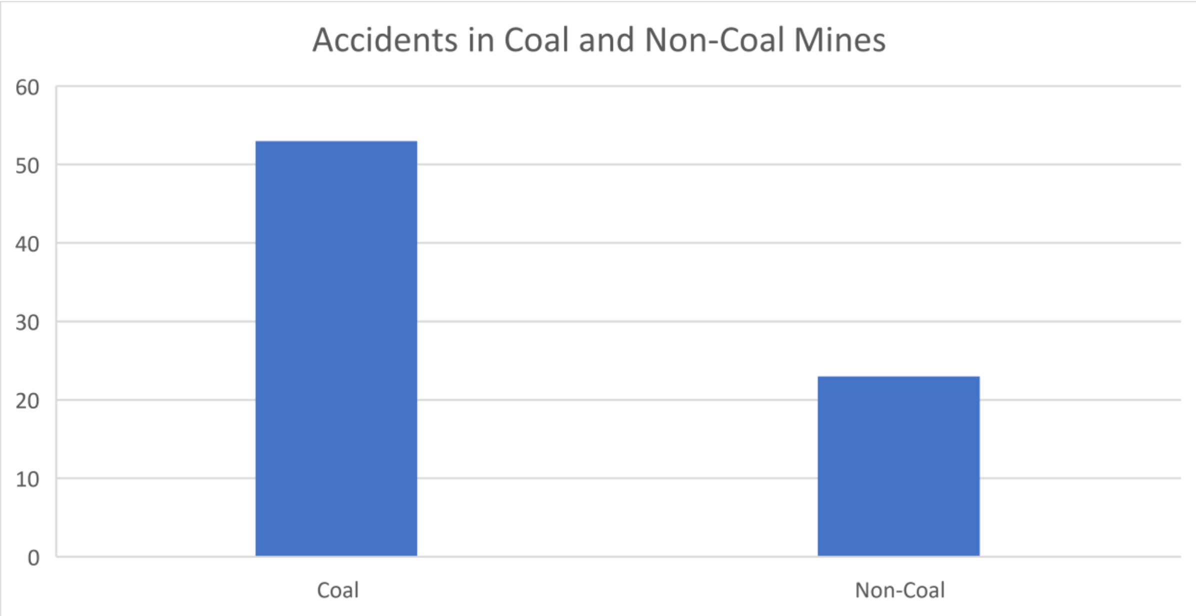


Figure 4.1.5 Number of accidents in coal and non-coal mines

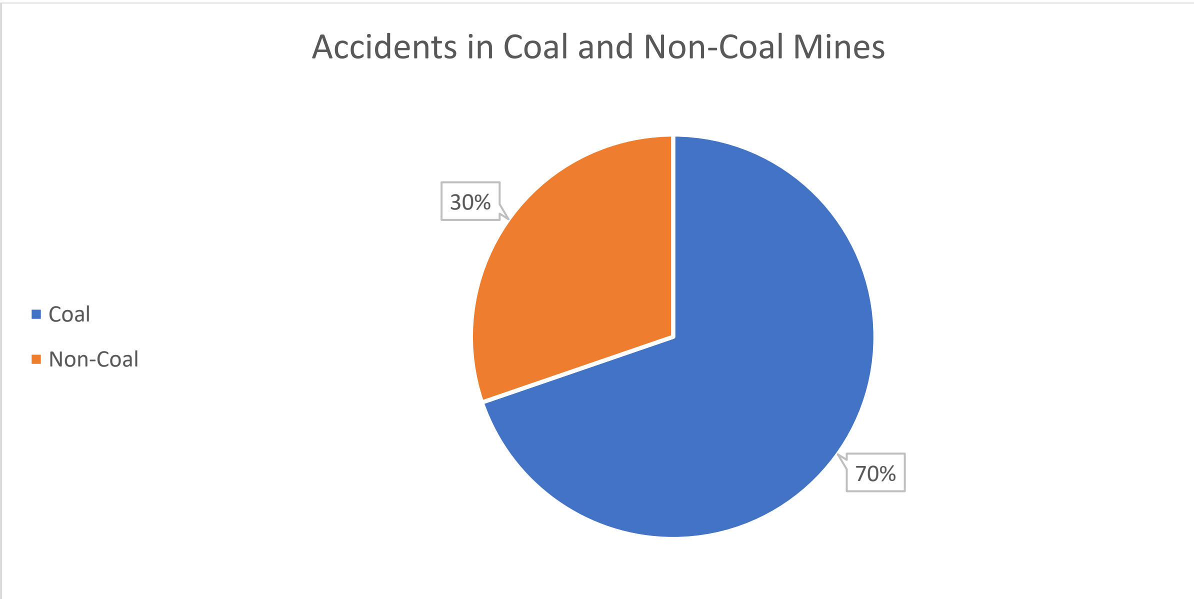


Figure 4.1.6 Pi Chart representation of number of accidents in coal and non-coal mines

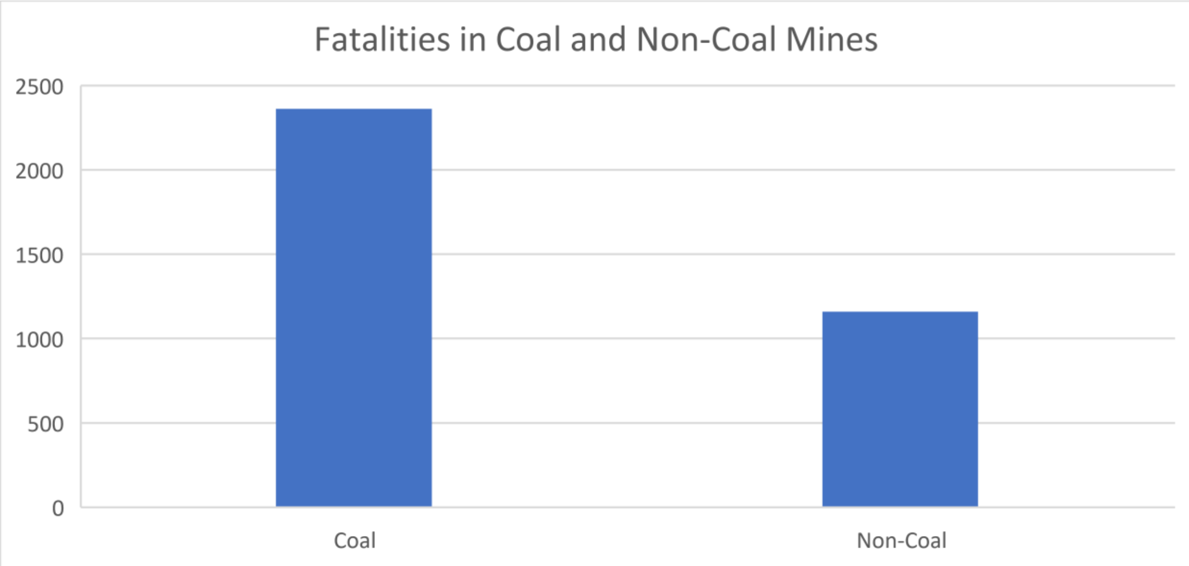


Figure 4.1.7 Number of fatalities in coal and non-coal mines

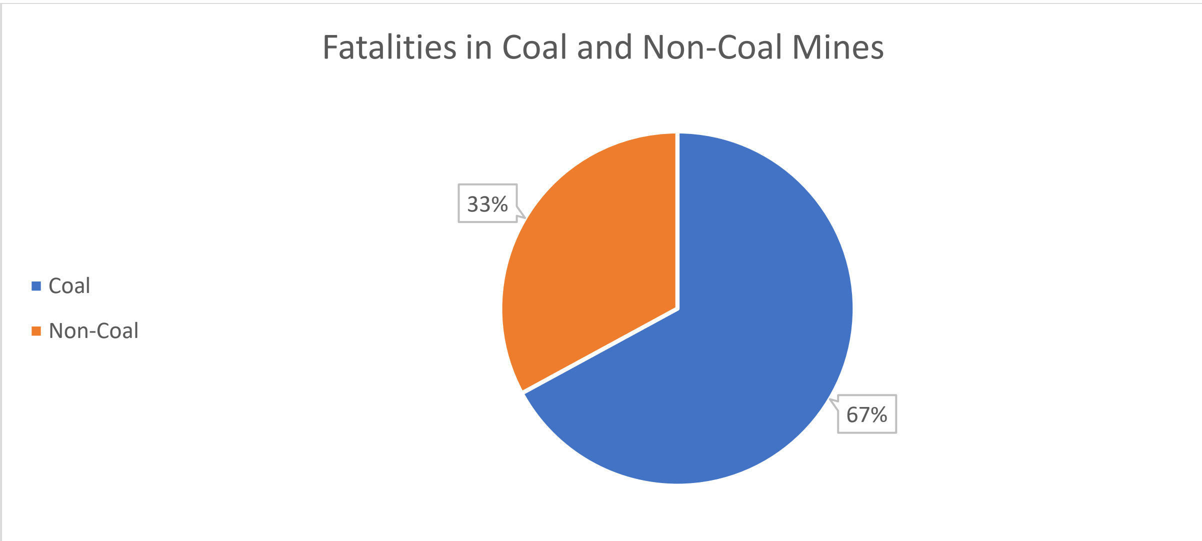


Figure 4.1.8 Pi Chart representation of number of fatalities in coal and non-coal mines

For the whole study, the total number of accidents and fatalities of coal mines is the largest with 53 accidents and 2363 fatalities corresponding to approximately 70% and 67% respectively while for non-coal mines it occupies 30% and 33% respectively as *Figures 4.1.5 and 4.1.6* and *Figures 4.1.7 and 4.1.8* show respectively.

Underground Mines		
Mine Operation	**Number of Accidents**	**Number of Fatalities**
Coal	44	1925
Non-Coal	6	68
TOTAL	50	1993

Table 4.1.3 Number of accidents and fatalities in underground coal and non-coal mines

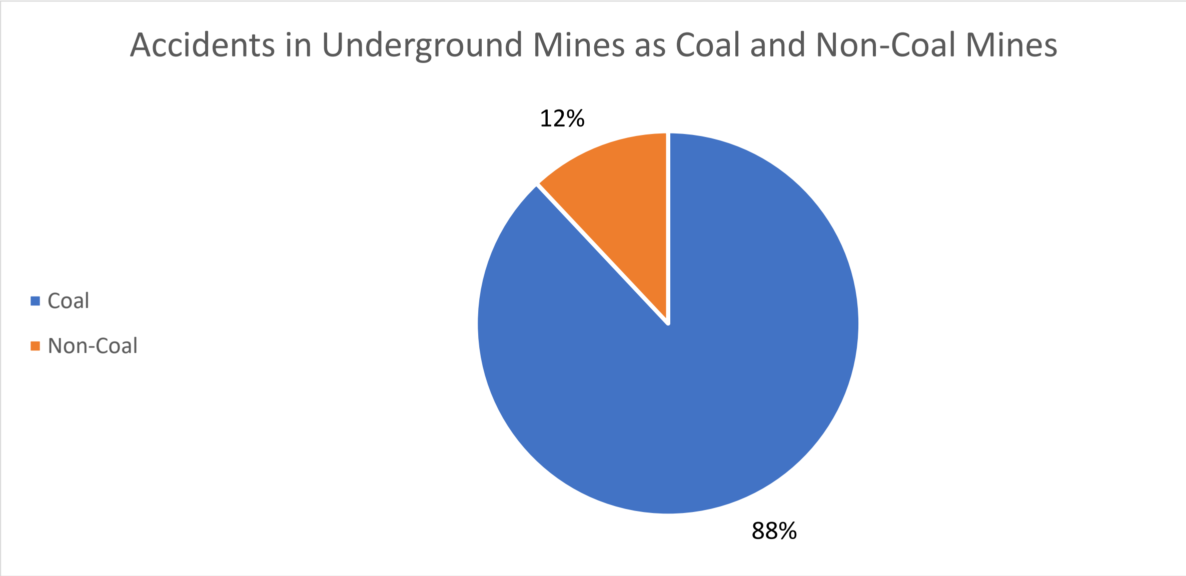


Figure 4.1.9 Pi Chart representation of number of accidents in underground coal and non-coal mines

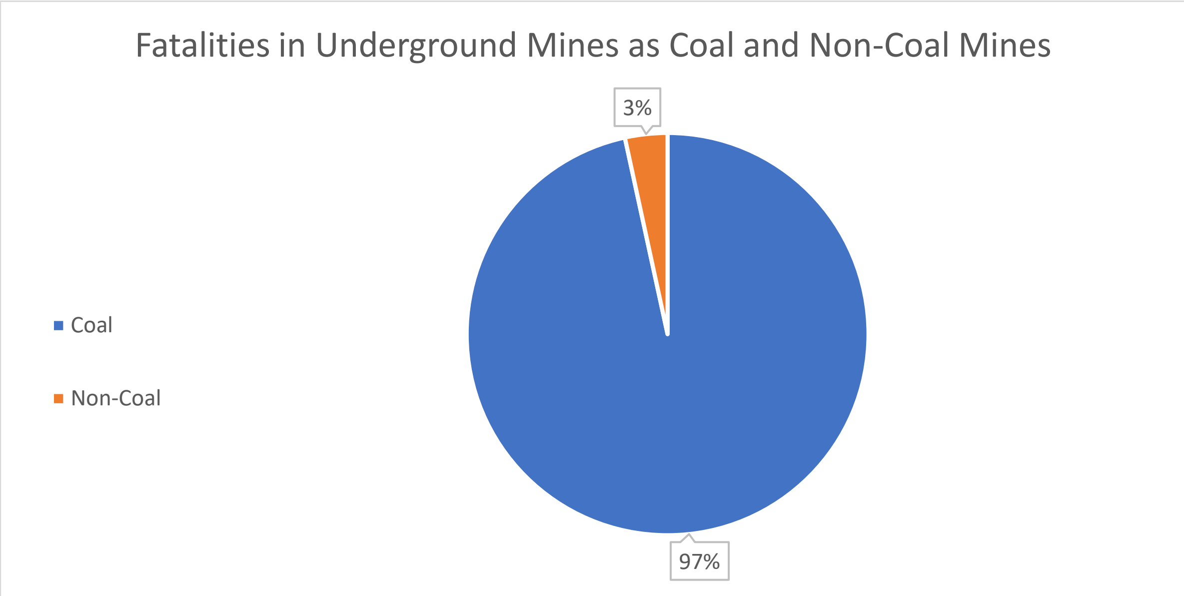


Figure 4.1.10 Pi Chart representation of number of fatalities in underground coal and non-coal mines

Among the underground mines and as *Table 4.1.3* and *Figure 4.1.9* show, there are 44 accidents that occur in non-coal mines which corresponds to 88% of the underground mine accidents. While only 6 accidents belong to the coal mining industry that represent about 12% of the underground mine accidents.

On the other hand, the underground coal mines have 1925 fatalities which corresponds to about 97% of the total underground fatalities, while there are only 68 fatalities for the coal mines that represents only 3% of the total underground fatalities as *Table 4.1.3* and *Figure 4.1.10* show.

Non-Coal Operation	Number of Accidents	Number of Fatalities
Gold	8	201
Copper-Gold	4	68
Lead	1	163
Lead-zinc	1	4
Platinum	1	47
Iron	3	544
Jadeite	2	96
Metal (Unknown)	2	32
Tanzanite	1	5
TOTAL	23	1160

Table 4.1.4 Number of accidents and fatalities in non-coal mine types

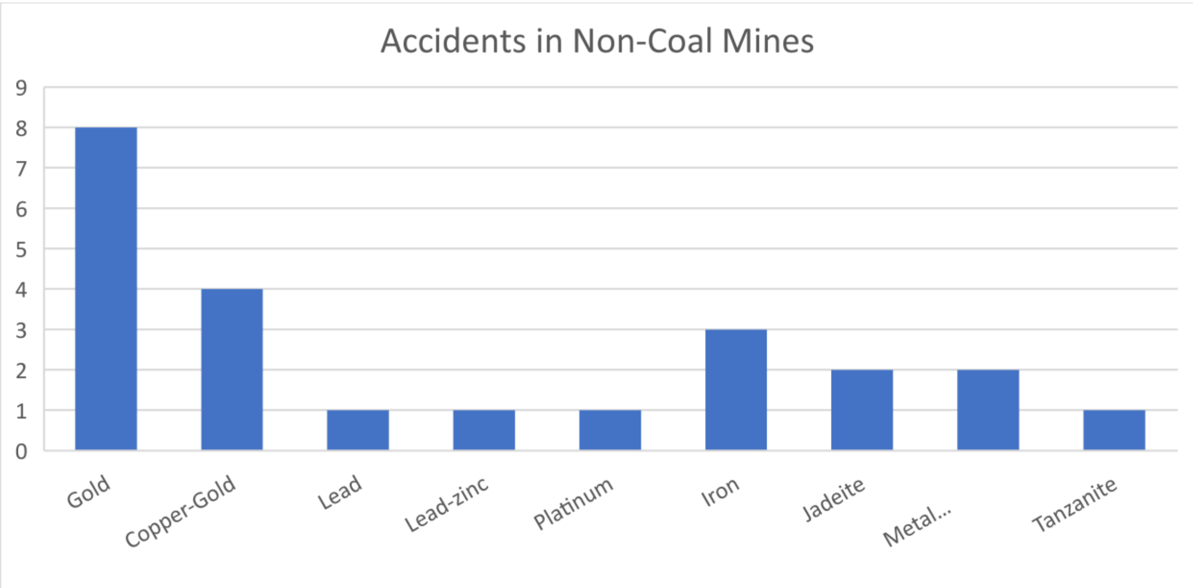


Figure 4.1.11 Number of accidents in non-coal mine types

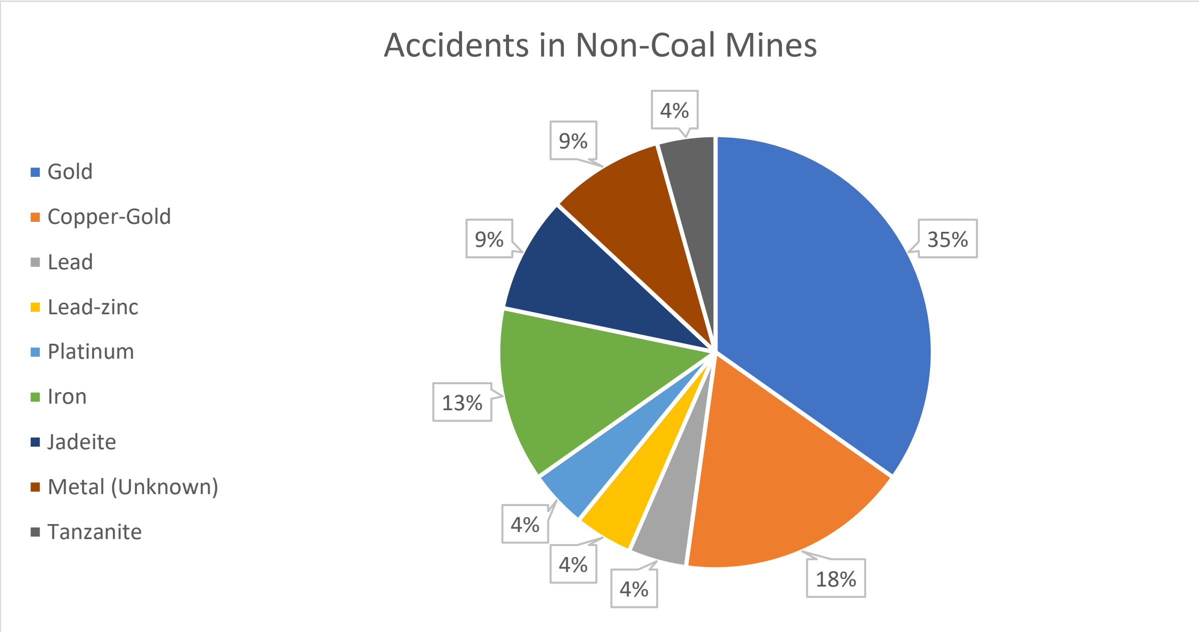


Figure 4.1.12 Pi Chart representation of number of accidents in non-coal mine types

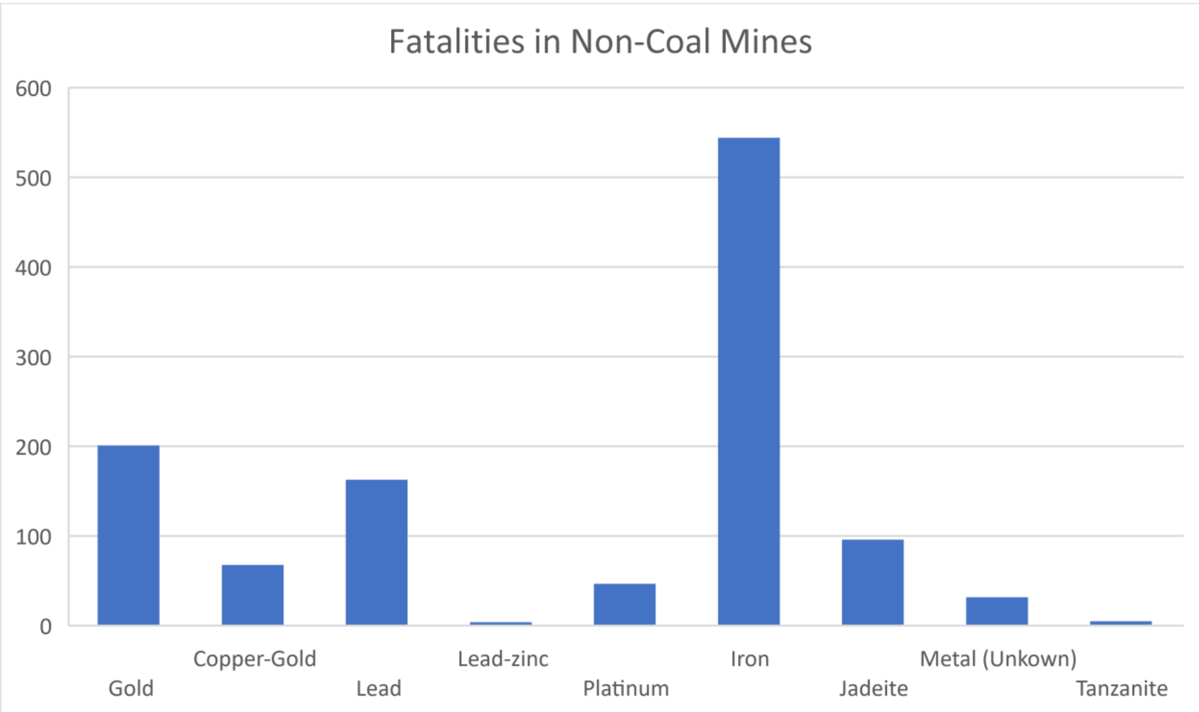


Figure 4.1.13 Number of fatalities in non-coal mine types

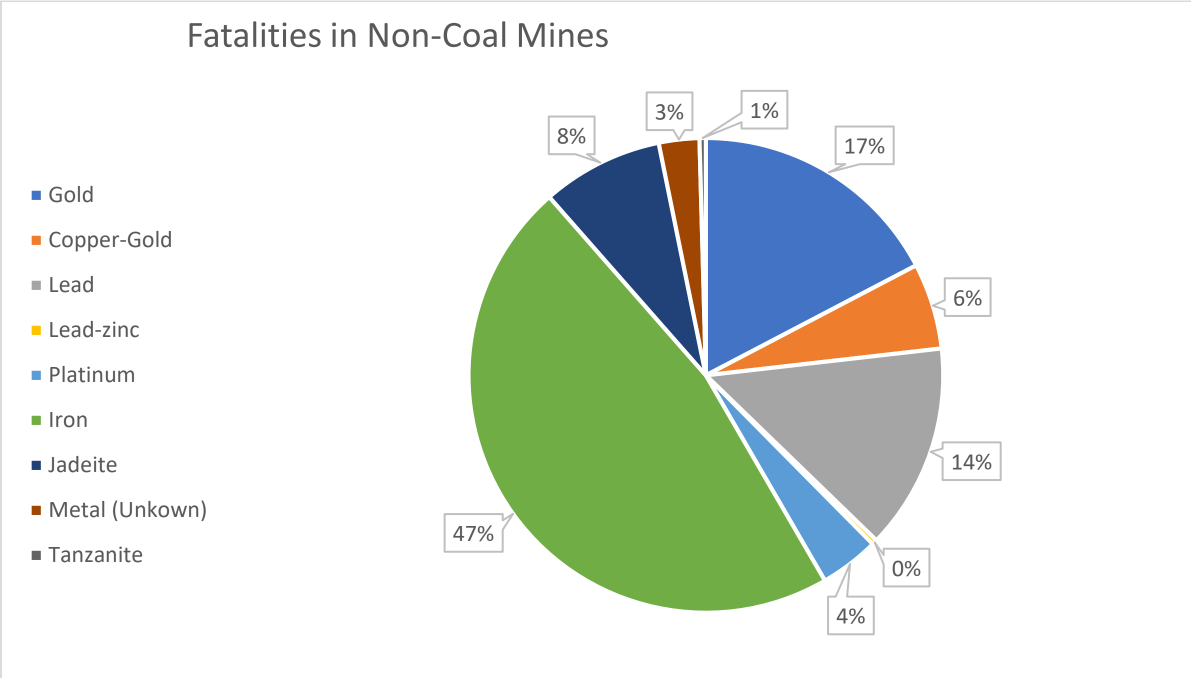


Figure 4.1.14 Pi Chart representation of number of fatalities in non-coal mine types

Among the non-coal mines, *Table 4.1.4* and *Figures 4.1.11 and 4.1.12* show that the largest number of accidents is for gold mines with 8 accidents representing 35% of the accidents of the non-coal mines while the remaining accidents are distributed as copper-gold mines 4 accidents, iron mines 3 accidents, Jadeite and unknows mines 2 accidents each and the remaining lead, lead-zinc, platinum and tanzanite mines 1 accident each.
On the other side, *Table 4.1.4* and *Figures 4.1.13 and 4.1.14* show that the largest number of fatalities is for iron mines with 544 fatalities corresponding to 47% of all the non-coal mine fatalities and then for gold mines with 201 fatalities representing 17% while lead mines have 163 fatalities which corresponds to 14% of the non-coal mine fatalities.

Accident Type	Number of Accidents	Number of Fatalities
Gas/ Coal Dust Explosion	28	1646
Flooding (Inundation)	9	408
Mine Collapse	14	488
Hoisting	2	14
Outburst	3	51
Landslide	2	156
Other Explosion	4	113
Fire	2	27
Gas Inhalation	3	90
Inrush	1	4
Powered Haulage	1	4
Other	7	522
TOTAL	76	3523

Table 4.1.5 Number of accidents and fatalities for different types of accidents

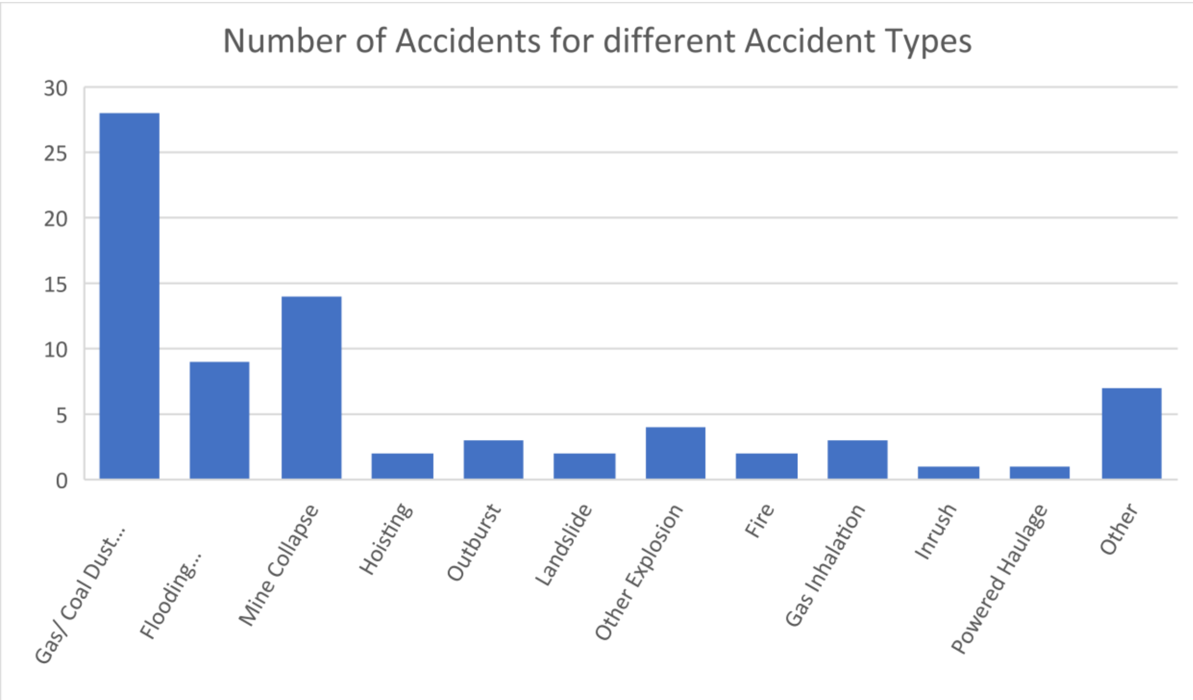


Figure 4.1.15 number of accidents for different types of accidents

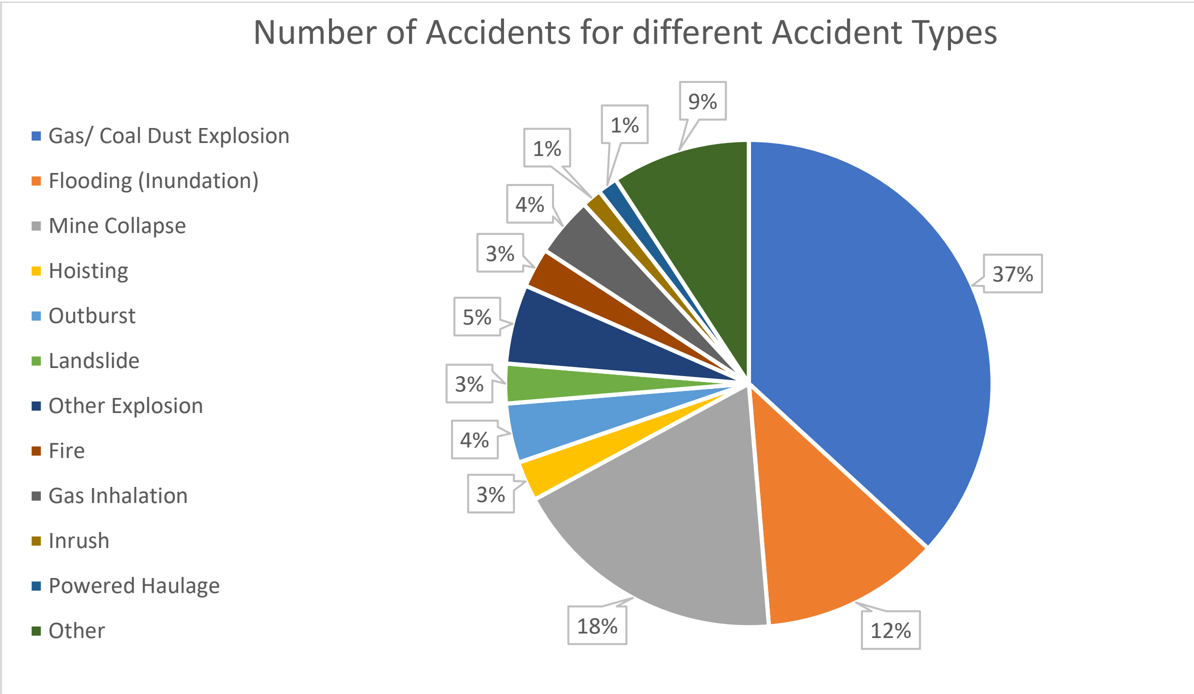


Figure 4.1.16 Pi Chart representation of number of accidents for different types of accidents

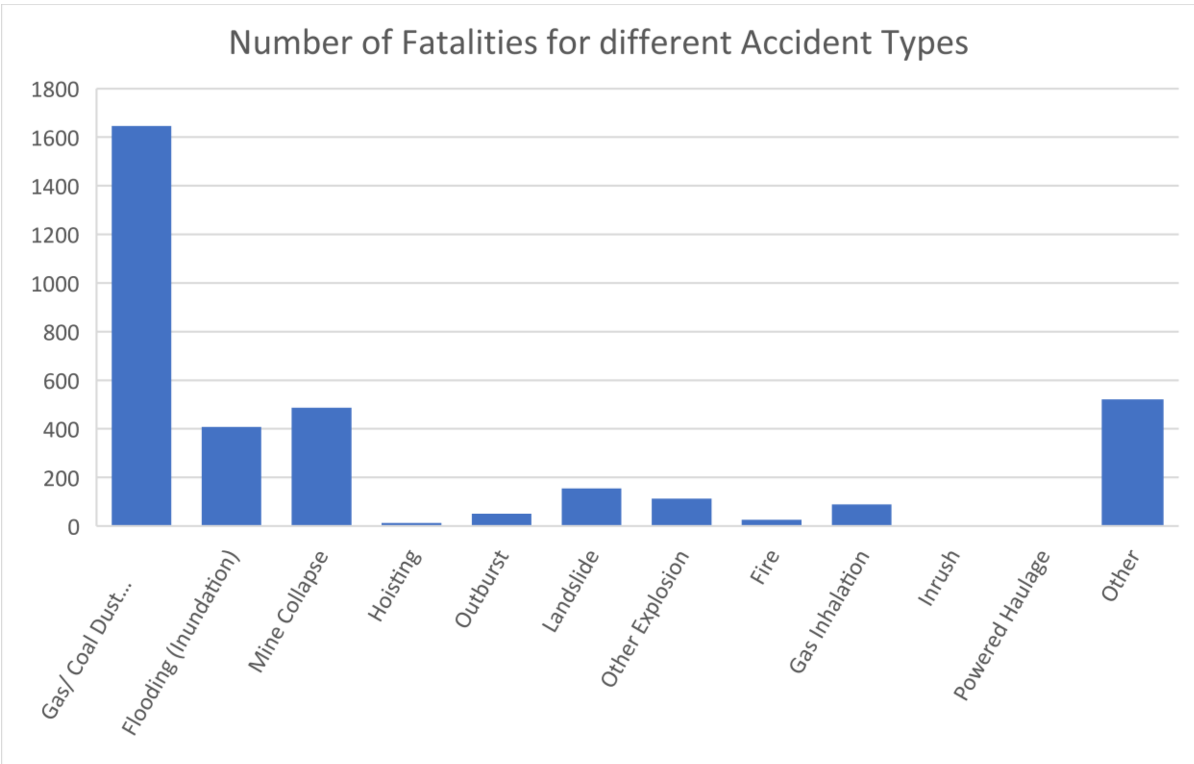


Figure 4.1.17 Number of fatalities for different types of accidents

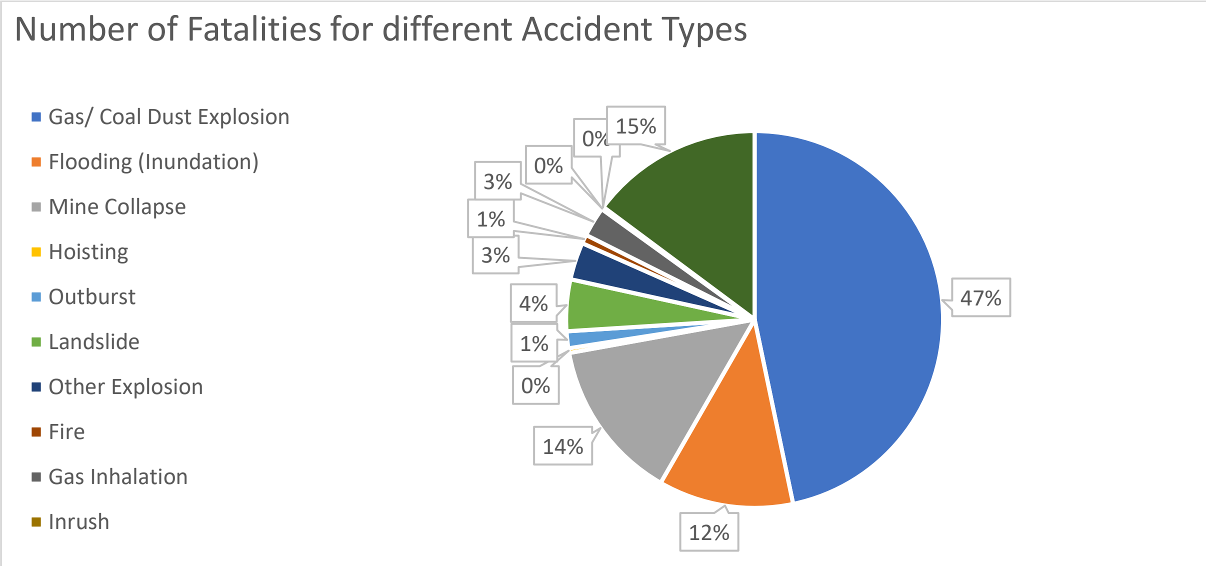


Figure 4.1.18 Pi chart representation of number of fatalities for different types of accidents

It can be seen from *Table 4.1.5* and *Figures 4.1.15 and 4.1.16* that the most frequent accident type is the gas and coal dust explosion by 28 accidents corresponding to 37% of all the accidents in the taxonomy, followed by mine collapse and flooding (inundation) with 14 and 9 accidents respectively representing 18% and 12% of all accidents respectively. Concerning the number of fatalities, *Table 4.1.5* and *Figures 4.1.17 and 4.1.18* show that also gas/ coal dust explosion has the largest number of fatalities with 1646 fatalities which represents 47% of all the fatalities, followed by other types of accidents that have 522 fatalities representing 15% of the total fatalities. They are followed the also by mine collapse and flooding with 488 and 408 fatalities each corresponding to 14% and 12% respectively.

Coal Mines		
Type of Accident	**Number of Accident**	**Number of Fatalities**
Gas/ Coal Dust Explosion	28	1646
Flooding (Inundation)	8	408
Mine Collapse	4	81
Hoisting	2	14
Outburst	3	51
Landslide	0	0
Other Explosion	3	111
Fire	2	27
Gas Inhalation	1	4
Inrush	1	4
Powered Haulage	0	0
Other	1	17
TOTAL	53	2363

Table 4.1.6 Number of accidents and fatalities for different types of accidents in coal mines

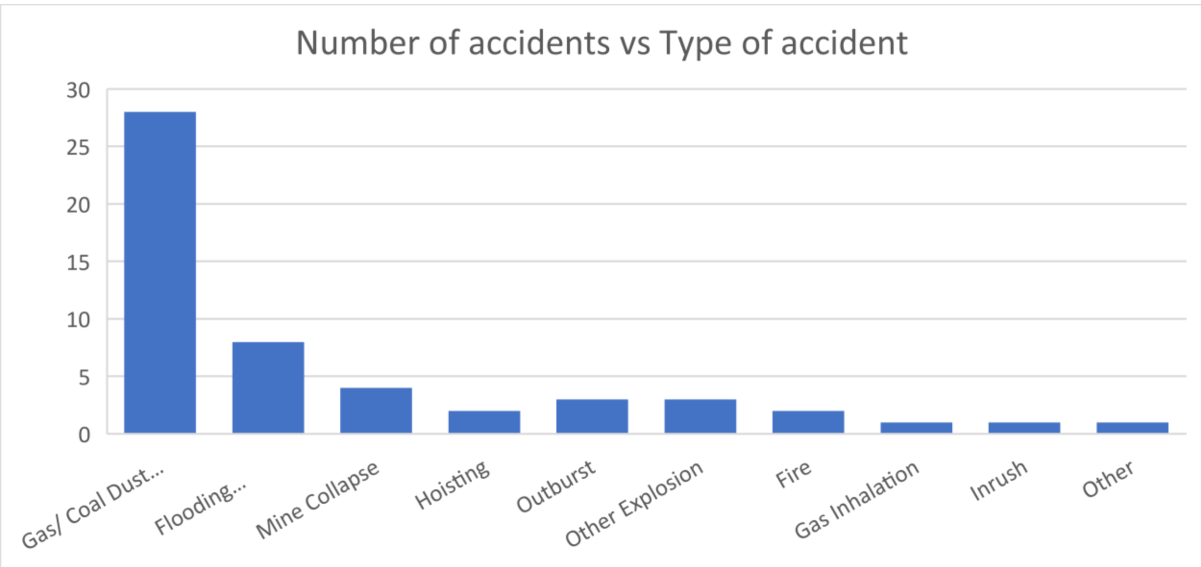
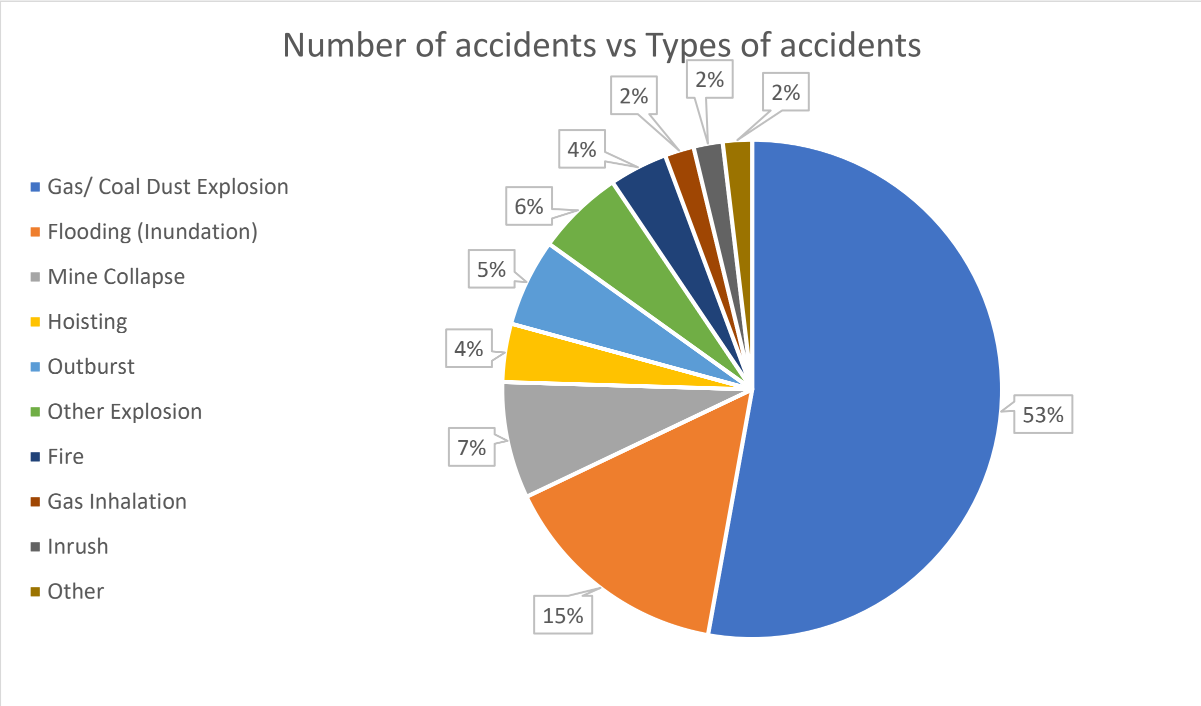


Figure 4.1.19 Number of accidents for different types of accidents in coal mines



4.1.20 Pi Chart representation of number of accidents for different types of accident in coal mines

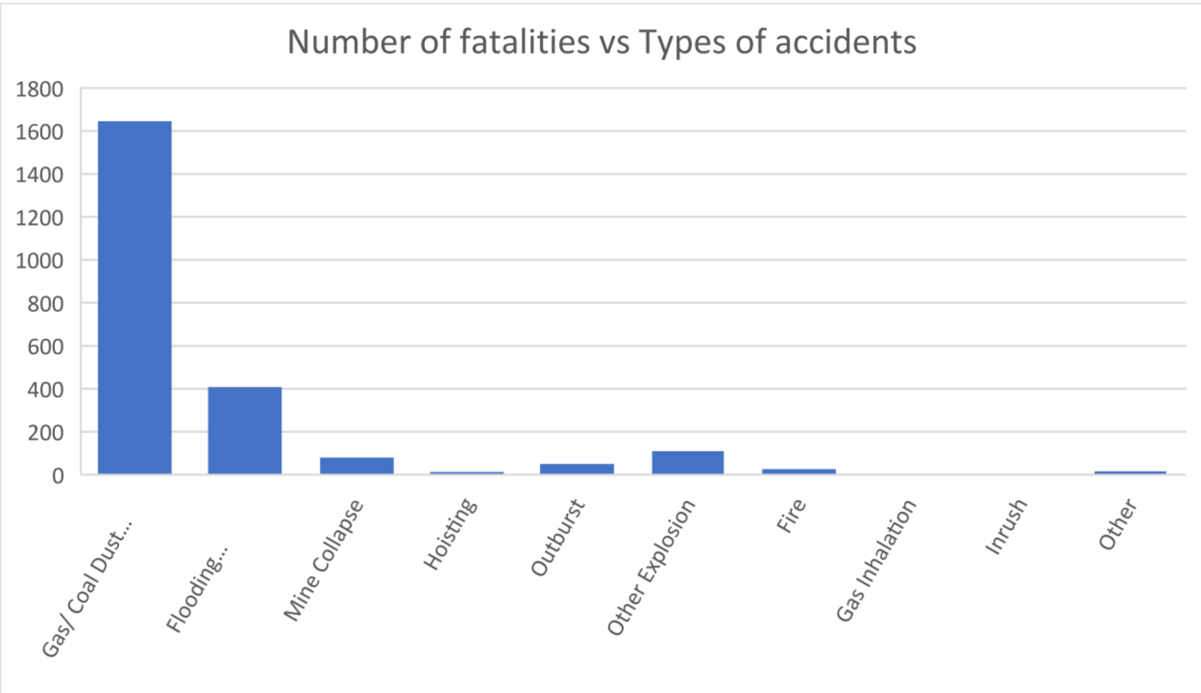


Figure 4.1.21 Number of fatalities for different types of accidents in coal mines

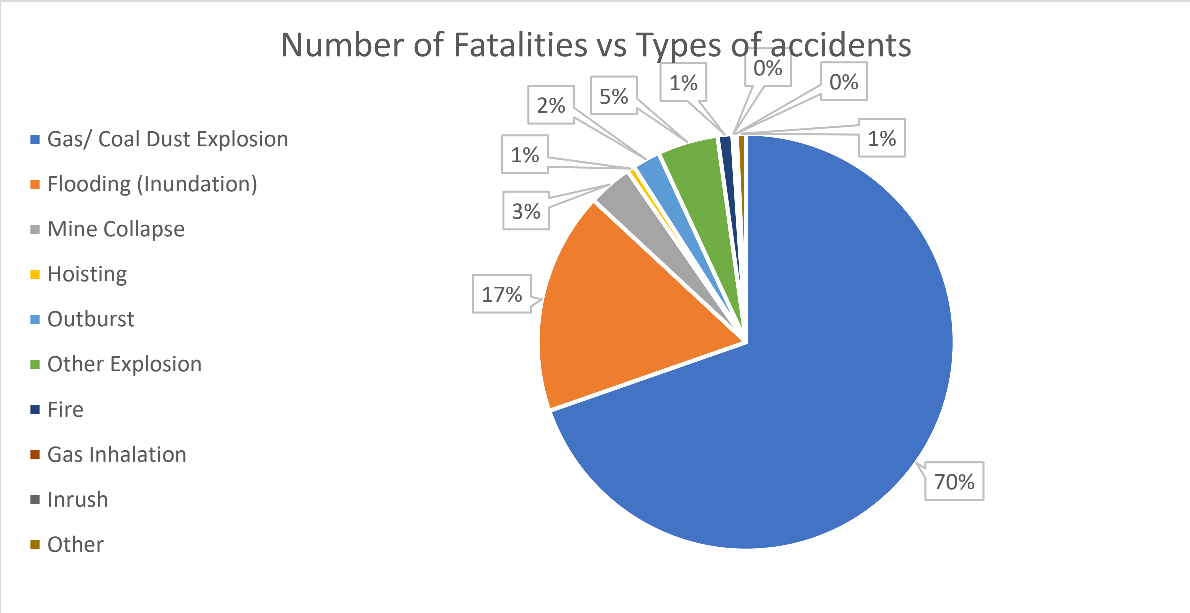


Figure 4.1.22 Pi Chart representation of number of fatalities for different types of accidents in coal mines

For the case of coal mines only, gas and coal dust explosion has the largest number of accidents with 28 accidents which corresponds to 53% of all the coal mining accidents, followed by flooding (inundation) with 8 accidents which represents 15% of the accidents as *Table 4.1.6* and *Figures 4.1.19 and 4.1.20* show.

Concerning the largest number of fatalities in the coal mines, gas and coal dust explosions have the large number with 1646 fatalities representing 70% of the coal mining fatalities and 100% of this type of accident. Instead, flooding (inundation) shows 408 fatalities followed by 111 fatalities for the other explosion accidents with 17% and 5% of the coal mining fatalities respectively as *Table 4.1.6* and *Figures 4.1.21 and 4.1.22* show.

Non-coal Mines		
Type of Accident	**Number of Accident**	**Number of Fatalities**
Gas/ Coal Dust Explosion	0	0
Flooding (Inundation)	1	0
Mine Collapse	10	407
Hoisting	0	0
Outburst	0	0
Landslide	2	156
Other Explosion	1	2
Fire	0	0
Gas Inhalation	2	86
Inrush	0	0
Powered Haulage	1	4
Other	6	505
TOTAL	23	1160

Table 4.1.7 Number of accidents and fatalities for different types of accidents in non-coal mines

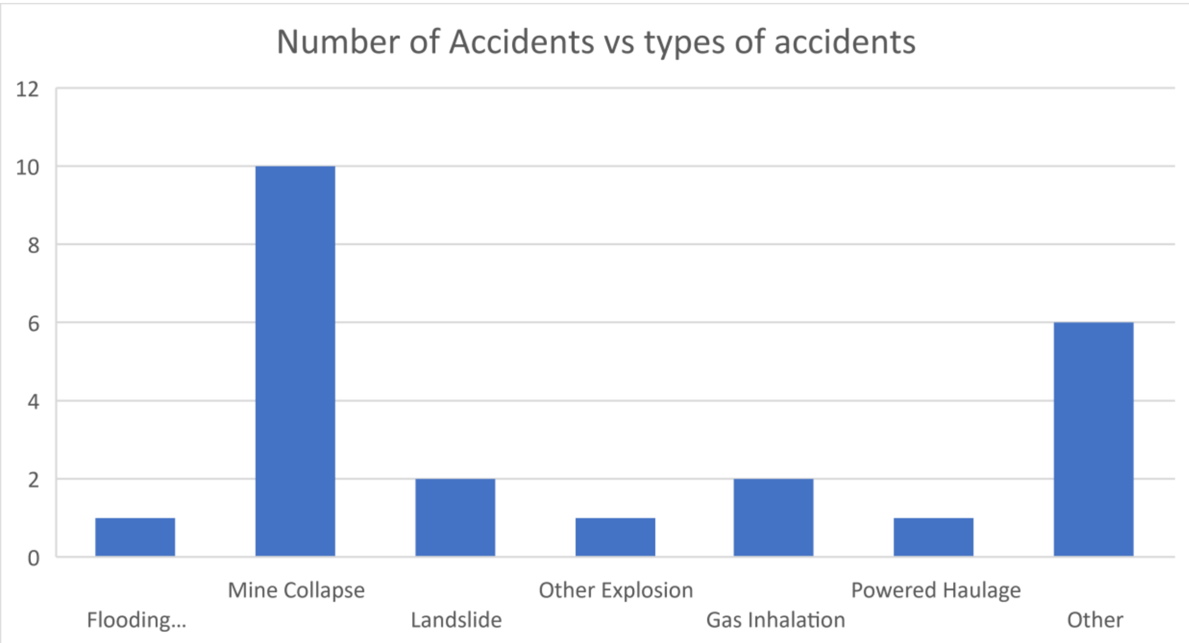


Figure 4.1.23 Number of accidents for different types of accidents in non-coal mines

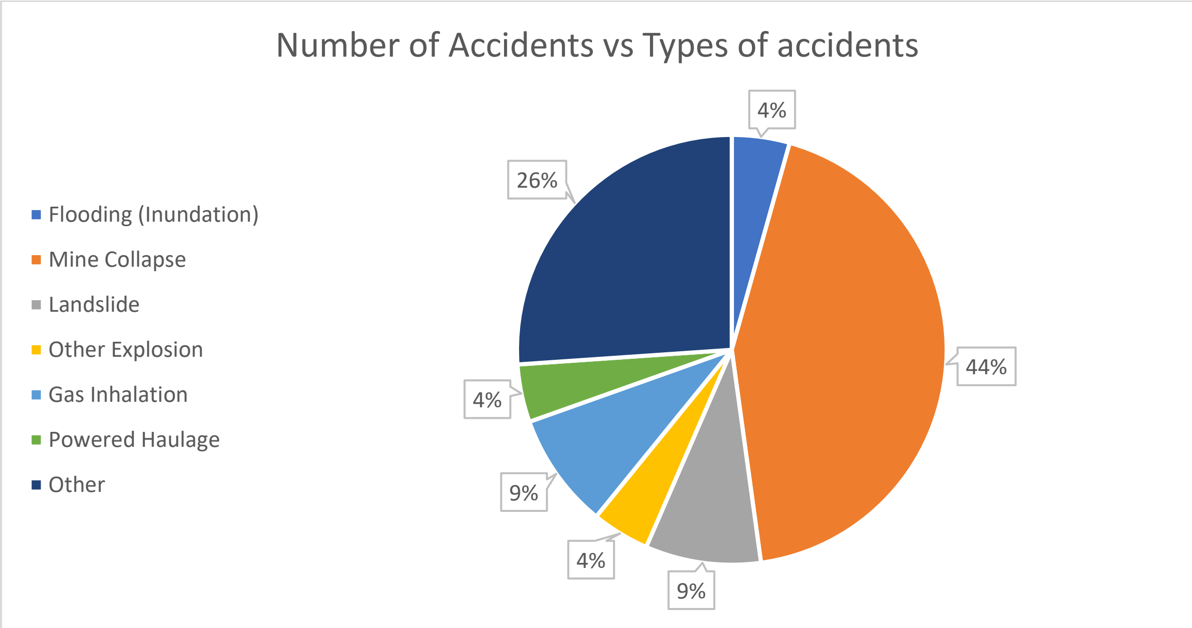


Figure 4.1.24 Pi Chart representation of number of accidents of different types of accidents in non-coal mines

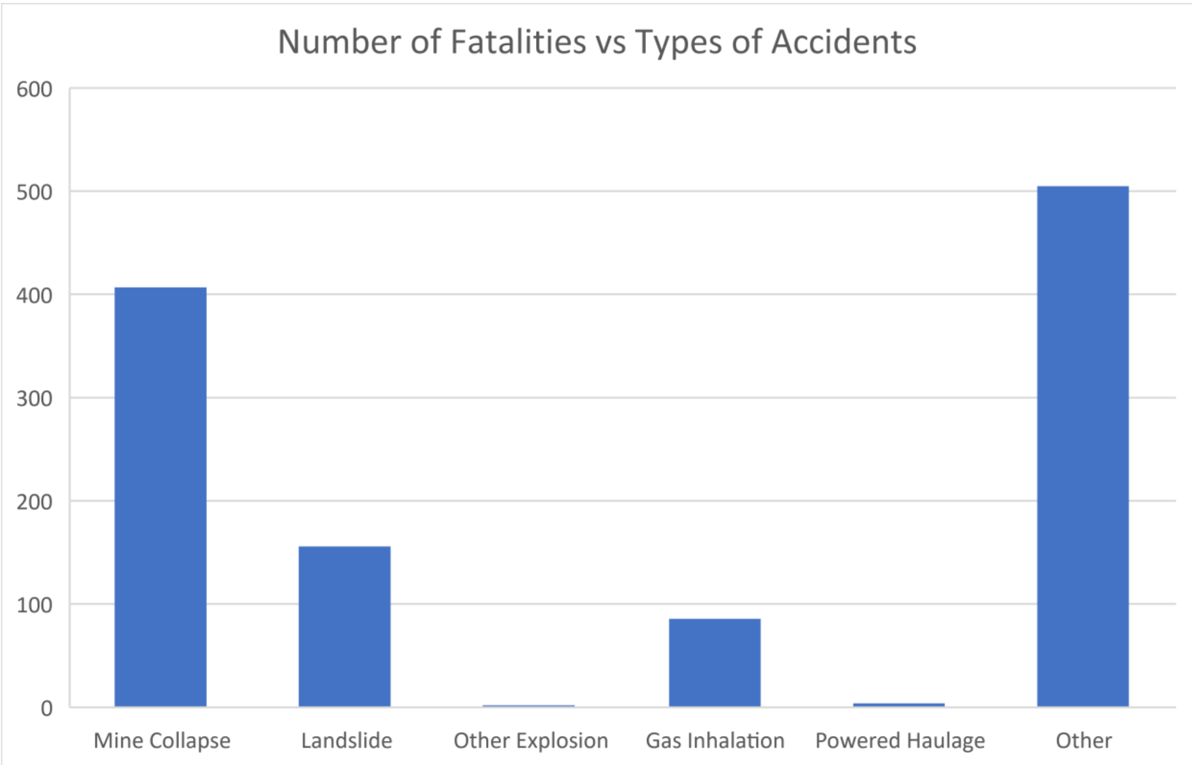


Figure 4.1.25 Number of fatalities for different types of accidents in non-coal mines

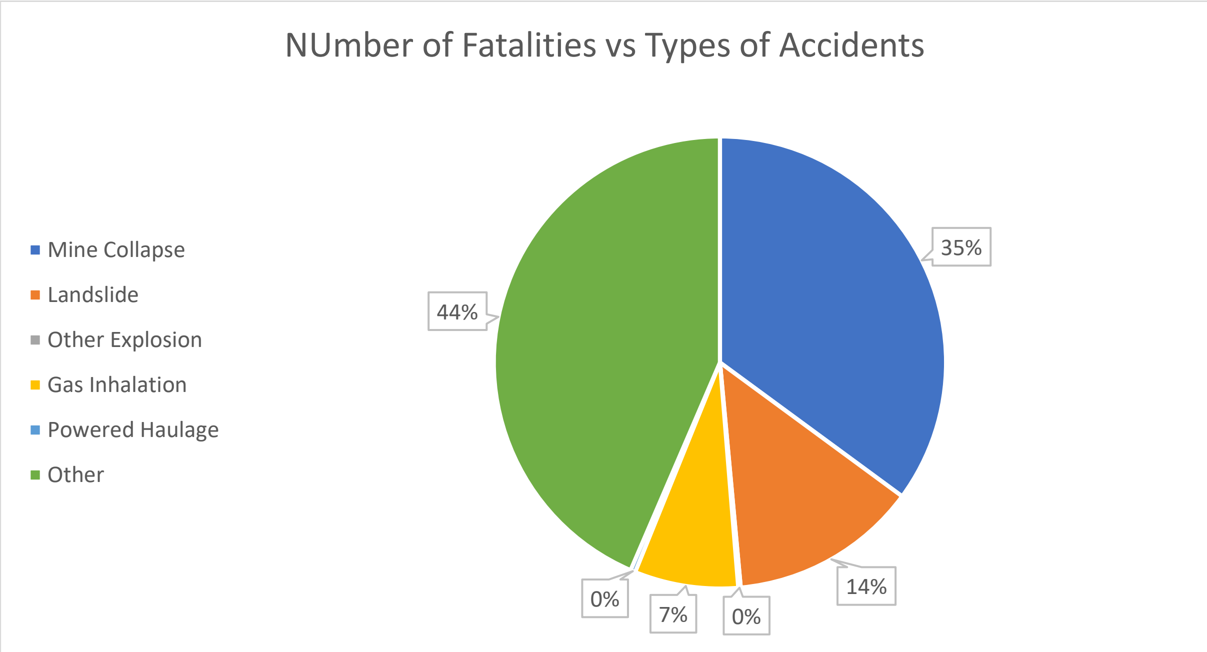


Figure 4.1.26 Pi chart representation of number of fatalities for different types of accidents in non-coal mines

For non-coal mines, mine collapse has the highest frequency of accidents with 10 accidents representing 44% of the non-coal mining accidents while other types of accidents have 6 accidents corresponding to 26% as *Table 4.1.7* and *Figures 4.1.23 and 4.1.24* show. However, other types of accidents have the largest number of fatalities with 505 fatalities that represents 44% followed by mine collapse with 407 fatalities and landslide with 156 fatalities which corresponds to 35% and 14% of all the non-coal mining accidents as shown in *Table 4.1.7* and *Figures 4.1.25 and 4.1.26.*

4.2 THE COMPARISON

For the second part of the study, the statistical analysis is limited to the coal and non-coal mines and the types of accidents for each country in year 2010 except for China as only the first three months are considered.

4.2.1 UNITED STATES

For the United States, the number of accidents and fatalities for the coal and non-coal mines are shown in *Table 4.2.1.1* with their representative graphs in *Figure 4.2.1.1* and *Figure 4.2.1.2*.

For the type of accident, the number of accidents and fatalities are shown in *Table 4.2.1.2* and their graphical representations are shown in *Figure 4.2.1.3 and 4.2.1.4 and Figures 4.2.1.5 and 4.2.1.6* respectively.

UNITED STATES	Number of Accidents	Number of Fatalities
Coal	19	47
Non-Coal	22	22
TOTAL	41	69

Table 4.2.1.1 Number of accidents and fatalities in coal and non-coal mines in USA in 2010

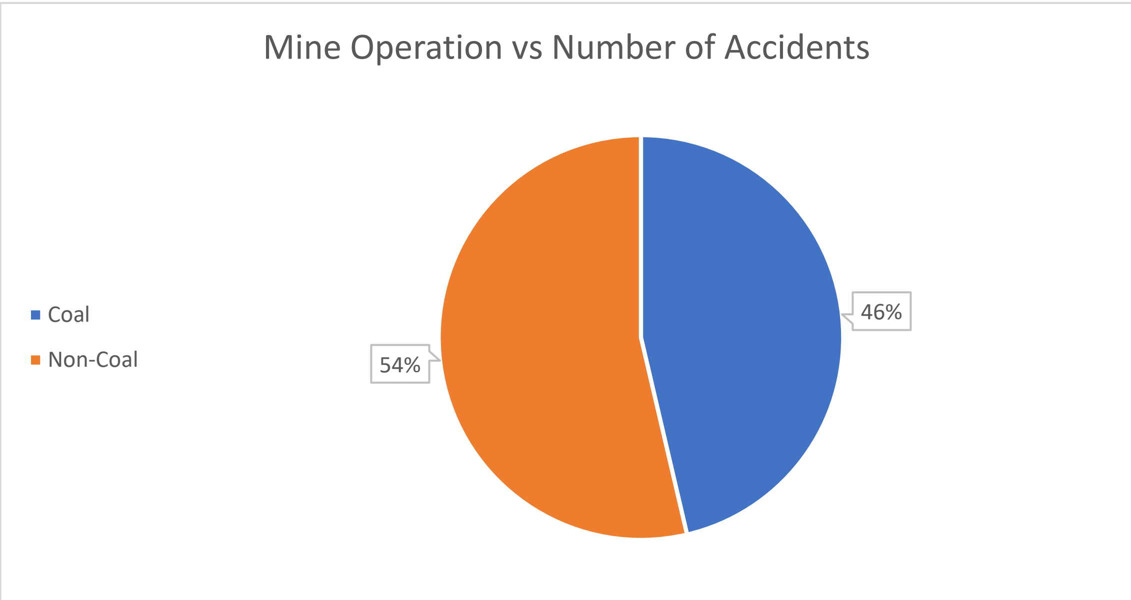


Figure 4.2.1.1 Pi chart representation of number of accidents in coal and non-coal mines in USA in 2010

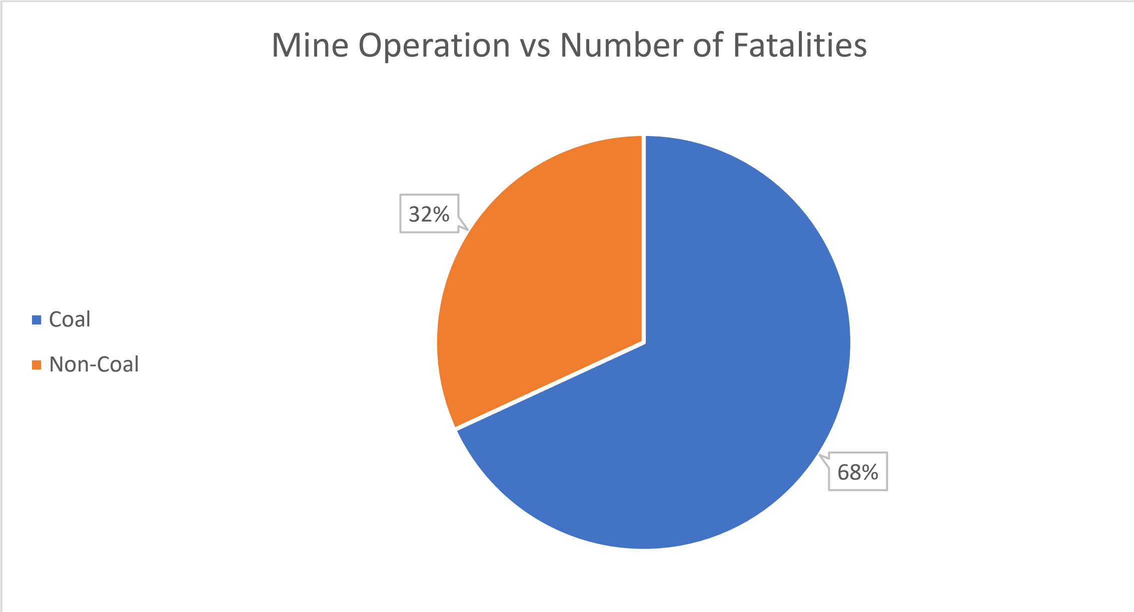


Figure 4.2.1.2 Pi chart representation of number of fatalities in coal and non-coal mines in USA in 2010

UNITED STATES	Number of Accidents	Number of Fatalities
Falling of Material	6	6
Powered Haulage	16	16
Slip or Fall of Person	2	2
Fall of Roof	3	3
Electrical	1	1
Drowning	1	1
Fall of Face	4	4
Machinery	5	5
Explosives	1	1
Gas/ Dust Explosion	2	30
TOTAL	41	69

Table 4.2.1.2 Number of accidents and fatalities for different types of accidents in USA in 2010

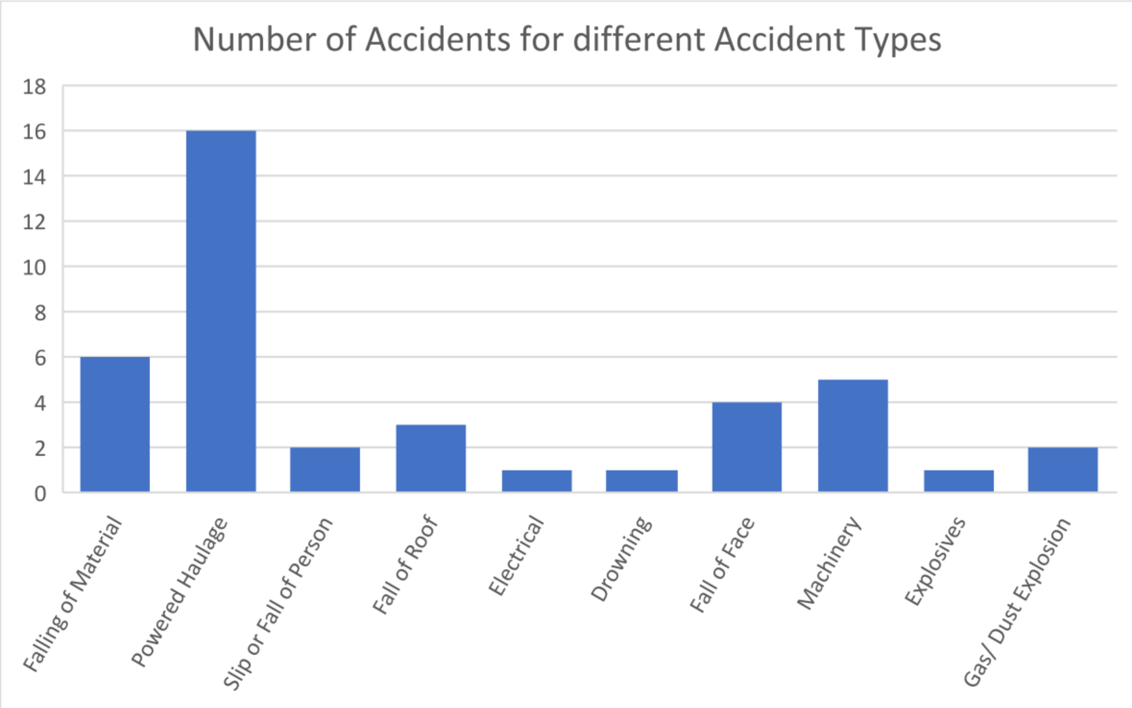


Figure 4.2.1.3 Number of accidents for different accident types in USA in 2010

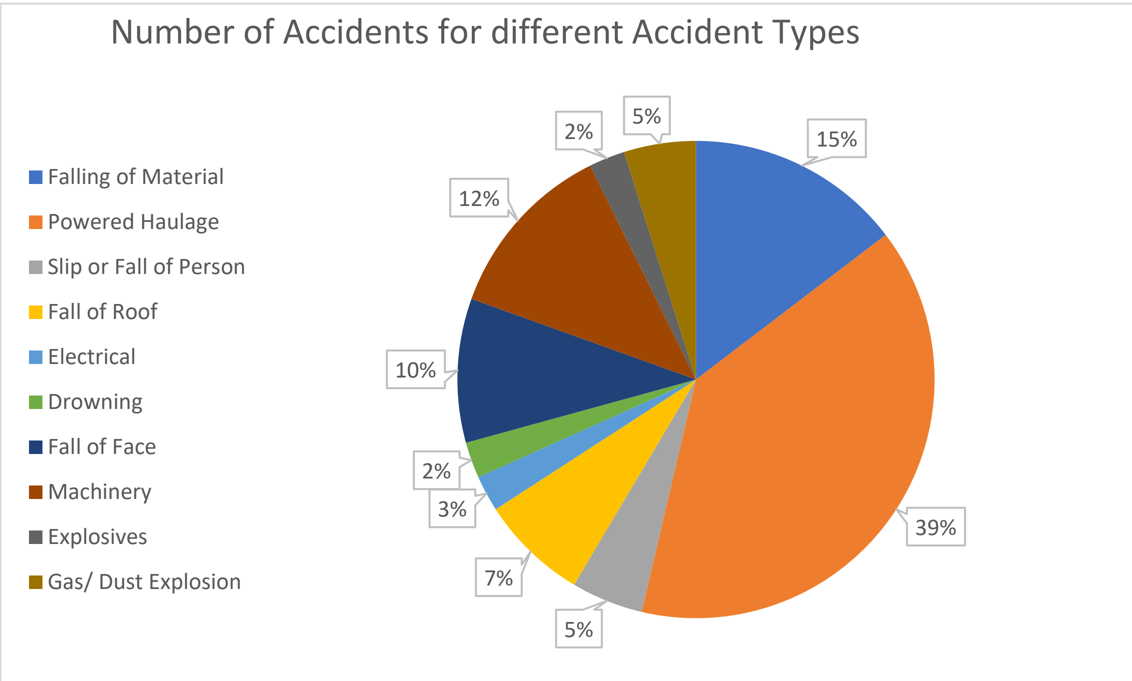


Figure 4.2.1.4 Pi Chart representation of number of accidents for different accident types in USA in 2010

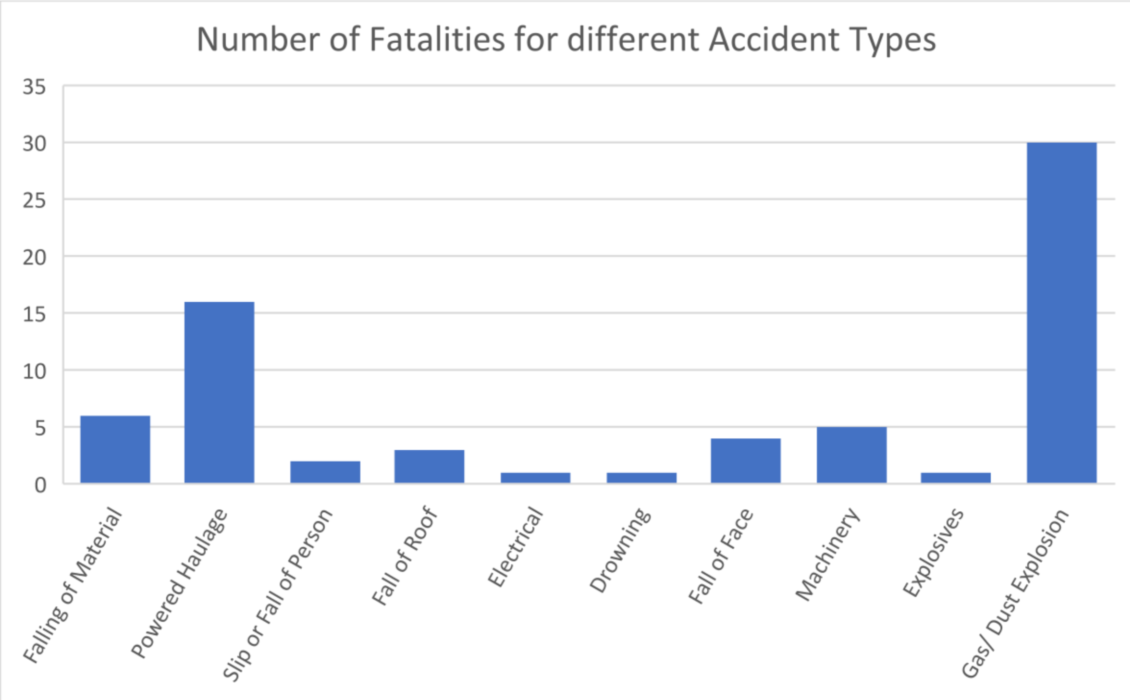


Figure 4.2.1.5 Number of fatalities for different types of accidents in USA in 2010

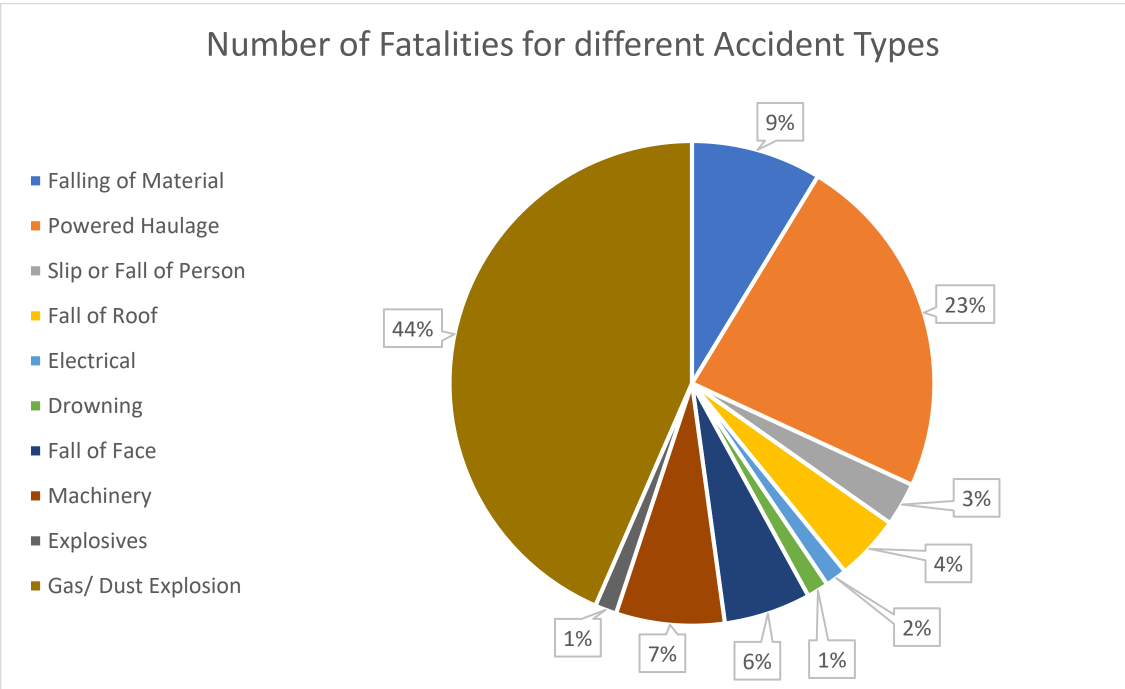


Figure 4.2.1.6 Pi chart representation of number of fatalities for different types of accidents in USA in 2010

For United States, the non-coal mines have the largest number of accidents in 2010 with 22 accidents representing about 54% while coal mines have 46% of all the accidents as Table 4.2.1.*1 and* Figure 4.2.1.1 *show. Regarding the number of fatalities,* Table 4.2.1.1 *and* Figure 4.2.1.2 *show that the coal mines have the largest number with 47 fatalities which represents 68% while the non-coal mines have 22 fatalities representing 32% of all the fatalities.*

In that year, powered haulage occurred the most with 39% representing 16 accidents followed by falling of material with 15% representing 6 accidents out of the total accidents, while the gas and coal dust explosions have 5% as shown in *Table 4.2.1.2 and Figures 4.2.1.3 and 4.2.1.4*. Instead, the number of fatalities of the gas and coal dust explosions accidents reach 30 fatalities which represents 44% followed by powered haulage with 16 fatalities representing 23% of all the fatalities as *Table 4.2.1.2* and *Figures 4.2.1.5 and 4.2.1.6* show.

4.2.2 AUSTRALIA

The same studies are done for Australia and the results are shown in *Tables 4.2.2.1 and 4.2.2.2 and Figures 4.2.2.1, 4.2.2.2., 4.2.2.3, 4.2.2.4, 4.2.2.5 and 4.2.2.6.*

AUSTRALIA	Number of Accidents	Number of Fatalities
Coal	2	2
Non-Coal	3	3
TOTAL	5	5

Table 4.2.2.1 Number of accidents and fatalities in coal and non-coal mines in Australia in 2010

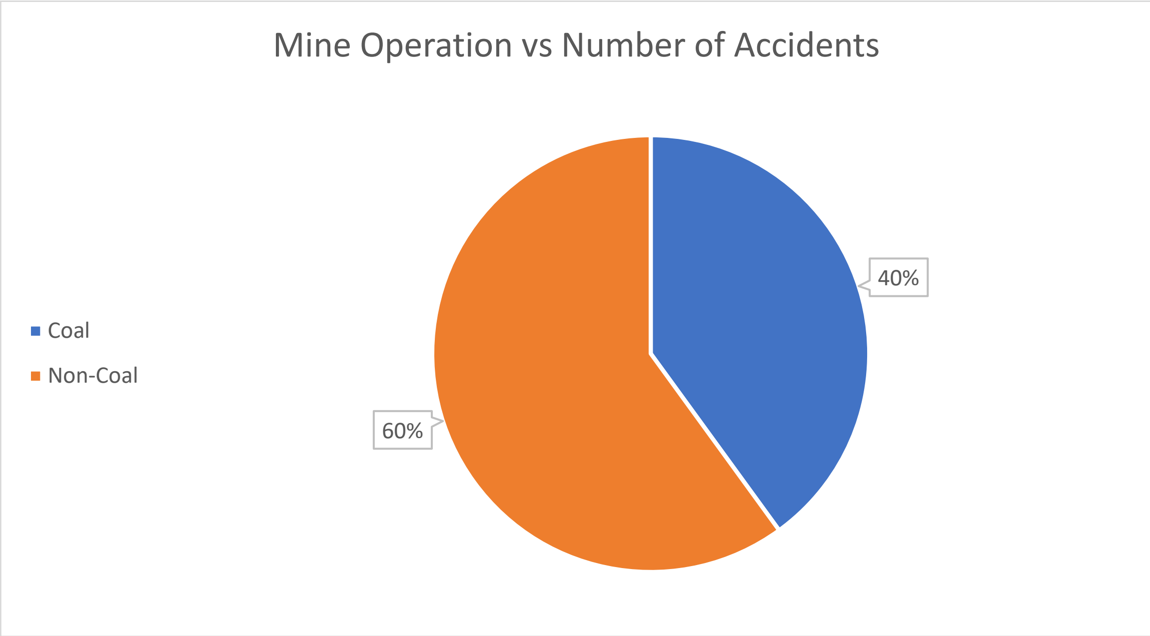


Figure 4.2.2.1 Pi chart representation of number of accidents in coal and non-coal mines in Australia in 2010

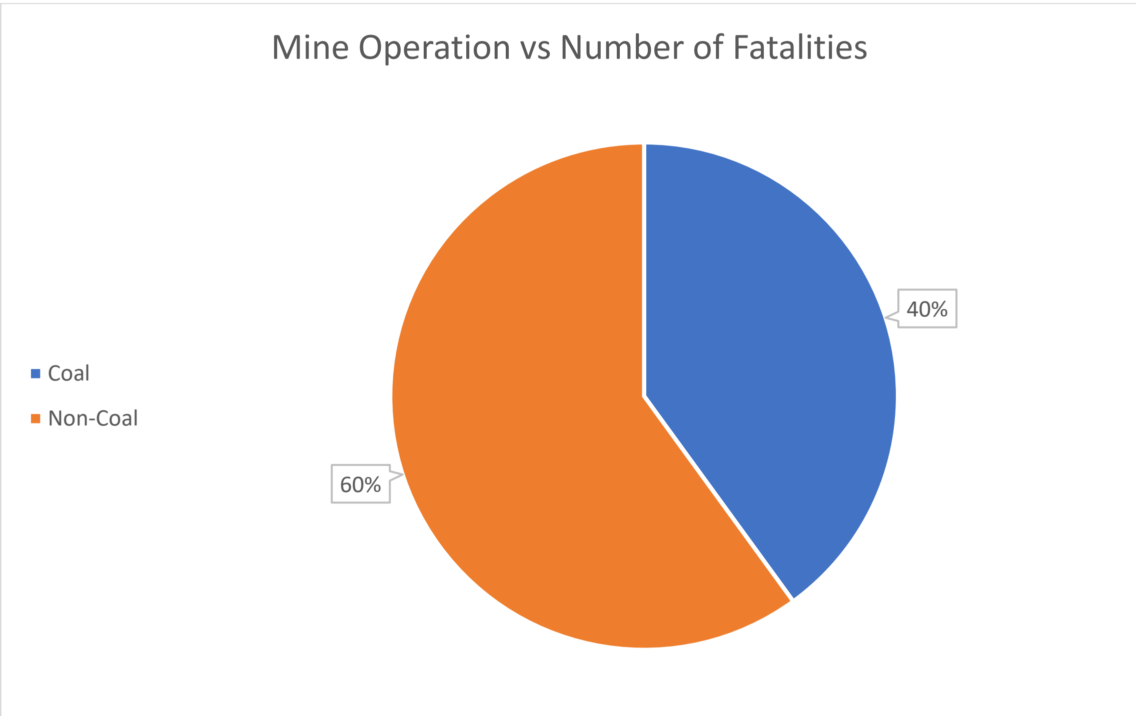


Figure 4.2.2.2 Pi chart representation of number of fatalities in coal and non-coal mines in Australia in 2010

AUSTRALIA	Number of Accidents	Number of Fatalities
Powered Haulage	2	2
Slip or Fall of Person	1	1
Machinery	2	2
TOTAL	5	5

Table 4.2.2.2 Number of accident and fatalities for different types of accidents in Australia in 2010

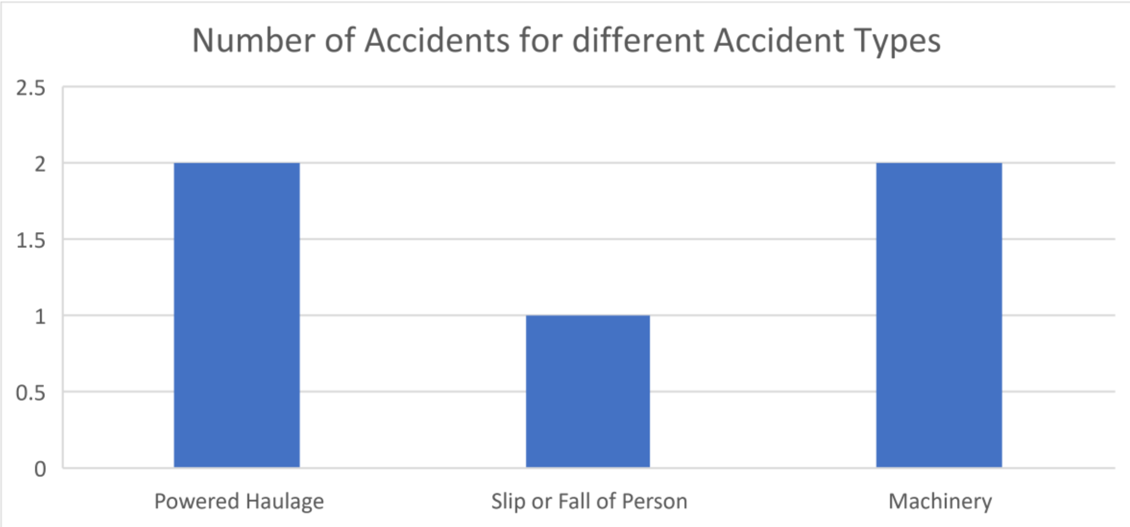


Figure 4.2.2.3 Number of accidents for different types of accidents in Australia in 2010

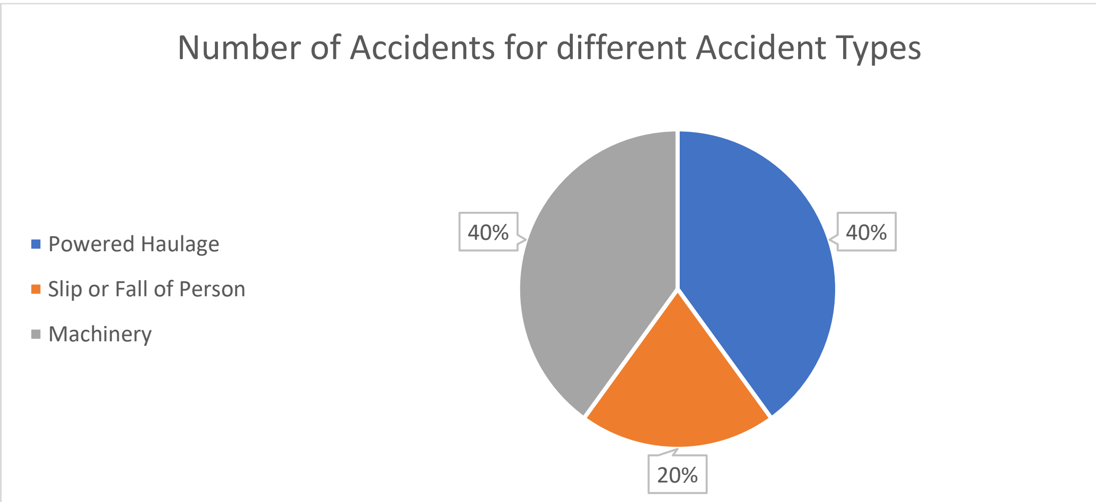


Figure 4.2.2.4 Pi chart representation of number of accidents for different types of accidents in Australia in 2010

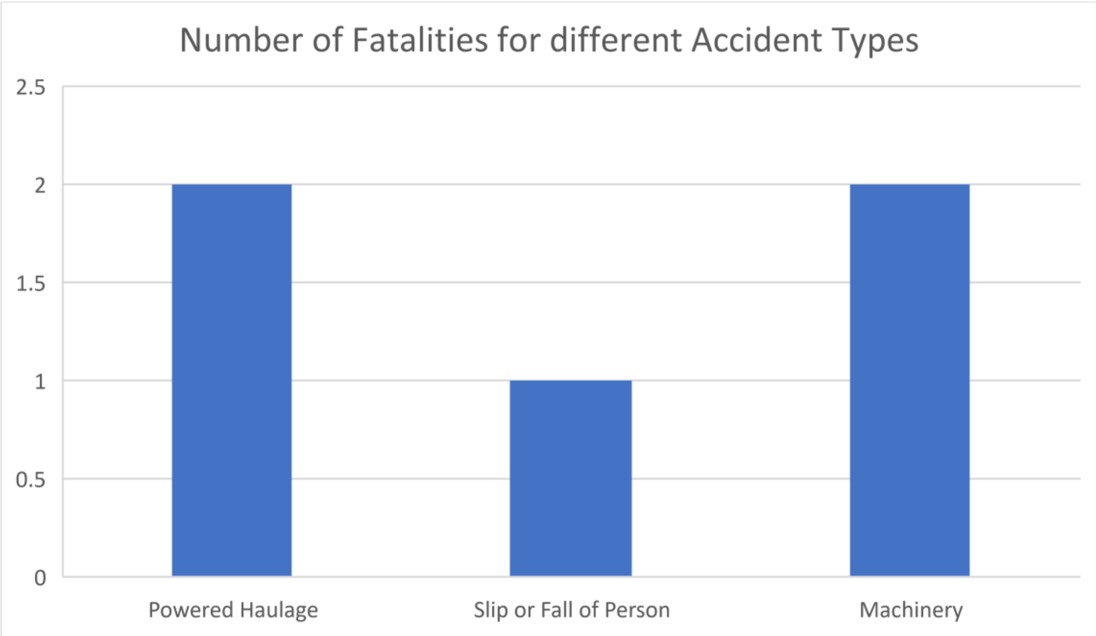


Figure 4.2.2.5 Number of fatalities for different accident types in Australia in 2010

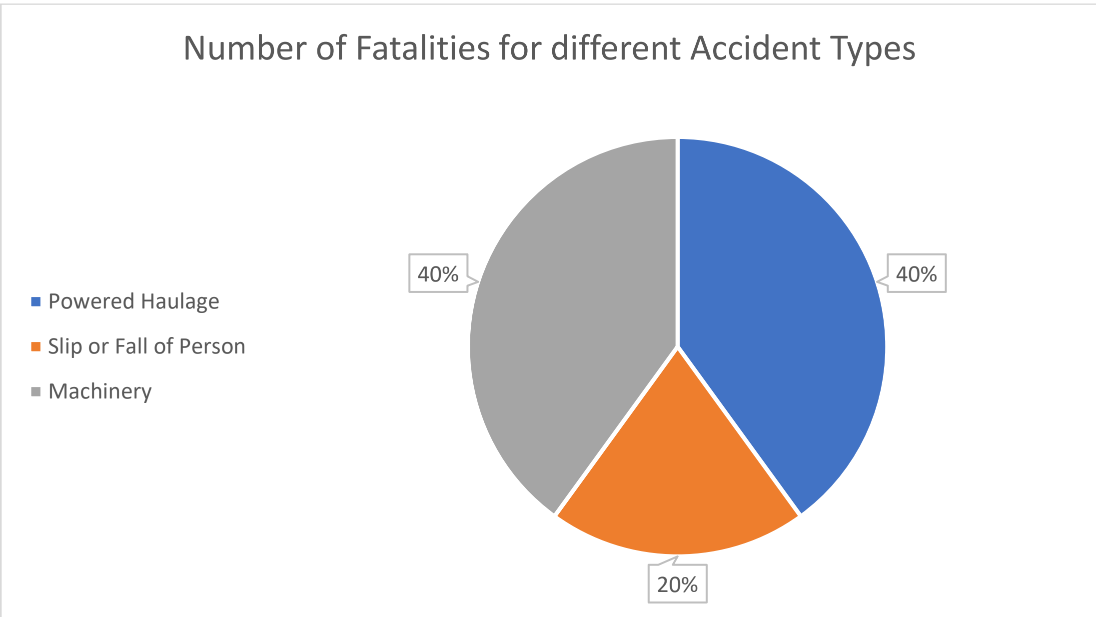


Figure 4.2.2.6 Pi chart representation of number of fatalities for different accident types in Australia in 2010

For Australia, 60% of accidents occur in non-coal mines which represents 3 accidents with the same percentage for the number of fatalities that also represents 3 fatalities as *Table 4.2.2.1* and *Figures 4.2.2.1 and 4.2.2.2* show.
On the other hand, Table 4.2.2.2 and Figures 4.2.2.3 and 4.2.2.4 show that the most type of accidents occurred were both machinery and powered haulage with 40% each that represents 2 accidents each, followed by slip or fall of person with 20% representing 1 accidents. The same results were for the number of fatalities as shown in *Figures 4.2.2.5 and 4.2.2.6.*

4.2.3 CHINA

For China the results are shown in *Tables 4.2.3.1 and 4.2.3.2* and *Figures 4.2.3.1, 4.2.3.2, 4.2.3.3, 4.2.3.4, 4.2.3.5 and 4.2.3.6*

CHINA	Number of Accidents	Number of Fatalities
Coal	31	311
Non-Coal	7	38
Unknown	3	14
TOTAL	41	363

Table 4.2.3.1 Number of accidents and fatalities in coal and non-coal mines in China in Jan-Feb-March 2010

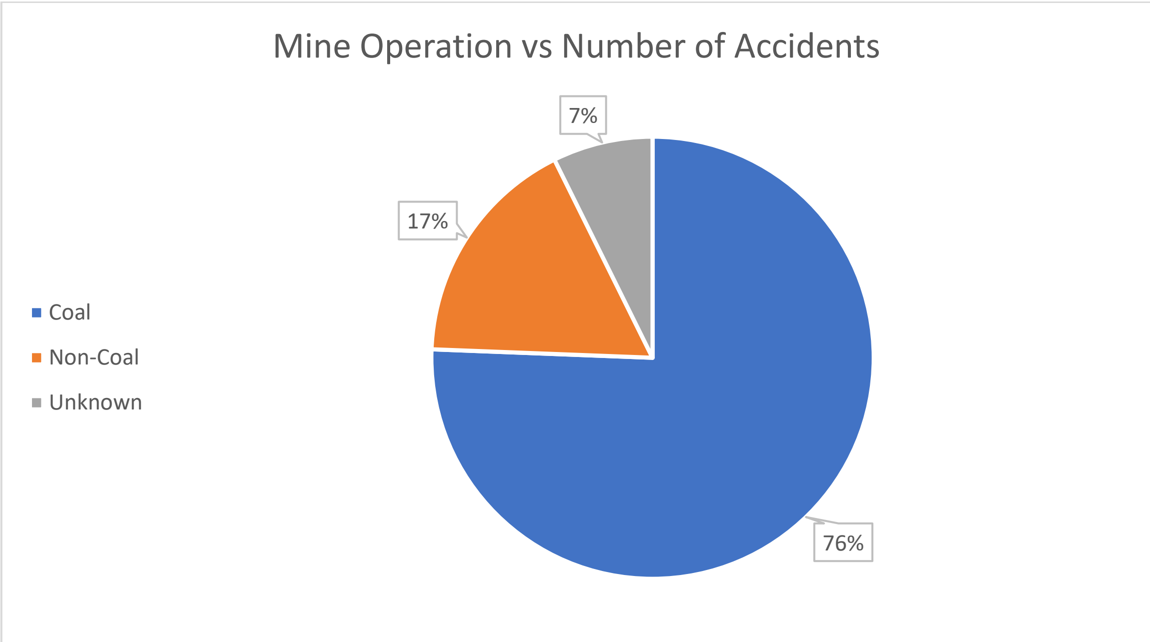


Figure 4.2.3.1 Pi chart representation of number of accidents in coal and non-coal mines in China in Jan-Feb-March 2010

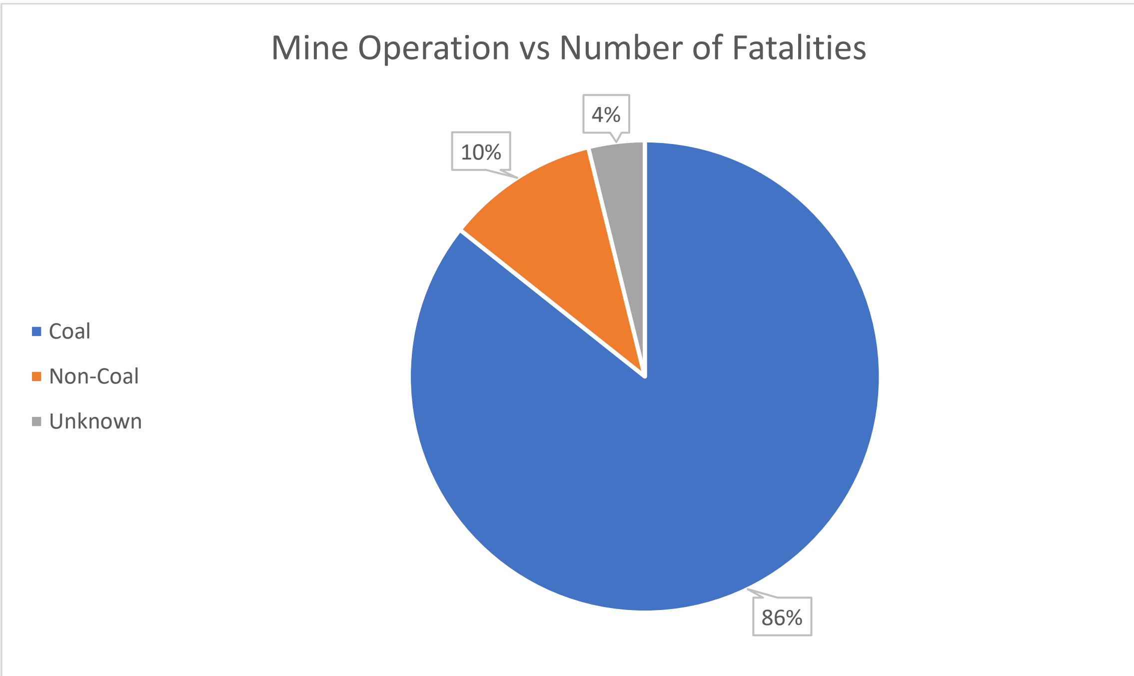


Figure 4.2.3.2 Pi chart representation of number of fatalities in coal and non-coal mines in Jan-Feb-Match 2010

CHINA	Number of Accidents	Number of Fatalities
Fire	3	71
Gas Suffocation	10	49
Gas Explosion	14	123
Flooding	5	92
Roof Fall	3	9
Gas Leakage	2	6
Other	4	13
TOTAL	41	363

Table 4.2.3.2 Number of accidents and fatalities for different types of accidents in China in Jan-Feb-March 2010

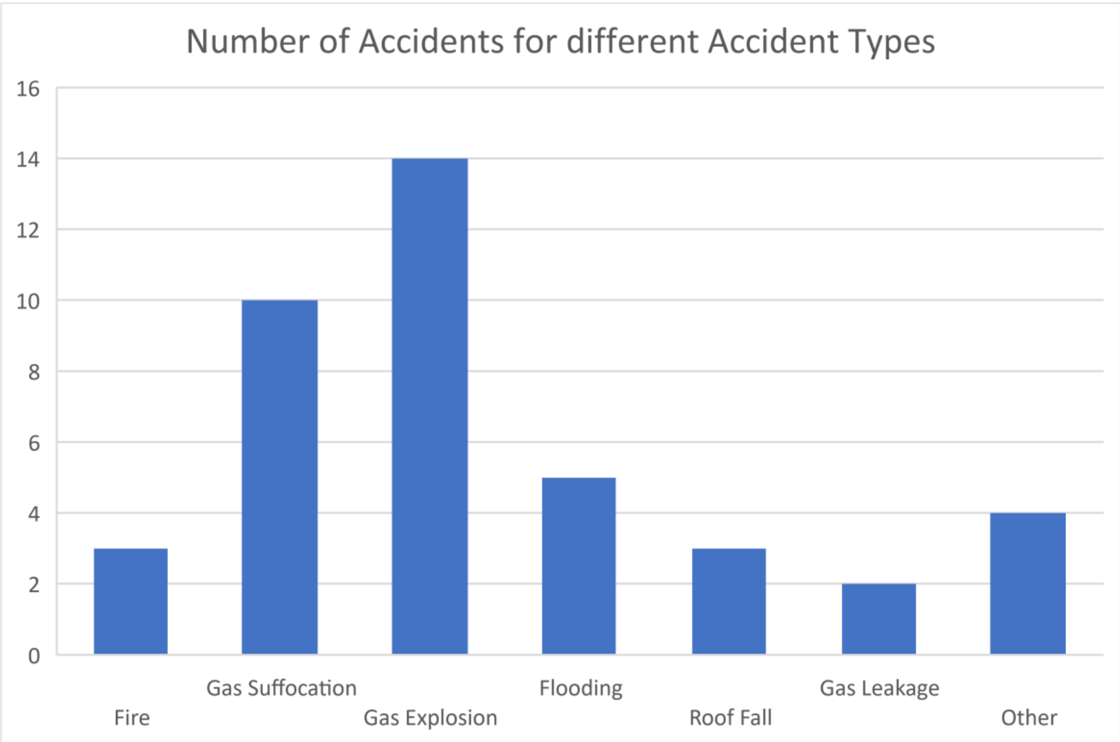


Figure 4.2.3.3 Number of accidents for different types of accidents in China in Jan-Feb-March 2010

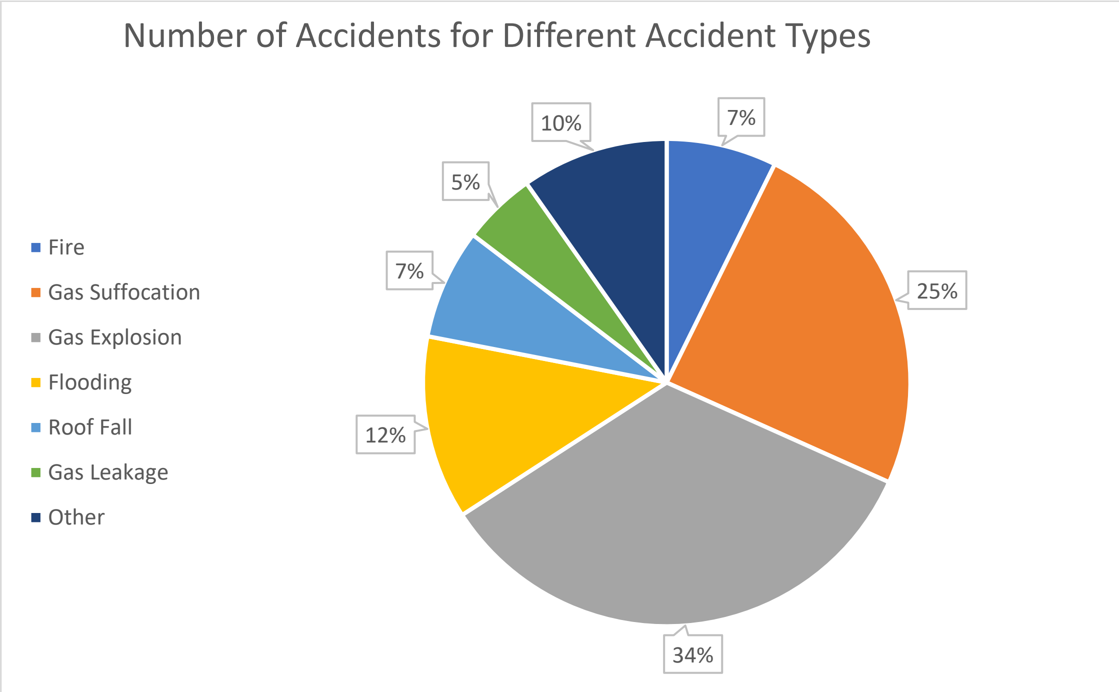


Figure 4.2.3.4 Pi chart representation of Number of accidents for different types of accidents in China in Jan-Feb-March 2010

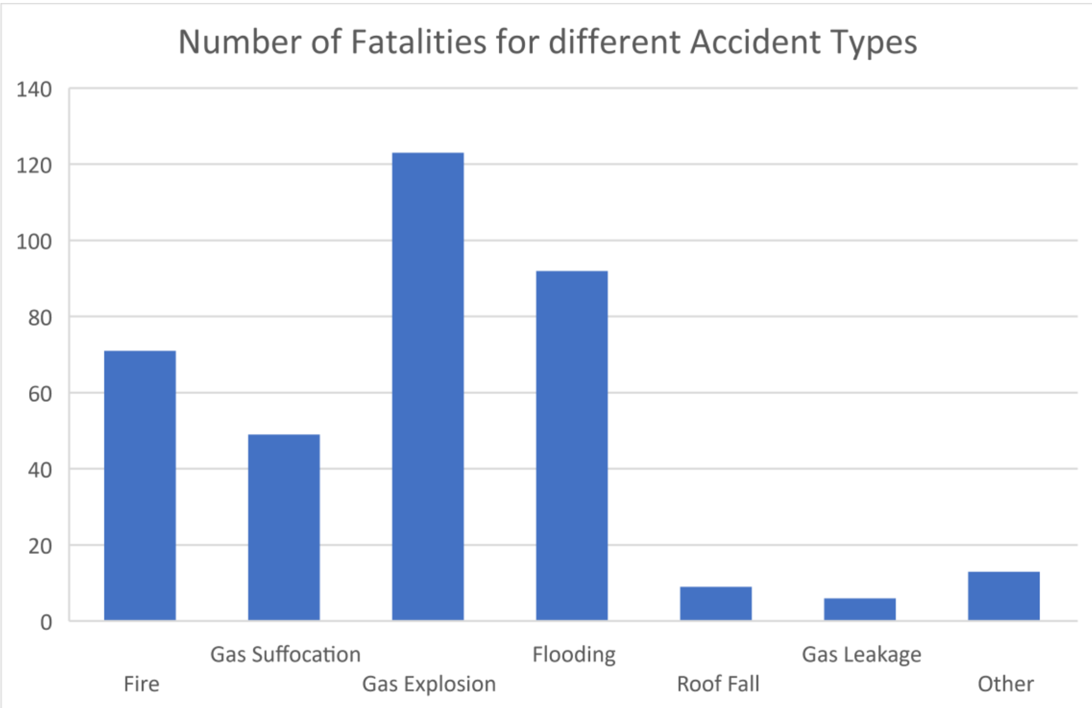


Figure 4.2.3.5 Number of fatalities for different types of accidents in China in Jan-Feb-March 2010

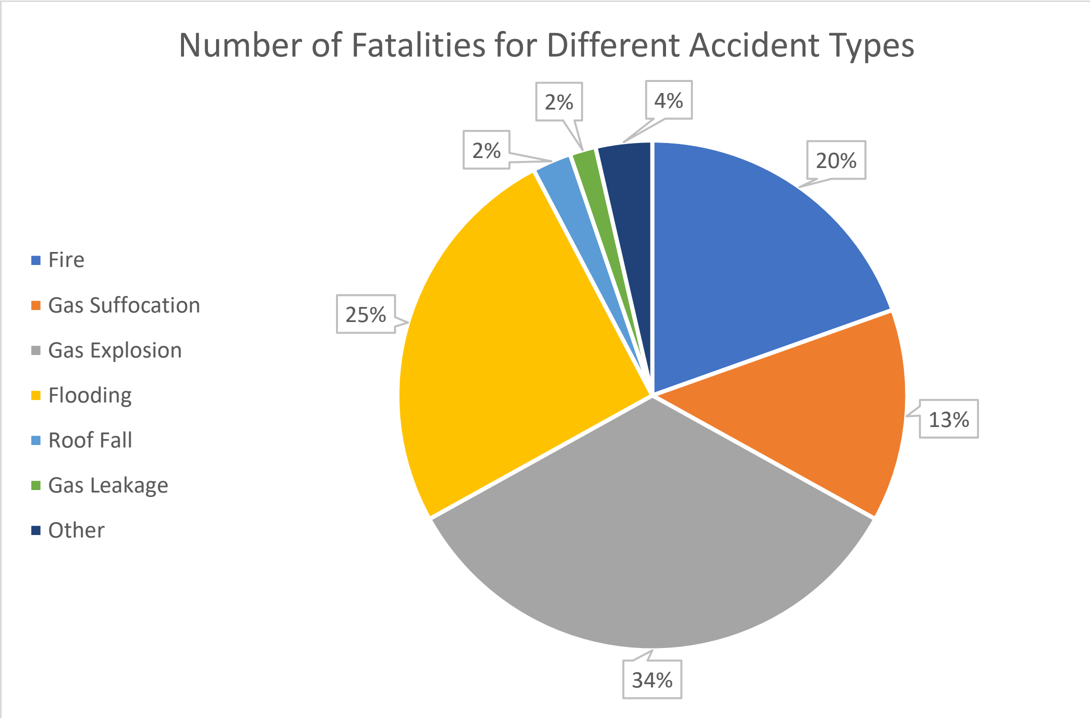


Figure 4.2.3.6 Pi chart representation of number of fatalities for different types of accidents in China in Jan-Feb-March 2010

For China, as *Table 4.2.3.1* and *Figure 4.2.3.1* show, 76% of the accidents occurred in the first 3 months were in coal mines which represents 31 accidents and 17% were in non-coal mines that represents 7 accidents. Regarding the fatalities, 86% of the fatalities were in the coal mines corresponding to 311 fatalities, and 10% that represents 38 fatalities were in the non-coal mines as *Table 4.2.3.1* and *Figure 4.2.3.2* show. Gas explosion was the cause of 14 accidents (34% of the total accidents) followed by gas suffocation with 10 accidents (25% of the total accidents) while they have 34% and 13% of the number of fatalities respectively (123 and 92 fatalities respectively). Instead, flooding and fire accidents show larger number of fatalities of that of gas suffocation which represents 25% and 20% respectively (92 and 71 fatalities respectively) as shown in *Table 4.2.3.2* and *Figures 4.2.3.3 and 4.2.3.4* and *Figure 4.2.3.5 and 4.2.3.6* respectively.

Now, considering the total number of accidents for China in year 2010, a factor of 4 should be multiplied by both the number of accidents and number of fatalities.

Country	Number of Accidents	Number of Fatalities
United States	41	69
Australia	5	5
China	164	1452

Table 4.2.4 Number of accidents and fatalities in United States, Australia and China in the whole year of 2010

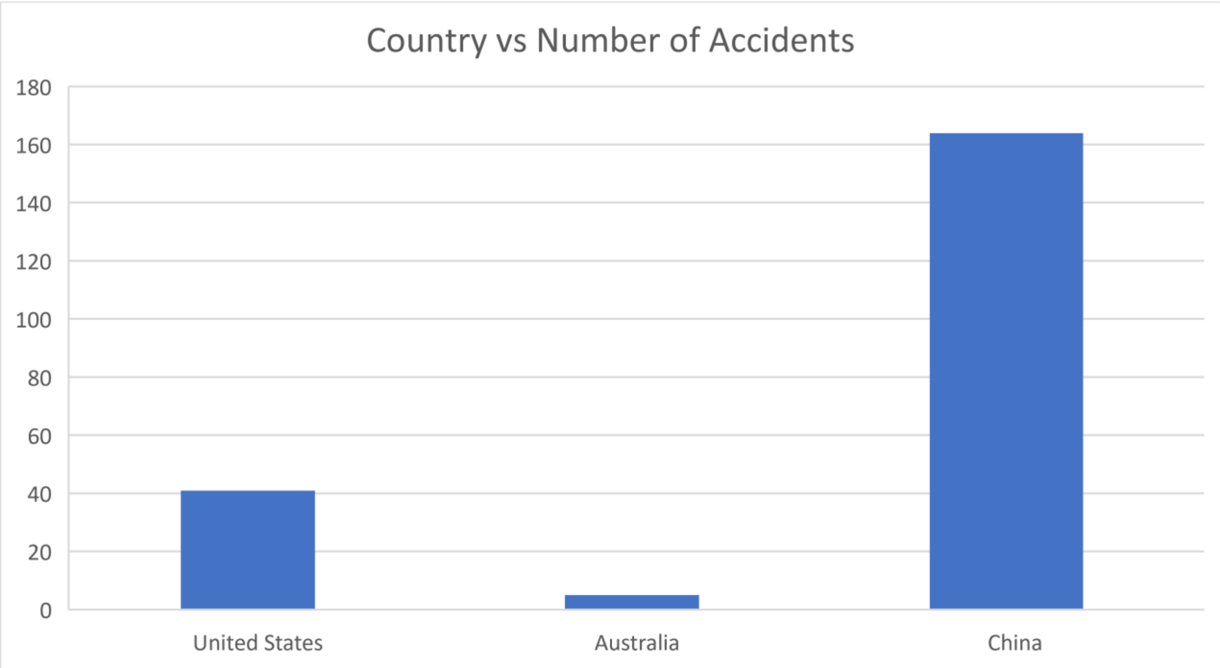


Figure 4.2.4 Number of accidents in United States, Australia and China for the whole year of 2010

Figure 4.2.4 shows the number of accidents for each of United States, Australia and China in 2010. It reflects the wide range of number of accidents in that year. China reached about 164 accidents in year 2010 while United States had only 41 accidents. Instead, Australia had only 5 accidents.

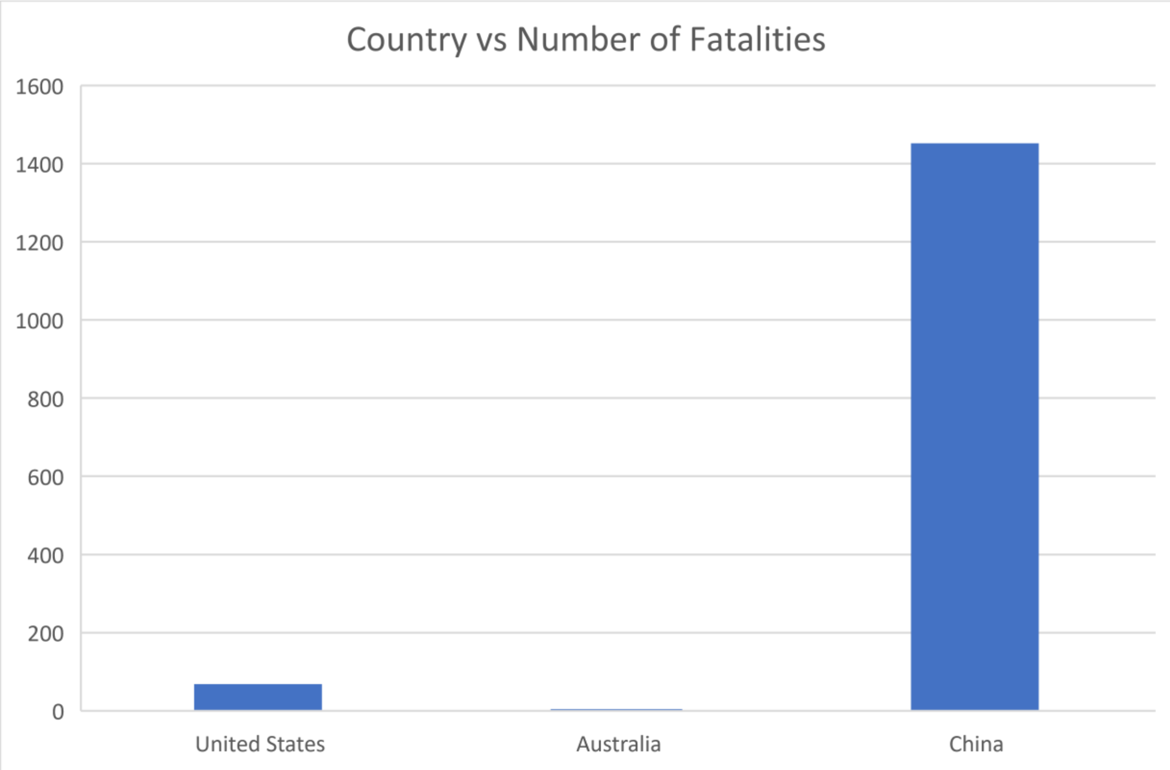


Figure 4.2.5 Number of fatalities in United States, Australia and China in the whole year of 2010

Figure 4.2.5 shows the number of fatalities for each of United States, Australia and China in 2010. It indicates the huge number of fatalities in China that reached more than 1,400 fatalities. However, in United States, the fatalities reached 69 while Australia had only 5 fatalities as 1 fatality for each accident.

CHAPTER FIVE: RESULTS AND LESSONS LEARNED

5.1 TAXONOMY

It can be seen from Figures 4.1.1 and 4.1.2 and Figures 4.1.3 and 4.1.4 that underground mines account for the largest number of accidents (about 66% of all the accidents) and the largest number of fatalities (about 56% of all the fatalities) respectively. This reflects the seriousness and the dangerous environment that underground mines have in general. While for the surface mines the number of accidents is 23 which represents 30% of the total accidents involved in this study and the number of fatalities is 1153 which accounts for 33% of the total fatalities.

For the whole study, the total number of accidents and fatalities of coal mines is the largest with approximately 70% and 67% respectively while for non-coal mines it occupies 30% and 33% respectively as Figures 4.1.5 and 4.1.6 and Figures 4.1.7 and 4.1.8 show respectively.

Among the underground mines and as Figures 4.1.9 and 4.1.10 show that non-coal mines occupy 88% of the underground mine accidents and about 97% of the underground mine fatalities.

Among the non-coal mines, the largest number of accidents is for gold mines with 35% followed by copper-gold mines with 18%, while the largest number of fatalities is for iron mines with 47% and then for gold mines with 17% as shown in Table 4.1.4 and Figures 4.1.11 and 4.1.12 and Figures 4.1.13 and 4.1.14 respectively.

It can be seen from Figures 4.1.15 and 4.1.16 that the most frequent accident type is the gas and coal dust explosion by 37% followed by mine collapse and flooding (inundation) with 18% and 12% respectively. Concerning the number of fatalities, Figures 4.1.17 and 4.1.18 show that also gas/ coal dust explosion has the largest number of fatalities with 47% followed also by mine collapse and flooding with 14% and 12% respectively.

For the case of coal mines only, gas and coal dust explosion have the largest number of accidents with 53% followed by flooding (inundation) with 15%. The largest number of fatalities in the coal mines is for the gas and coal dust explosion with 70% followed by flooding

(inundation) with 17% as Figures 4.1.19 and 4.1.20 and Figures 4.1.21 and 4.1.22 show respectively.
While for non-coal mines, mine collapse has the highest frequency of accidents with 44% while other types of accidents have 26% of accidents with the largest number of fatalities with 44% followed by mine collapse with 35% as shown in Figures 4.1.23 and 4.1.24 and Figures 4.1.25 and 4.1.26.

From the above listed results, one can deduce that the underground coal mines are the most hazardous places to work in due to the presence of methane gases and coal dusts which are harmful in general and any lapse in doing any task can lead to huge accidents. The consequences for the accidents involved in the taxonomy are not related only to operators, but there are many accidents that have bad consequences on the assets and environment especially the gas and coal dust explosions due to high level of toxic gases that have negative impacts on the environment.

Having a look at the possible causes and initial causes for most of the accidents in the taxonomy in ANNEX 1, most of the causes of the gas / coal dust explosion are poor ventilation of the mines, gas leakage, illegal working in illegal mines especially in case of China mines, and breaching of the safety rules.

For the other accident types, some natural factors (work environment) caused the accident while for others unclear or unstated events caused those accidents.
In general, most of the accidents were due to management and personnel causes. Additionally, as the taxonomy shows, some types of accidents are the main cause of the main catastrophic accident occurred.

5.2 THE COMPARISON

For United States, the non-coal mines have the largest number of accidents in 2010 with 54% while coal mines have 46% as Figure 4.2.1.1 shows. But focusing on the number of fatalities, Figure 4.2.1.2 shows that the coal mine have the largest number with 68%.
In that year, powered haulage occurred the most with 39% followed by falling of material with

15% while the gas and coal dust explosion has 5% as shown in Figures 4.2.1.3 and 4.2.1.4. But for the number of fatalities, gas and coal dust explosion has the most with 44% followed by powered haulage with 23%.

For Australia, 60% of accidents occur in non-coal mines with the same percentage for the number of fatalities as Figures 4.2.2.1 and 4.2.2.2 show. Figures 4.2.2.3 and 4.2.2.4 show that the most type of accidents occurred were both machinery and powered haulage with 40% each followed by slip or fall of person with 20%. The same results were for the number of fatalities as shown in Figures 4.2.2.5 and 4.2.2.6.

For China, as Figure 4.2.3.1 shows, 76% of the accidents occurred in the first 3 months were in coal mines and 17% were in coal mines. 86% of the fatalities were in the coal mines and 10% in the non-coal mines as Figure 4.2.3.2 shows.

Gas explosion was the cause of 34% of the accidents followed by gas suffocation with 25% while they have 34% and 13% of the number of fatalities respectively as shown in Figures 4.2.3.3 and 4.2.3.4 and Figure 4.2.3.5 and 4.2.3.6 respectively.

These results show that Australia has the safest mining environment with only three accidents in 2010. While for the case of United States, 41 accidents occurred in 2010 the same number of accidents that China had in only the first three months of the year 2010 (Jan-Feb-March). This reflects the worse safety environment of China especially in the coal mining industry where most of the accidents occurred due to human errors and organisational and supervisory levels.

USA is considered as one of the safest countries of the world to work in [33].

The results for Australia are confirmed with "*From 2003, Australia has almost realized zero fatality*" [34].

China's safety record is far worse than that of other nations, this is partly because China has the world's large mining industry which has many workers, which inevitably makes the accident numbers look high. A Chinese miner is 100 times more likely to die in an accident than a miner in United States. So, the huge number of workers in the Chinese mining industry reflect the large number of accidents and thus fatalities. [35]

For the reason to decrease mining accidents and fatalities, China will shut down 6000 non-coal mines in 2020. Beijing will seek to reduce major accidents by 15% by 2020 from 2015 levels in which more than 500 workers died in 2015 in non-coal mining accidents. The toll has fallen by more than 50% since 2010. Under the plan, China will improve safety legislation and intensify mine inspections. Authorities say there were some 37,000 illegal non-coal mines in 2015. [36]

A reason why Australia's mines are relatively safe is that they are mostly surface mines (open cast). Underground mines tend to be more dangerous that operations in surface mines. [35]

Measuring safety using the FIFR (number of fatal injuries per one million hours worked), it showed an average value for Australia for the ten-year period 1997-1998 to 2006-2007 equals to 0.07. Compared internationally to United States of America which recorded a rate around 0.17 for this period. [5]

5.3 HOW TO IMPROVE SAFETY?

All these data, statistics and causes have the same big problem which is safety in mines. Although safety is in a good situation nowadays, but a lot of accidents are still occurring. The main solution is to improve safety more and more so it could be the number one concern for every mining industry around the world and it should be.

Safety improvement can be achieved in different ways. Here are some tips on how to improve safety in order to reduce mining accidents.

First important aspect is to let everyone know the importance of safety and its benefits to them [34]. Another important point is not to ignore the danger. Every single worker in the mine should be careful every moment on the job because working in mining is hazardous and mining industry is full of dangers and risks [37]. Each worker has a personal responsibility for the safety and health of himself and the others, for this reason improvement of safety consciousness of workers is important to let them know what the possible hazards are [34]. In addition, professional training about safety procedure is essential for all workers, not only the new members. Regular safety sessions should be done with theoretical and practical parts which strength workers' skills, awareness, knowledge and judgement [38]. Another important point is to guide workers and to force them to obey the safety rules [34], to wear the safety equipment from helmets to safety glasses and gloves and never allow them to breach the safety rules [37].

Providing clear safety procedures can help a lot to reduce accidents. A description of the different incidents that might occur and how to handle it and what needs to be done and whom to contact, etc... should be provided [37].

For the purpose to improve safety underground, automation can help in this. Trying to eliminate human errors can give, in most cases, a safer working environment. Automation can do this by inserting remote and wireless remote devices and equipment to the mines, keep individuals in safe positions, out of dangerous and hazardous environment, while they can check equipment remotely [39].

It is important also to detect every hazard and report it because even if something was normal today this doesn't mean it will not cause a hazard then. Investigation of every incident whether it was a near miss or an accident that caused deaths and injuries has its great role in safety improvement. It can help in finding the root cause and to correct it. Knowing the cause and reporting it is not the only main point, learning lessons is much more important [38]. Previous mining accidents are the key to avoid these accidents to reoccur in the future and to eliminate similar possible hazards.

Another key factor to improve safety in mines is to manage the risk. Risk management can play a big rule to significantly reduce accidents. It should be done regularly as new equipment or machines are introduced in the mine or new procedures methods are activated. Risk assessment is essential for developing risk management plans, and thus they should be closely linked.

What is Risk Assessment? What are the steps involved in Risk Assessment? What is Risk Analysis? What is Acceptable Risk? What are the Methodologies for Risk Analysis? What are the Risk Assessment Procedures?

CHAPTER SIX: RISK ASSESSMENT

Risk assessment is the overall process of assessing and evaluating risks that can affect worker's health and safety and may cause harm to them resulting from workplace hazards. A risk is the likelihood that harm (injury, illness, death, etc…) may occur due to the exposure of hazards. A hazard is any situation, process, condition that has the potential to cause harm [40].

Risk assessment is very important to create awareness of risks and hazards and to prevent injuries and illnesses. It is considered as an integral part of an occupational health and safety management plan as it helps to identify who may at risk and if the existing control program is adequate for a hazard or another control program needed [41].

6.1 RISK ASSESSMENT PROCEDURE

Risk assessment can be implemented in the following procedure as shown in *Figure 6.1.1*

Figure 6.1.1 Risk Assessment Procedure [42]

Step 1: Identify Hazards

The purpose of this step is to identify all possible hazardous conditions that have the potential to cause harm. These conditions can be found in three different areas: physical work environment activities, work tasks and their procedures and equipment, materials or substances used.

Step 2: Assess Risks

Risk assessment involves the process of determining the likelihood that people exposed to a hazard in the workplace and considering the possible results. It helps in determining the severity of the hazard, whether the existing control measures are effective and what possible mitigation measures should be implemented and when.

Step 3: Risk Control

Risk control is the process used to identify, develop and implement all workable measures responsible for eliminating, or reducing the likelihood of hazards and their resulting injuries, illness or diseases.

Step 4: Implementation and Review Control Measures

After the identification of hazards and assessing them, the implementation of the risk control measure is the next step. All the hazards that have been assessed should be prioritised in one or more of the following hierarchy of controls:

1- Elimination of hazards

2- Substitute something safer

3- Isolate the hazard

4- Use engineering controls

5- Use administrative actions such as safe work procedure

6- Protect the workers by training and using the Personal Protective Equipment

HIERARCHY OF CONTROLS Start at the top and work down	
Most Effective Control	**Elimination** E.g. Discontinue use of product, equipment, cease work process
	Substitution E.g. Replace with a similar item that does the same job but with a lower hazard level
	Isolation E.g. Put a barrier between the person and the hazard
	Engineering controls E.g. Change the process, equipment or tools so the risk is reduced
	Administration controls E.g. Guidelines, procedures, rosters, training etc to minimise the risk
Least Effective Control	**Personal protective equipment** E.g. Equipment worn to provide a temporary barrier

Figure 6.1.2 Hierarchy of Controls [43]

6.2 WHAT IS RISK ANALYSIS?

Risk analysis is the step following the risk identification and classification. It consists of examining the possibility and the consequences of each risk factor in order to find the level of risk. The purpose of this analysis is to determine the most potential risk factors that have the greatest impact [44].

6.2.1 RISK ANALYSIS METHODS

There are three methods used to determine the level of risk.

1- Qualitative Method:

Qualitative method is the most used method in risk analysis. It defines risk by significant levels using the risk matrix based on the probability and the consequence of the risk [45].

R=P*D

where P is the likelihood of occurrence,

and D is the hazard severity

Score	Descriptor	Likelihood of Occurrence (P)
1	Very unlikely to occur	Will only occur in exceptional circumstances
2	Unlikely to occur	Unlikely to occur but the potential exists
3	Could occur	Reasonable chance of occurring – has happened before on occasions
4	Likely to occur	Likely to occur – strong possibility
5	Almost certain to occur	The event is expected to occur in most circumstances

Table 6.2.1.1 Likelihood of occurrence [46]

Descriptor/Grade	Hazard Severity (D)
Negligible (1)	Negligible impact on strategic objectives
Low (2)	Small variance from overall strategic objective
	First aid treatment with full recovery
Moderate (3)	Notable variance from overall strategic objective
	Medical treatment required up to 3 months to recover
Major (4)	Significant variance from overall strategic objective
	Long term illness or injury (up to one year)
Extreme/ Catastrophic (5)	Failure to meet strategic objective threatens independent functioning or stability of the Trust

Table 6.2.1.2 Hazard Severity Rankings [46]

Likelihood of Occurrence	Almost certain to occur	5	5	10	15	20	25
	Likely to occur	4	4	8	12	16	20
	Could occur	3	3	6	9	12	15
	Unlikely to occur	2	2	4	6	8	10
	Very unlikely to occur	1	1	2	3	4	5
Risk Matrix			1	2	3	4	5
			Negligible	Low	Moderate	Major	Extreme/ Catastrophic
			Hazard Severity				

Table 6.2.1.3 Risk Score Matrix [46]

2- Semi-Qualitative Method:

Semi-quantitative method uses numerical rating scales for consequence and probability and merge them to produce a level of risk using a formula. Scales used may be linear or logarithmic or may have some other relationship [45].

3- Quantitative Method:

Quantitative method is used to determine the probability of the accident with a practical value and the consequences in terms of equivalent costs [45]. It is increasingly applied in the mining industry because of business requirements to support financial decisions [6].

6.3 RISK ASSESSMENT METHODS

1- Hazard and Operability Analysis (HAZOP)

HAZOP is a systematic and structured examination of a process, procedure or system. It is a qualitative technique used determine based on guide words, how the operating conditions might not be accomplished at each step in the design, process or system [45].

2- Failure Modes and Effect Analysis (FMEA) and Failure Modes and Effect and Criticality Analysis (FMECA)

FMEA is a systematic method used to identify the ways in which components can fail to achieve their design purpose and their consequences. It involves the listing of all the components in the system, their failure modes or mechanisms and then the effects of these failure modes on the system. In addition, it identifies how is it possible to avoid the failure and to mitigate their effects [45].

While FMECA consists of two separate investigations, FMEA and Criticality Analysis (CA) with FMEA completed prior to CA. It will provide each fault mode with a rank according to its importance or criticality. The Criticality Analysis allows the analysts to identify reliability and severity related concerns with components [45].

3- Fault Tree Analysis (FTA)

Fault tree analysis is a technique used for identifying and describing the combinations of failures that can contribute to a specific undesired event called "top event" [45]. It is a top-down analysis represented in a tree diagram with several causal factors and contributing elements that would lead to the undesirable top event [6].

The conditions identified in the tree can be events that are related to component hardware failures, human errors, etc… It can be used qualitatively to determine the potential causes and their pathways to the top event or quantitatively to calculate the probability of the top event, provided the probabilities of causal events [45].

The main steps for a fault tree analysis can be summarized in the figure below.

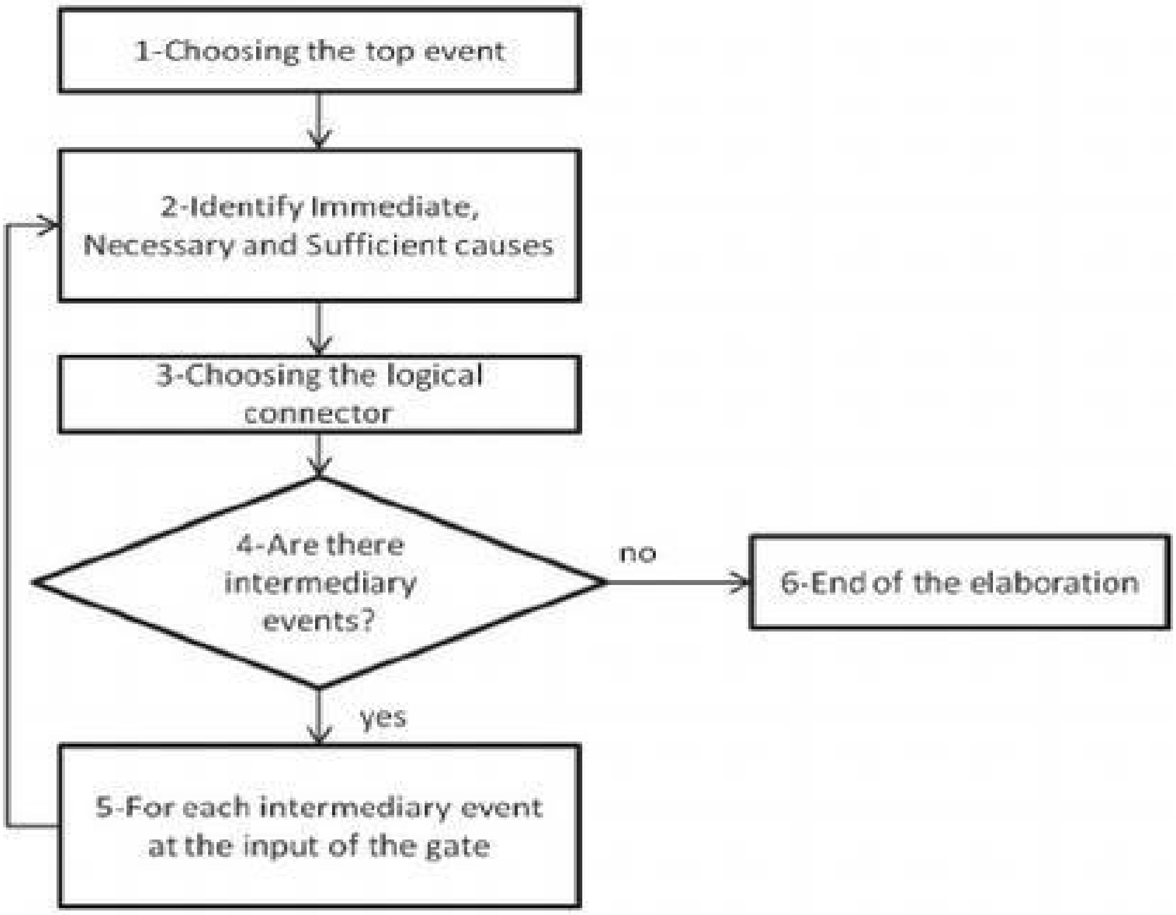


Figure 6.3.1 Fault tree analysis steps [47]

4- Event Tree Analysis (ETA)

Event tree analysis is a forward, logical graphical model that represents the mutually exclusive sequences of events functioning / not functioning based on an initiating event capable of producing a consequence. It is used to analyse the effects of functioning or failed systems given that an event has occurred. It can be used at any stage in the lifecycle of a process. Event tree analysis can be applied both qualitatively and quantitatively [45].

The figure below shows the steps followed in the event tree analysis:

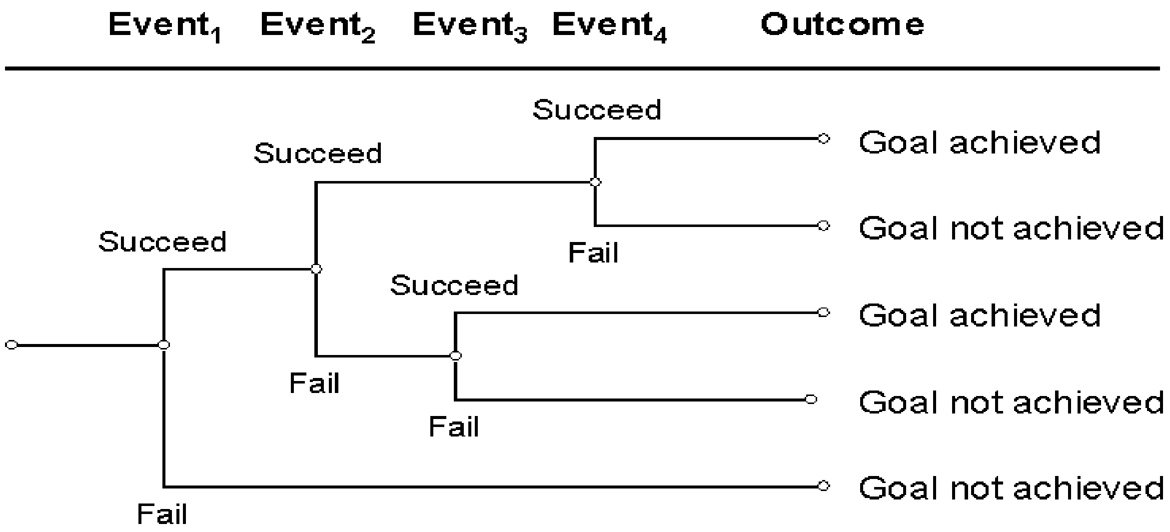


Figure 6.3.2 Event tree analysis steps [48]

CHAPTER SEVEN: CONCLUSION

Based on the results obtained in this study we can find that mining accidents and fatalities are still occurring regularly even with much improved safety systems. The number of catastrophic events shown in this database should remind that the danger of major accidents in the mining industry does not decrease just because it has not happened for some time. A great effort is needed in this area and this is the primary reason for regulating and managing bodies in the prevention of disastrous accidents.

Understanding how and why accidents occur and how to prevent their recurrence is a paramount part of improving safety in the mining industry. Accident analysis is performed for the goal to find the possible cause or causes and the initial causes that give rise to the accident so as trying to prevent similar kind of events to occur further. It is a part of the accident investigation.

Underground coal mining appears to be the most hazardous working area in the mining industry. Specifically, gas ignition and gas and coal dust explosions in coal mines are the most frequent mining accidents that can occur. They are also considered as the most catastrophic accidents in terms of lives lost. Other different types of accidents that make the coal mining industry dangerous are gas suffocation and outbursts. The safety of coal mines is associated with many factors, it is mainly connected with the action of workers, the management of the leaders and the production condition of the coal mine. Focusing on coal mining accidents should not overlooked other mining accidents that may have the same level of damage.

Various causes can act to lead to the catastrophic accidents. These can include possible natural conditions, human errors and managerial lapses and errors. A great effort should be paid in order to eliminate these errors and thus improve safety. Learning lessons from previous accidents and performing risk management are the most important approaches to the safety improvement.

To sum up, mine managers should wake up, know their situation, make great efforts and attain their aim-guaranteeing the mine workers' safety where safety is considered as a cheapest industry as the Chairman of Easy Groups say: "If you think safety is expensive, try an accident".

BIBLIOGRAPHY

[1] Elgstrand, K., Vingård, E., Kaj Elgstrand, E., Vingård Arbete och Hälsa, E., Albin, M., Lotta Dellve, L., … Gerd Sällsten, L. (2013). Occupational Safety and Health in Mining - Anthology on the situation in 16 mining countries. In Arbete och hälsa (Vol. 47). Retrieved from http://www.amm.se/aoh

[2] Wei, L., Zhang, Y., Zhao, Z., Zhong, X., Liu, S., Mao, Y., & Li, J. (2018). Analysis of mining waste dump site stability based on multiple remote sensing technologies. Remote Sensing, 10(12), 3–18. https://doi.org/10.3390/rs10122025

[3] Standards Australia. (1986). Australian Standard AS1470 - 1986: Health and Safety at Work: Principles and Practices.

[4] Corporate Social Responsibility of Coal India Limited: Chapter 5, Safety in Mining

[5] Duncan, N. J. (1985). Mine Safety. CIM Special Volume, 31, 314–315.

[6] Paithankar, A. (2011). Hazard Identification and Risk Analysis in Mining Industry.

[7] Accident_analysis @ en.wikipedia.org. (n.d.). Retrieved from https://en.wikipedia.org/wiki/Accident_analysis

[8] Abbasi, S. (2018). Defining Safety Hazards & Risks in Mining Industry: A Case-Study in United States. Asian Journal of Applied Science and Technology (AJAST) (Open Access Quarterly International Journal, 2(2), 1071–1078. Retrieved from www.ajast.net

[9] Wagenaar, W. A., & Van Der Schrier, J. (1997). Accident analysis. The goal, and how to get there. Safety Science, 26(1–2), 25–33. https://doi.org/10.1016/S0925-7535(97)00026-X

[10] Wienen, H. C. A., Bukhsh, F. A., Vriezekolk, E., & Wieringa, R. J. (2017). Accident analysis methods and models – a systematic review. (Tech
nical Report No. TR-CTIT-17-04). 57. Retrieved from http://files/3406/Hans Christian Augustijn Wienen et al. - 2018 - Accident Analysis Methods and Models – a Systemati.pdf%0Ahttp://idl.iscram.org/files/hanschristianaugustijnwienen/2018/1565_HansChristianAugustijnWienen_etal2018.pdf

[11] Fu G, Zhang JS, Xu SR. Critical examination of safety science. Eng Sci. 2004;6(8):12–6 (in Chinese).

[12] HSE. (2004). Investigating accidents and incidents. Health and Safety Executive, 1–89. Retrieved from http://www.hse.gov.uk/pubns/priced/hsg245.pdf

[13] New International Standard to Reduce Mining Accidents ref2242 @ www.iso.org. (n.d.). Retrieved from https://www.iso.org/news/ref2242.html
[14] Industry, Q. M. (2011). Queensland mining industry. (August).
[15] Safety, M. (2000). MSHA HANDBOOK SERIES Accident / Illness Investigations Procedures. Safety And Health, (November).
[16] index @ www.safeminers.com. (n.d.). Retrieved from http://www.safeminers.com
[17] Mining Feature: Coal Mine Explosion Prevention coalmineexplosion @ www.cdc.gov. (n.d.). Retrieved from https://www.cdc.gov/niosh/mining/features/coalmineexplosion.html
[18] Approach, M. A. C. (2018). Study of the Hazard of Endogenous Fires in Coal. https://doi.org/10.3390/en11113047
[19] Mining Feature: Inundations Can Put Miners at Risk by Blocking Escape Routes inundation @ www.cdc.gov. (n.d.). Retrieved from https://www.cdc.gov/niosh/mining/features/inundation.html
[20] Bajpayee, T. S., Bhatt, S. K., Rehak, T. R., Mowrey, G. L., & Ingram, D. K. (2003). Fatal accidents due to flyrock and lack of blast area security and working practices in mining. Journal of Mines, Metals and Fuels, 51(11–12), 344–349.
[21] Safety in Rock Engineering, Zong-Xian Zhang, in Rock Fracture and Blasting, 2016
[22] mine-accidents-causes-prevention-and-control @ www.slideshare.net. (n.d.). Retrieved from https://www.slideshare.net/rathinmining/mine-accidents-causes-prevention-and-control
[23] Ilmarinen, J. E. (2001). Aging workers. Occupational and Environmental Medicine, 58(8), 546–552. https://doi.org/10.1136/oem.58.8.546
[24] worst-mining-disasters-in-human-history @ www.worldatlas.com. (n.d.). Retrieved from https://www.worldatlas.com/articles/worst-mining-disasters-in-human-history.html
[25] Health and Safety Executive. (2017). Accident Aetiology Lecture Notes. 1–19.
[26] aviation:accident-causation-model @ aviationknowledge.wikidot.com. (n.d.). Retrieved from http://aviationknowledge.wikidot.com/aviation:accident-causation-model
[27] Perneger, T. V. (2005). The Swiss cheese model of safety incidents: Are there holes in the metaphor? BMC Health Services Research, 5, 1–7. https://doi.org/10.1186/1472-6963-5-71
[28] swiss-cheese-model @ yourrootinfo.blogspot.com. (n.d.). Retrieved from http://yourrootinfo.blogspot.com/2017/11/swiss-cheese-model.html
[29] The Domino Theory c68e58fc6f47aa0ff2ac6fc8d3cbb8215821298e @ www.hrdp-

idrm.in. (n.d.). Retrieved from http://www.hrdp-idrm.in/e5783/e17327/e24075/e27357
[30] Incident Investigation investig @ www.ccohs.ca. (n.d.). Retrieved from https://www.ccohs.ca/oshanswers/hsprograms/investig.html
[31] HSE. (2004). Investigating accidents and incidents. Health and Safety Executive, 1–89. Retrieved from http://www.hse.gov.uk/pubns/priced/hsg245.pdf
[32] Root Cause Analysis root-cause-analysis @ des.wa.gov. (n.d.). Retrieved from https://des.wa.gov/services/risk-management/about-risk-management/enterprise-risk-management/root-cause-analysis
[33] Page, K. (2009). Blood on the coal: The effect of organizational size and differentiation on coal mine accidents. Journal of Safety Research, 40(2), 85–95. https://doi.org/10.1016/j.jsr.2008.12.007
[34] Wu, L., Jiang, Z., Cheng, W., Zuo, X., Lv, D., & Yao, Y. (2011). Major accident analysis and prevention of coal mines in China from the year of 1949 to 2009. Mining Science and Technology, 21(5), 693–699. https://doi.org/10.1016/j.mstc.2011.03.006
[35] business-11497070 @ www.bbc.com. (n.d.). Retrieved from https://www.bbc.com/news/business-11497070
[36] china-to-shut-6000-non-coal-mines-by-2020-to-improve-safety-idUSKCN1B607M @ www.reuters.com. (n.d.). Retrieved from https://www.reuters.com/article/us-china-mining-safety/china-to-shut-6000-non-coal-mines-by-2020-to-improve-safety-idUSKCN1B607M
[37] 7 Safety Tips to Reduce Mining Accidents mining-safety-tips @ www.reliableplant.com. (n.d.). Retrieved from https://www.reliableplant.com/Read/29927/mining-safety-tips
[38] Prevent Repeat Accidents at Mines prevent-repeat-accidents-at-mines @ www.miningsafety.co.za. (n.d.). Retrieved from https://www.miningsafety.co.za/dynamiccontent/81/prevent-repeat-accidents-at-mines
[39] Mine safety: Seven ways to make mines safer and more efficient mine-safety-seven-ways-make-mines-safer-efficient @ www.mining-technology.com. (n.d.). Retrieved from https://www.mining-technology.com/mining-safety/mine-safety-seven-ways-make-mines-safer-efficient
[40] What is a Risk Assessment? what-risk-assessment @ oiraproject.eu. (n.d.). Retrieved from https://oiraproject.eu/en/what-risk-assessment
[41] Risk Assessment risk_assessment @ www.ccohs.ca. (n.d.). Retrieved from https://www.ccohs.ca/oshanswers/hsprograms/risk_assessment.html

[42] Sydney, U. of W. (2011). Hazard Identification , Risk Assessment and Control Procedure. Hazard Identification , Risk Assessment and Control Procedure, 1–9.

[43] Resources, H. (2013). OH & S Procedure. 1–13.

[44] Analysis, R. (n.d.). 1 What is Risk Analysis ? 2 . Risk Analysis Methods 3 . The Monte Carlo Method 4 . Risk Model 5 . What steps must be taken for the development of a Risk Model ?

[45] Valis, D., & Koucky, M. (2009). Selected Overview of Risk Assessment Techniques. Problemy Eksploatacji, 19–32. Retrieved from http://www.process-improvement-institute.com/_downloads/Selection_of_Hazard_Evaluation_Techniques.pdf

[46] Portman, T. T. and. (2018). Conducting a Risk Assessment Procedure. (March 2015), 21.

[47] Lohne, H. P. (2017). Barrier definitions and risk assessment tools for geothermal wells. (November), 1–98.

[48] Silvianita, Redana, F., Rosyid, D. M., Chamelia, D. M., & Suntoyo. (2017). Project Delay Analysis on Jacket Structure Construction. Applied Mechanics and Materials, 862(January), 315–320. https://doi.org/10.4028/www.scientific.net/amm.862.315

[1.1] https://www.irishtimes.com/news/explosion-kills-203-chinese-coal-miners-1.415488

[1.2] http://ismenvis.nic.in/Database/Central_Saunda_Colliery_15062005_9451.aspx

[1.3] https://www.irishtimes.com/news/boom-turns-china-s-mines-into-death-traps-1.481391

[1.4] https://usminedisasters.miningquiz.com/saxsewell/2006_Sago_Report_of_Investigation.pdf

[1.5] https://usminedisasters.miningquiz.com/saxsewell/aracoma_msha_report.pdf

[1.6] https://web.archive.org/web/20101021081715/http://www.esmas.com/noticierostelevisa/internacionales/505551.html

[1.7] https://www.latimes.com/archives/la-xpm-2006-feb-20-fg-mexmine20-story.html

[1.8] http://www.mineaccidents.com.au/uploads/beaconsfield-original.pdf

[1.9] https://www.miningnewsnorth.com/story/2006/11/26/news/sullivan-deaths-ruled-unprecedented/1509.html

[1.10] https://arlweb.msha.gov/Fatals/2006/Darby/FTL06c2731.pdf

[1.11] https://en.wikipedia.org/wiki/Nanshan_Colliery_disaster

[1.12] https://www.reuters.com/article/us-poland-mine/poland-mourns-after-coal-mine-explosion-kills-23-idUSL2113082820061123

[1.13] http://www.mineaccidents.com/mine-event/226/ulyanovskaya-mine

[1.14] https://www.reuters.com/article/us-russia-mine-explosion/siberian-coal-mine-blast-kills-38-people-idUSL248894620070524

[1.15] https://usminedisasters.miningquiz.com/saxsewell/crandall_canyon_2007.pdf

[1.16] https://arlweb.msha.gov/FATALS/2007/FTL07c1214.asp

[1.17] http://www.china.org.cn/china/local/2007-08/18/content_1221290.htm

[1.18] http://news.bbc.co.uk/2/hi/europe/7103086.stm

[1.19] https://www.nytimes.com/2007/12/07/world/asia/07mine.html

[1.20] https://www.theguardian.com/world/2008/sep/10/china

[1.21] https://www.telegraph.co.uk/news/worldnews/europe/romania/3467135/Romanian-coal-mine-explosions-kill-12-people.html

[1.22] https://www.nytimes.com/2009/02/23/world/asia/23miners.html

[1.23] http://www.chinadaily.com.cn/china/2009-05/31/content_7954398.htm

[1.24] https://web.archive.org/web/20110712235110/http://business.iafrica.com/news/1723474.htm

[1.25] http://news.bbc.co.uk/2/hi/europe/8194505.stm

[1.26] http://www.chinadaily.com.cn/china/2009-09/09/content_8669122.htm

[1.27] https://www.aljazeera.com/news/europe/2009/09/200991814505689 5158.html

[1.28] https://www.rte.ie/news/2009/1112/124134-ghana/

[1.29] http://edition.cnn.com/2009/WORLD/asiapcf/11/23/china.mine.blast/

[1.30] https://www.ctvnews.ca/19-turkish-miners-dead-in-mine-collapse-1.463727

[1.31] http://news.bbc.co.uk/2/hi/asia-pacific/8544682.stm

[1.32] https://www.msf.org/lead-poisoning-crisis-zamfara-state-northern-nigeria

[1.33] http://english.sina.com/china/2010/0316/309180.html

[1.34] http://news.bbc.co.uk/2/hi/asia-pacific/8603102.stm

[1.35] http://www.mineaccidents.com/mine-event/180/upper-big-branch

[1.36] http://www.mineaccidents.com/mine-accident/193/anjan-hill-explosion-2010

[1.37] http://www.mineaccidents.com/mine-accident/192/raspadskaya-mine

[1.38] http://news.bbc.co.uk/2/hi/asia-pacific/8681855.stm

[1.39] http://edition.cnn.com/2010/WORLD/europe/05/20/turkey.miners/

[1.40] https://en.wikipedia.org/wiki/2010_Copiap%C3%B3_mining_accident#Collapse

[1.41] https://www.britannica.com/event/Chile-mine-rescue-of-2010

[1.42] http://www.mineaccidents.com/mine-event/120/pike-river-nz-2010

[1.43] http://www.mineaccidents.com/mine-event/244/2011-gleison-colliery-inrush

[1.44] https://en.wikipedia.org/wiki/Sukhodilska%E2%80%93Skhidna_coal_mine

[1.45] https://en.wikipedia.org/wiki/Bazhanov_coal_mine

[1.46] https://www.dailymaverick.co.za/opinionista/2012-10-12-marikana-prequel-num-and-the-murders-that-started-it-all/

[1.47] https://www.telegraph.co.uk/news/worldnews/asia/china/9508039/Up-to-47-dead-in-Chinese-mine-explosion.html

[1.48] http://www.dailystar.com.lb/ArticlePrint.aspx?id=186590&mode=print

[1.49] https://www.bbc.com/news/world-europe-21108531

[1.50] http://www.gz.chinanews.com/content/2013/03-19/28768.shtml

[1.51] https://www.bbc.com/news/world-asia-china-21992525

[1.52] https://en.wikipedia.org/wiki/2013_Babao_Coal_Mine_explosions

[1.53] https://en.wikipedia.org/wiki/2013_Taozigou_Coal_Mine_explosion

[1.54] https://en.tempo.co/read/484065/big-gossan-collapse-learning-from-tragedy

[1.55] https://www.mining.com/gold-mine-collapse-in-central-african-republic-kills-25-65064/

[1.56] https://allafrica.com/stories/201307080002.html

[1.57] https://edmontonsun.com/2014/02/27/extent-of-environmental-damage-caused-by-obed-mine-spill-will-not-be-known-until-spring/wcm/5e86c0a5-585f-4495-b5dd-09b99d5b7190

[1.58] https://www.bbc.com/news/world-europe-27408394
http://www.mineaccidents.com/mine-event/183/soma-2014

[1.59] https://visibleearth.nasa.gov/view.php?id=84202
https://en.wikipedia.org/wiki/Mount_Polley_mine_disaster

[1.60] https://www.ibtimes.com/bosnia-mine-accident-34-coal-miners-trapped-after-gas-explosion-minor-earthquake-1679516

[1.61] http://www.mineaccidents.com/mine-accident/207/freeport-hv-lv-collision-2014

[1.62] https://www.foxnews.com/world/turkish-rescue-workers-pump-out-water-trying-to-save-18-workers-trapped-in-flooded-coal-mine

[1.63] http://www.mineaccidents.com/uploads/20150310-mine-recovery-and-arrest.pdf
http://www.mineaccidents.com/uploads/zasyadko.pdf

[1.64] https://www.csmonitor.com/Science/2015/0813/How-are-they-going-to-clean-up-that-Colorado-mine-spill

[1.65] https://en.wikipedia.org/wiki/Mariana_dam_disaster#Incident

[1.66] https://www.bbc.com/news/world-asia-34892888
https://en.wikipedia.org/wiki/Hpakant_jade_mine_disaster

[1.67] http://www.mineaccidents.com/mine-event/225/severnaya-russia

[1.68] http://www.mineaccidents.com/mine-event/239/ecl-rajmahal-mine-dump-failure

[1.69] http://www.minersconference.org/index.php/en/worldwide-struggles/574-iran-notifying-announcement-explosion-in-zemestan-yurt-coal-mine-in-northwest-of-iran-with-miners-buried-alive.html

[1.70] http://www.industriall-union.org/pakistan-19-miners-including-rescue-workers-die-in-coal-mine-accident

[1.71] https://nypost.com/2018/10/21/coal-mine-accident-in-china-kills-2-people-leaves-20-trapped/

[1.72] https://indianexpress.com/article/north-east-india/meghalaya/meghalaya-mine-collapse-have-sought-powerful-pumps-they-will-arrive-soon-says-coal-india-5512614/

[1.73] https://www.bbc.com/news/world-asia-46772155

[1.74] https://www.bbc.com/news/business-47432134
https://en.wikipedia.org/wiki/Brumadinho_dam_disaster

[1.75] https://www.aljazeera.com/news/2019/02/dozens-feared-buried-landslide-indonesia-190227005033273.html

[1.76] https://www.aljazeera.com/news/2019/04/50-feared-dead-landslide-myanmar-jade-190423104209902.html

[1.77] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-24-december-29-2010/final-report

[1.78] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-23-december-23-2010/final-report

[1.79] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-22-december-17-2010/final-report

[1.80] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-25-december-9-2010/final-report

[1.81] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-48-december-4-2010/final-report

[1.82] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-21-november-30-2010/final-report

[1.83] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-47-november-23-2010/final-report

[1.84] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-20-november-13-2010/final-report

[1.85] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-46-october-27-2010/final-report

[1.86] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-19-october-20-2010/final-report

[1.87] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-18-october16-2010/final-report

[1.88] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-45-october-11-2010/final-report

[1.89] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-16-october-10-2010/final-report

[1.90] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-17-october-7-2010/final-report

[1.91] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-44-september-3-2010/final-report

[1.92] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-43-august-31-2010/final-report

[1.93] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-15-august-14-2010/final-report

[1.94] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-13-and-14-august-12-2010/final-report

[1.95] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-42-july-29-2010/final-report

[1.96] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-41-july-9-2010/final-report

[1.97] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-40-july-1-2010/final-report

[1.98] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-39-june-24-2010/final-report

[1.99] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-12-june-20-2010/final-report

[1.100] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-11-june-18-2010/final-report

[1.101] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-38-june-16-2010/final-report

[1.102] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-10-june-12-2010/final-report

[1.103] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-37-june-8-2010/final-report

[1.104] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-9-may-28-2010/final-report

[1.105] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-8-may-26-2010/final-report

[1.106] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-7-may-24-2010/final-report

[1.107] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-36-may-10-2010/final-report

[1.108] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-5-may-5-2010/final-report

[1.109] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-34-35-april-28-2010/final-report

[1.110] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-33-april-22-2010/final-report

[1.111] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-32-april-11-2010/final-report

[1.112] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-3-through-31-april-5-2010/final-report

[1.113] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-4-march-24-2010/final-report

[1.114] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-4-march-24-2010/final-report

[1.115] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-2-january-22-2010/final-report

[1.116] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-1-january-9-2010/final-report

[1.117] https://www.msha.gov/data-reports/fatality-reports/2010/fatality-1-january-2-2010/final-report

[1.118] http://www.mineaccidents.com.au/mine-event/201/wayne-mcdonald-2010

[1.119] http://www.mineaccidents.com.au/mine-event/266/2010-curragh-roll-over

[1.120] https://en.wikipedia.org/wiki/Fatality_statistics_in_the_Western_Australian_mining_industry#2011_to_2020

[1.121] https://zh.wikipedia.org/wiki/2010%E5%B9%B4%E4%B8%AD%E5%9B%BD%E7%9F%BF%E9%9A%BE%E5%88%97%E8%A1%A8 (in Chinese)

ANNEX 1: TAXONOMY OF MINING ACCIDENTS

Number of Accident	Date	Location	Mine Type	Machine/ Material	Type of Accident	Cause(s)	Initial Cause(s)	Consequences			Emergency Management
								Operators	Environment	Assets	
1	14/02/2005	Sunjiawan Mine, Fuxin, Liaoning, China	Underground/ Coal	Material (Coal gases)	Gas Explosion	Earthquake	Poor Ventilation	203 dead & 22 injured	High levels of Carbon monoxide and other toxic gases	**Not Stated**	Recue Operations started immediately and conditions of workers were verified Illegal mines were shut down
2	15/06/2005	Central Saunda Mine, India	Underground/ Coal	Material	Inundation & Flooding	Failure as keeping Hatidari seam free of water as required	Fall of roof	14 dead	**Not Stated**	**Not Stated**	Recue Operations started immediately and draining out the mine started
3	07/08/2005	Guangdong Mine, Daxing, China	Surface/ Coal	Material	Inundation & Flooding	Water seeping through the wall	Reclining of bosses & forcing workers to go down the pit again (Human Error)	123 dead	**Not Stated**	**Not Stated**	Rescue operations started 7000 unsafe mines were closed
4	02/01/2006	Sago Mine, Sago, West Virginia, United States	Underground/ Coal	Material	Gas Explosion	Atmosphere was not monitored (contained explosive methane/air mixtures) Lightning was the most likely ignition source for this explosion		12 dead	High toxic levels of carbon monoxide and methane gas	Closure of the mine for 2 months	Rescue operations started after 12 hrs
5	19/01/2006	Alma Mine Melville, Logan County, West Virginia, United States	Underground/ Coal	Machine	Fire	Frictional Heating	2 stopping walls were missing and the ventilation controls were removed	2 dead	High toxic levels of carbon monoxide and methane gas	**Not Stated**	Mine management failed to locate miners & extinguish the fire. Rescue and figherfighting operations started
6	20/01/2006	San José Mine, Atacama Desert near Copiapó, Chile	Underground/ Copper-Gold	Machine (2 trucks)	Explosion	Collision of 2 trucks	**Not Stated**	2 dead & 2 injured	**Not Stated**	**Not Stated**	Workers at nearby mine digged a tunnel to rescue the trapped miners which were treated on site
7	19/02/2006	Pasta de Conchos, San Juan de Sabinas, Coahuila, México	Underground/ Coal	Material	Methane Explosion	Gas leak	**Not Stated**	65 dead	High levels of toxic natural gas	**Not Stated**	Mexican soldiers and civilian rescue teams worked to clear air shafts and communicate with the workers
8	25/04/2006	Beaconsfield Mine, Tasmania, Australia	Underground/ Gold	Material	Mine Collapse	Seismic event	Slip along a shear	1 dead, 14 escaped	**Not Stated**	Immediate closure of the mine	A remote-controlled earth mover began clearing the rock underground A rescue tunnel was drilled

Number of Accident	Date	Location	Mine Type	Machine/ Material	Type of Accident	Cause(s)	Initial Cause(s)	Consequences			Emergency Management
								Operators	Environment	Assets	
9	15/05/2006	Sullivan Mine, Southeastern British Columbia , Canada	Underground/ Lead-Zinc	Material	Toxic Gas Inhalation	Oxygen-deficient atmosphere	**Not Stated**	4 dead	**Not Stated**	**Not Stated**	The province's chief inspector of mines recommended to ensure the safety of workers and rescue personnel at all mines
10	20/05/2006	Darby No. 1 Mine Holmes Mill, Harlan County, Kentucky, United States	Underground/ Coal	Material	Methane Explosion	Cutting of a metal roof strap	The operator didn't observe mine safety practices & safety standards were violated	5 dead	High levels of toxic carbon monoxide	**Not Stated**	Initial rescue and recovery operation did not follow accepted past practices
11	13/11/2006	Nanshan Colliery, Jinzhong, Shanxi Province, China	Underground/ Coal	Material	Gas Explosion	Incorrect usage of explosives	No safety licences	24 dead	**Not Stated**	**Not Stated**	**Not Stated**
12	21/12/2006	Halemba Coal Mine, Ruda Śląska, Poland	Underground/ Coal	Material	Methane and Coal Dust Explosion	**Not Stated**	**Not Stated**	23 dead	High levels of toxic gases	**Not Stated**	**Not Stated**
13	19/03/2007	Ulyanovskaya Mine, Russian Federation	Underground/ Coal	Material	Methane and Coal Dust Explosion	Sudden discharge of a large amount of methane	Breach of mining safety	110 dead	High levels of toxic gases	**Not Stated**	Rescuers emerging from the mine and scores of ambulances were on standby to treat those brought to the surface
14	24/05/2007	Yubileynaya Mine, Kemerovo Oblast area of Siberia, Russia	Underground/ Coal	Material	Methane Explosion	Spark from a damaged cable	**Not Stated**	39 dead & 6 injured	**Not Stated**	**Not Stated**	Recue operations started Russia's industrial safety had twice applied to have the mine closed for safety violations, but were overruled by local courts
15	06/08/2007	Crandall Canyon Mine, Huntington, Emery County, Utah	Underground/ Coal	Material	Mine Collapse	Coal outburst	**Not Stated**	9 dead (6 miners & 3 rescues)	3.9 seismic event	**Not Stated**	Rescue works started clearing rubble to reach the cavity
16	10/08/2007	Princeton, Gibson County, Indiana, United States	Underground/ Coal	Machine	Hoisting	Failure to ensure the hoist was under the control of the hoistman Failed to ensure that fall protection was utilized while persons were transported in the sinking bucket		3 dead	**Not Stated**	**Not Stated**	**Not Stated**

Number of Accident	Date	Location	Mine Type	Machine/ Material	Type of Accident	Cause(s)	Initial Cause(s)	Consequences			Emergency Management
								Operators	Environment	Assets	
17	17/08/2007	Xintai Mine, Shandong, China	Surface/ Coal	Material	Flooding (Inundation)	River burst a leeve	Heavy rain	181 dead	**Not Stated**	It needed 100 days to drain the water inside the mine	Rescue headquarters has ordered all coal mines near the banks of the Wenhe River to stop production and evacuate all workers
18	18/11/2007	Zasyadko Mine, Ukraine	Underground/ Coal	Material	Methane Explosion	Build up of methane gas	**Not Stated**	101 dead	**Not Stated**	**Not Stated**	Families of the deceased miners received compensations Aa decree was signed that calls for investigation as well as prevention of such disasters in the future
19	07/12/2007	Gujiao Mine, Taiyuan, Shanxi, China	Underground/ Coal	Unknown	Methane/ Gas Explosion	Illegal activity in an unauthorized area of the mine	**Not Stated**	105 dead	High levels of toxic gases	**Not Stated**	The rescued miners were hospitalized after the explosion
20	08/09/2008	Xiangfen, Shanxi, China	Iron Ore	Material	Mudslide (Collapse)	Collapse of unlicensed mine landfill	**Not Stated**	277 dead, 4 missing & 33 injured	**Not Stated**	A village and crowded marketplace were inundated	5,300 police and rescuers, using more than 110 excavators, were looking for survivors.The rescuers covered about 90% of the mudslide zone so far. In addition, 2,100 medical workers were at the site to provide medical care.
21	15/11/2008	Petrila Mine, Hunedoara County, Romania	Underground/ Coal	Material	2 Methane/ Gas Explosions	Accumulation of methane gas	**Not Stated**	13 dead & 13 injured	High levels of toxic gases	**Not Stated**	Several people were treated for extensive burns
22	21/02/2009	Gujiao Mine, Taiyuan, Shanxi, China	Underground/ Coal	Material	Gas Explosion	Accumulation of methane gas	Poor Ventilation	74 dead	High levels of toxic gases	**Not Stated**	One hundred rescuers worked and injured miners were taken into ambulances Many of the injured are being treated for carbon monoxide poisoning
23	30/05/2009	Qijiang County, Chongqing, China.	Underground/ Coal	Material	Gas Explosion	Not stated	**Not Stated**	30 dead & 59 injured	**Not Stated**	**Not Stated**	**Not Stated**
24	01/06/2009	Harmony Mine, Free State, South Africa	Gold	Material	Toxic Gas Inhalation	Fire	**Not Stated**	82 dead	High levels of toxic gases	**Not Stated**	Rescue works started

Number of Accident	Date	Location	Mine Type	Machine/ Material	Type of Accident	Cause(s)	Initial Cause(s)	Consequences			Emergency Management
								Operators	Environment	Assets	
25	10/08/2009	Handlova Mine, Trecin Region, Slovakia	Underground/ Coal	Material	Gas Explosion	Accumulation of gases	Fire	20 dead	High levels of toxic gases	**Not Stated**	Rescue efforts were launched immediately
26	08/09/2009	Pingdingshan, Henan, China	Underground/ Coal	Material	Gas Explosion	illegal activity in an illegal mine	**Not Stated**	67 dead & 9 missing	High levels of toxic gases	**Not Stated**	Illegal mines were shut down
27	18/09/2009	Wujek-Śląsk Mine, Ruda Śląska, Poland	Underground/ Coal	Material	Gas Explosion	Methane Ignition	**Not Stated**	20 dead	High levels of toxic gases	**Not Stated**	Rescure efforts were launched immediately and the miners were transpoted to the hospitals
28	12/11/2009	Dompoase Mine, Ashanti Region, Ghana	Gold	Material	Mine Collapse	Landslide	illegal work in illegal mine	18 dead	**Not Stated**	**Not Stated**	Police in the Ghanaian capital of Accra have launched an investigation, and are looking into the possibility of criminal negligence
29	21/11/2009	XinXing Mine,Heilongjiang, China	Underground/ Coal	Material	Gas Explosion	Trapped, pressurised gases	Poor Ventilation	108 dead & 29 injured	High levels of toxic gases	**Not Stated**	Rescue works were initiated and 29 people were hospitalised
30	10/12/2009	Bursa Province Mine, Turkey	Underground/ Coal	Material	Methane Explosion	Use of dynamite	**Not Stated**	19 dead	High levels of toxic gases	**Not Stated**	The rescue work has been complicated by high concentration of gas inside the mine and fog
31	01/03/2010	Luotuoshan Mine, Inner Mongolia Autonomous Region , China	Surface/ Coal	Material	Flooding (Inundation)	Workers broke into a large pool of limestone water	Breach of mining safety	32 dead	**Not Stated**	**Not Stated**	Rescue works started immediately and stopped after 14 days when all the 32 trapped miners were believed dead closure of some 1,000 smaller and less well-regulated mines
32	06/03/2010	Zamfara State, Nigeria	Surface/ Lead	Material	Lead Poisoning	Illegal extraction of ore by villagers	**Not Stated**	163 dead	**Not Stated**	**Not Stated**	Clamping down on illegal mining and carrying out a clean-up of the area

Number of Accident	Date	Location	Mine Type	Machine/ Material	Type of Accident	Cause(s)	Initial Cause(s)	Consequences			Emergency Management
								Operators	Environment	Assets	
33	15/03/2010	Dongxing Mine, Xinmi, Zhengzhou, China	Surface/ Coal	Cable	Fire	Electrical cables in the main pit caught on fire	**Not Stated**	25 dead	**Not Stated**	**Not Stated**	Rescue operation started and saved 6 miners
34	28/03/2010	Wangjialing Mine, Shanxi, China	Surface/ Coal	Material	Flooding (Inundation)	workers broke through an abandoned shaft filled with water	**Not Stated**	38 dead, 18 injured	**Not Stated**	**Not Stated**	Rescuers efforts were launched to pump out the water and to save people and send them to hospitals
35	05/04/2010	Upper Big Branch Mine-South, West Virginia, United States	Underground/ coal (Bituminous)	Material	Ignition or Explosion of Gas or Dust	Unknown source with high methane levels	Flagrant safety violations	29 dead & 2 injured	High levels of methane and carbon monoxide	**Not Stated**	Emergency crews initially gathered at one of the portals and started to drill into the mine in order to release the gases and test the air
36	06/05/2010	Anjan Hill, India	Underground/ Coal	Material	Explosion/ Gas Explosion, Coal Dust Explosion	Gas Leak	Human failures	14 dead	High levels of methane and carbon monoxide	**Not Stated**	Injured persons on surface were shifted to hospitals It was decided to seal the mine from surface and monitor the atmosphere below ground before further actions can be initiated
37	08/05/2010	Raspadskaya Mine, Mezhdurechensk, Kemerovo Oblast, Russia	Underground/ Coal	Material	Explosion/ Methane Explosion	Collapse of the mine's ventilation shaft	Poor observation of safety regulations	91 dead	High levels of methane	**Not Stated**	Rescue efforts were suspended after the second blast Rescue work resumed after methane levels had dropped below safety limits
38	13/05/2010	Yuanyang Mine, Puding County, Anshun, Guizhou, China	Underground/ Coal	Explosives	Outburst	Explosives were responsible for the outburst	Illegal mining	21 dead & 5 injured	**Not Stated**	**Not Stated**	Rescue work started and miners were hospitalised and receiving treatment for carbon monoxide poisoning
39	17/05/2010	Karadon Mine, Zonguldak, Turkey	Underground/ Coal	Material	Firedamp Explosion	High levels of methane	**Not Stated**	30 dead	High levels of methane	**Not Stated**	Rescue works started Prime Minister, Erdogan, called protests against the unsafe working conditions in the state mines
40	05/08/2010	San José Mine, Atacama Desert near Copiapó, Chile	Surface/ Copper-Gold	Material	Mine Collapse	Ignored warnings over unsafe working conditions	**Not Stated**	No dead	**Not Stated**	Total Closure and Loss as of August 2010	The trapped miners' emergency shelter had an area with two long benches They had access to some 2 kilometers of open tunnels in which they could move around and get some exercise or privacy

Number of Accident	Date	Location	Mine Type	Machine/ Material	Type of Accident	Cause(s)	Initial Cause(s)	Consequences			Emergency Management
								Operators	Environment	Assets	
41	15/10/2010	Portovelo Mine, Ecuador	Underground/ Gold	Material	Mine Collapse	Mine disturbance	**Not Stated**	4 dead	**Not Stated**	**Not Stated**	A local emergency squad attempted a rescue that night but was unsuccessful Chilean government ordered Codelco, the state-owned mining company, to coordinate the rescue effort
42	19/11/2010	Pike River Mine, Greymouth, New Zealand	Underground/ Coal	Material	Explosion/ Gas Explosion	Methane accumulated in a void and expelled by roof fall Methane accumulated in the working areas of the mine		29 dead	High levels of methane	**Not Stated**	The emergency response was led by New Zealand Police, Operation Pike, mine rescue experts from New Zealand and Australia, the Red Cross, ambulance services, New Zealand Defence Force, and the Fire Service
43	15/09/2011	Gleison Colliery, Wales, United Kingdom	Underground/ Coal	Material	Inrush	Round of explosives blasted near old workings	**Not Stated**	4 dead	**Not Stated**	**Not Stated**	Initial on-site investigation was started Invaluable support was also provided by specialist contractors, equipment suppliers, and other people with long experience of working small coal mines in South Wale
44	29/07/2011	Sukhodilska–Skhidna Mine, Molodohvardiysk, krasnodon, Ukraine	Underground/ Coal	Material	Methane and Coal Dust Explosion	Buildups of methane and coal dust	**Not Stated**	26 dead	High levels of methane and coal dust	**Not Stated**	**Not Stated**
45	29/07/2011	Bazhanov Mine, Makiiva, Ukraine	Suface/ Coal	Machine	Elevator Collapse (Hoisting)	Negligence	**Not Stated**	11 dead	**Not Stated**	16 month of loss due to the repair of the mine	**Not Stated**
46	10/08/2012 - 20/09/2012	Wonderkop, near Marikana, Rustenburg municipality, South Africa	Surface/ Platinum	Other	Fatal Clashes		**Not Stated**	47 dead	**Not Stated**	**Not Stated**	**Not Stated**
47	29/08/2012	Xiaojiawan Mine, Panzhihua, Sichuan, China	Underground/ Coal	Material	Gas Explosion	**Not Stated**	**Not Stated**	45 dead & 1 missing	**Not Stated**	**Not Stated**	Rescue operations are complicated due to high temperatures reaching 90 °C China's central government has introduced measures aimed at improving standards
48	03/09/2012	Gaokeng Mine, Jiangxi, Pingxiang, China	Underground/ Coal	Material	Methane/ Gas Explosion	Ignored safety rules	**Not Stated**	14 dead	**Not Stated**	**Not Stated**	**Not Stated**

Number of Accident	Date	Location	Mine Type	Machine/ Material	Type of Accident	Cause(s)	Initial Cause(s)	Consequences			Emergency Management
								Operators	Environment	Assets	
49	20/01/2013	Kuznetsk Basin Region, Russia	Underground/ Coal	Material	High Methane Smoke Inhalation	Unclear souce	Poor safety record	4 dead & 4 missing	**Not Stated**	**Not Stated**	Vladimir Putin urged mine operators to improve safety standards when he announced a big increase in investment in the sector
50	12/03/2013	Machang Mine, Shuicheng County, Guizhou, China	Underground/ Coal	Unknown	Outburst	Breach of mining safety	**Not Stated**	25 dead	**Not Stated**	**Not Stated**	Rescue operation started with 58 miners were saved
51	29/03/2013	Gyama Mine, Tibet Autonomous Region, China	Suface/ Copper-Gold	Material	Mine Landslide	The site of the landslides is located in a very steep V-shaped valley There are a lot of neotectonic activities the area experienced several snowfalls in after an extreme dry period		66 dead & 17 missing	**Not Stated**	**Not Stated**	Rescue operations saved first worker after 36 hours Illegal mines were closed
52	29/03/2013	Babao Coal Mine, Jiangyuan District, China	Underground/ Coal	Unknown	Explosion	Unclear souce	**Not Stated**	53 dead	**Not Stated**	**Not Stated**	**Not Stated**
53	11/05/2013	Taozigou Mine, Sichuan, China	Underground/ Coal	Material	Explosion	No ventilation system	Illegal Mining	28 dead & 18 injured	High levels of toxic gases	**Not Stated**	Rescue works saved 81 worker
54	14/05/2013	Freeport Indonesia	Underground/ Metal	Material	Strata/ Roof Fall	Rock erosion of the ceiling	Continuous dropping of acidic and corrosive rainwater	28 dead	**Not Stated**	Stopping Production	This incident treated as an important wake-up call for the company's management
55	06/06/2013	Ndassima gold mine, Bambari, Central African Republic	Surface/ Gold	Material	Mine Collapse	Heavy rain	**Not Stated**	37 dead	**Not Stated**	**Not Stated**	Rescued Works saved 10 workers but no solutions were found for these illegal mines
56	06/07/2013	Mererani Mining Hills, Tanzania	Tanzanite Quarry	Material	Mine Collapse	Unknown	**Not Stated**	5 dead & 1 injured	**Not Stated**	**Not Stated**	Working safety were improved

Number of Accident	Date	Location	Mine Type	Machine/ Material	Type of Accident	Cause(s)	Initial Cause(s)	Consequences			Emergency Management
								Operators	Environment	Assets	
57	31/10/2013	Obed Mountain Mine, Alberta, Canada	Surface/ Coal	Material (Tailing dam)	Flooding (Inundation)	Tailing dam collapse		No dead	Presence of metals and chemicals in the water	**Not Stated**	Residents were discouraged from both drinking any of the Athabasca as well as watering any livestock or pets
58	13/05/2014	Eynez Mine, Soma, Manisa, Turkey	Underground/ Coal	Material	Methane/ Gas Explosion	Electrical fault	**Not Stated**	301 dead	High levels of methane gases	**Not Stated**	Rescue crews arrived and provided fresh air to the mine workings in an effort to keep those workers still trapped underground alive
59	04/08/2014	Mount Polley Mine, British Columbia, Canada	Surface/ Copper-Gold	Material	Flooding (Inundation)	Breach of the Imperial Metals-owned Mount Polley copper and gold mine tailings pond		No dead	Elevated levels of selenium, arsenic and other metals	**Not Stated**	An action plan for the Preliminary Environmental Impact Assessment, stopping the flow from the "Tailings Impoundment" breach, as required
60	04/09/2014	Raspotočje Mine Zenica, Bosnia and Herzegovina	Underground/ Coal	Other	Outburst	3.5 earthquake	**Not Stated**	5 dead & 29 injured	**Not Stated**	**Not Stated**	Rescue workers secured 29 worker
61	27/09/2014	Freeport Indonesia	Surface/ Metal	Machine	HV LV Collision (Powered Haulage)	a Caterpillar 785 haul truck collided with a shift change light vehicle	**Not Stated**	4 dead	**Not Stated**	**Not Stated**	**Not Stated**
62	28/10/2014	Has Sekerler Mine, Ermenek, Turkey	Underground/ Coal	Pipe	Flooding (Inundation)	Broken pipe	**Not Stated**	18 dead	**Not Stated**	**Not Stated**	Rescue workers pumped out water to save the 18 trapped miners
63	04/03/2015	Zasyadko Mine, Ukraine	Underground/ Coal	Material	Methane/ Gas Explosion	**Not Stated**	Bad safety conditions	23 dead	high levels of toxic gases	**Not Stated**	Rescue workers tried to remove toxic gases and then to enter to save workers

Number of Accident	Date	Location	Mine Type	Machine/ Material	Type of Accident	Cause(s)	Initial Cause(s)	Consequences			Emergency Management
								Operators	Environment	Assets	
64	05/08/2015	Gold King Mine Silverton, Colorado, United States	Surface/ Gold	Material	Waste Water Spill	Attempting to drain ponded water near the entrance of the mine	destroyed the plug holding water trapped inside the mine	No dead	levels of six metals were above limits allowed for domestic water	**Not Stated**	The EPA's emergency cleanup is a quick version of typical mine treatment The agency has excavated four holding ponds below the mine breach
65	05/11/2015	Mariana, Minas Gerais, Brazil	Surface/ Iron Ore	Material	Dam Failure	Leakages and Rupture occurred	**Not Stated**	19 dead & 16 injured	**Not Stated**	2 villages damaged, around 200 homes destroyed	Brazilian army units nearby stood ready to help the rescue effort Civil defence authorities evacuated about 600 people to ground from Bento Rodrigues villageand another village called Paracatú de Baixo
66	22/11/2015	Hpakant Mine, Kachin State, Myanmar	Surface/ Jadeite	Material	Landslide	Collapse of man-made heap of waste soil	**Not Stated**	90 dead & 100 missing	**Not Stated**	**Not Stated**	Rescue efforts by the Myanmar Red Cross and other groups have been made to find and recover survivors
67	25/02/2016	Severnaya mine in Arctic Russia	Underground/ Coal	Material	Methane Explosion	Sudden discharge of a large amount of methane	**Not Stated**	36 dead	high levels of toxic gases	**Not Stated**	Authorities launched a massive search operation involving hundreds of rescue workers who had been trying to track down the missing miners despite almost zero visibility, smoke, gas-polluted air and rubble
68	29/12/2016	Rajmahal Open Cast Expansion Project in District Goda, Jharkhand, India	Surface/ Coal	Material	Mine Dump Failure	Failure of the bench edge along the hidden fault line/slip	**Not Stated**	17 dead	**Not Stated**	**Not Stated**	Senior management of ECL and State Government officials have been supervising the rescue operations NDRF Team has also been engaged for rescue and relief operations
69	03/05/2017	Zemestan-Yurt Mine, Golestan Province, Iran	Underground/ Coal	Material	Mine Collapse	Gas explosion	Methance gas accumulation	42 dead & 75 injjured	high levels of toxic gases	**Not Stated**	No management occurred which increased the scale of catastrophe
70	12/08/2018	Sanjidi Mine, Quetta, Baluchistan, Pakistan	Underground/ Coal	Material	Mine Collapse	Methane Gas Explosion	**Not Stated**	19 dead (13 miners & 6 recue workers)	**Not Stated**	**Not Stated**	Senior management of ECL and State Government officials have been supervising the rescue operations

Number of Accident	Date	Location	Mine Type	Machine/ Material	Type of Accident	Cause(s)	Initial Cause(s)	Consequences			Emergency Management
								Operators	Environment	Assets	
71	20/10/2018	Xintai Mine, Shandong, China	Surface/ Coal	Material	Mine Collapse	Rock burst (kind of earthquake induced by excavation)		11 dead	**Not Stated**	**Not Stated**	140 rescuers were dispatched Ventilation has returned to around 200 metres of the damaged tunnel, with 50m left to repair, according to officials.
72	13/12/2018	Ksan Mine, Meghalaya, India	Underground/ Coal	Material	Flooding (Inundation)	Miners cut into an adjacent mine which was full of water		2 dead, 13 missing & 5 escaped	**Not Stated**	It took a long time to drain the mine	Over 100 service personnel from the National Disaster Response Force and State Disaster Response Force were deployed to rescue the miners 1,200,000 litres have been pumped out of the mine
73	06/01/2019	Kohistan District of Badakhshan Province, Afghanistan	Surface/ Gold	Material	Mine Collapse	Mining operation was unregulated and illegal	**Not Stated**	30 dead	**Not Stated**	**Not Stated**	Rescue team was sent to the area but villagers have already started removing bodies from the site
74	25/01/2019	Córrego do Feijão, Brumadinho, Minas Gerais, Brazil	Surface/ Iron Ore	Material (Tailing dam)	Dam Failure	Brazil's weak regulatory structures and regulatory gaps	**Not Stated**	248 dead & 22 missing	12 million cubic meters of tailings were released	3 locomotives and 132 wagons were buried. Loss of US$ 19 billion	The President of Brazil, Jair Bolsonaro, sent three ministers to follow the rescue efforts Brazilian authorities issued arrest warrants for 5 employees believed to be connected with the dam collapse
75	26/02/2019	Lolayan, Bolaang Mongondow, Indonesia	Underground/ Gold	Material	Mine Collapse	Fracturing of the support structures of the mineshafts		29 dead	**Not Stated**	**Not Stated**	Around 140 personnel from multiple agencies were involved in the evacuation process. The provincial government remarked that local governments had made plans to certify the communal mines to ensure compliance with safety regulations
76	22/04/2019	Hpakant Mine, Kachin State, Myanmar	Surface/ Jadeite	Material	Mine Collapse	Landslide	**Not Stated**	6 dead & 50+ missing	**Not Stated**	**Not Stated**	Rescue efforts were started by the local government and welfare organizations The acting UN Resident Coordinator to Myanmar called on the country to implement new safety legislation to protect mine workers

ANNEX 2
1- AUSTRALIA

Number of Accident	Date	Location	Mine Type	Type of Accident	Number of Fatalities
1	31/08/2010	Curragh Mine, Queensland	Surface/ Coal	Vehicle/ Roll over (Powered Haulage)	1
2	18/12/2010	Foxleigh Mine, Queensland	Surface/ Coal	Vehicle/ Tyre Explosion (Powered Haulage)	1
3	24/12/2010	Cloud Break Mine, Pilbara	Surface/ Iron Ore	Machinery	1
4	05/08/2010	Norseman Mine, Eastern Goldfields	Underground/ Gold	Slip or Fall of Person	1
5	11/04/2010	Perseverance Mine, Leinster	Underground/ Nickel	Machinery	1

2- United States

Number of Accident	Date	Location	Mine Type	Type of Accident	Number of Fatalities
1	29/12/2010	Martinez Stone, Texas	Surface/ Dimension Sandstone	Falling, Rolling, or Sliding Rock or Material of Any Kind	1
2	23/12/2010	Mid-Coast Aggregates LLC-Mazak Mine, Florida	Surface/ Crushed, Broken Limestone NEC	Falling, Rolling, or Sliding Rock or Material of Any Kind	1
3	17/12/2010	S W Barrick & Sons, Maryland	Surface/ Crushed, Broken Limestone NEC	Powered Haulage	1
4	09/12/2010	Blue Star Materials II, Texas	Surface/ Crushed, Broken Limestone NEC	Slip or Fall of Person	1
5	04/12/2010	Republic Energy, West Virginia	Surface/ Coal (Bituminous)	Powered Haulage	1
6	30/11/2010	Portable Crusher, Washington	Surface/ Crushed, Broken Stone NEC	Falling, Rolling, or Sliding Rock or Material of Any Kind	1
7	23/11/2010	Rex Strip #1, Kentucky	Surface/ Coal (Bituminous)	Powered Haulage	1
8	13/11/2010	Hollingsworth Sand & Gravel LLC, Texas	Surface/Construction Sand & Gravel	Powered Haulage	1
9	27/10/2010	River View Mine, Kentucky	Underground/ Coal (Bituminous)	Powered Haulage	1
10	20/10/2010	Simpson, Georgia	Surface/ Fullers Earth	Powered Haulage	1
11	16/10/2010	Plant #80013, Kansas	Surface/ Crushed, Broken Limestone NEC	Powered Haulage	1
12	11/10/2010	Kingston No 1, West Virginia	Underground/ Coal (Bituminous)	Fall of Roof or Back	1
13	10/10/2010	Snyder, Oklahoma	Surface/ Crushed, Broken Granite	Electrical	1
14	07/10/2010	Wheeler Rock Quarry, Kansas	Surface/ Dimension Stone NEC	Powered Haulage	1
15	03/09/2010	Kansas Mine, Alabama	Surface/ Coal (Bituminous)	Powered Haulage	1
16	31/08/2010	Freelandville Underground, Indiana	Surface or Underground/ Coal	Powered Haulage	1
17	14/08/2010	Southwestern State Sand, Oklahoma	Surface/Construction Sand & Gravel	Drowning	1
18	12/08/2010	Meikle Mine, Nevada	Underground/ Gold Ore	Falling, Rolling, or Sliding Rock or Material of Any Kind	1
19	29/07/2010	Loveridge #22, West Virginia	Underground/ Coal (Bituminous)	Fall of Face, Rib, Side or Highwall	1
20	09/07/2010	Willow Lake Portal, Illinois	Underground/ Coal (Bituminous)	Powered Haulage	1
21	01/07/2010	ocahontas Mine , West Virginia	Underground/ Coal (Bituminous)	Powered Haulage	1
22	24/06/2010	No. 68, Kentucky	Underground/ Coal (Bituminous)	Machinery	1
23	20/06/2010	Ray, Arizona	Surface/ Copper Ore NEC	Powered Haulage	1
24	18/06/2010	Galena, Idaho	Underground/ Silver Ore	Fall of Roof or Back	1
25	16/06/2010	Clover Fork No 1, Kentucky	Underground/ Coal (Bituminous)	Fall of Face, Rib, Side or Highwall	1
26	12/06/2010	OTTAWA PIT & PLANT, Minnesota	Surface/ Crushed, Broken Sandstone	Slip or Fall of Person	1
27	08/06/2010	Choctaw Mine, Alabama	Surface/ Coal (Bituminous)	Ignition or Explosion of Gas or Dust	1
28	28/05/2010	Discovery Day Mine, California	Underground/ Gold Ore	Explosives and Breaking Agents	1
29	26/05/2010	Pandora Complex, Utah	Underground/ Uranium Ore	Fall of Face, Rib, Side or Highwall	1
30	24/05/2010	U.S. Lime Company-St. Clair, Oklahoma	Underground/ Lime	Machinery	1
31	10/05/2010	Ruby Energy, West Virginia	Underground/ Coal (Bituminous)	Powered Haulage	1
32	05/05/2010	Brierfield Quarry, Alabama	Surface/ Crushed, Broken Limestone NEC	Machinery	1
33	28/04/2010	Dotiki Mine, Kentucky	Underground/ Coal (Bituminous)	Fall of Roof or Back	1
34	22/04/2010	Beckley Pocahontas Mine, West Virginia	Underground/ Coal (Bituminous)	Machinery	1
35	11/04/2010	MC#1 Mine, Illinois	Underground/ Coal (Bituminous)	Machinery	1
36	05/04/2010	Upper Big Branch Mine-South, West Virginia	Underground/ Coal (Bituminous)	Ignition or Explosion of Gas or Dust	29
37	24/03/2010	Cayuga Mine, New York	Underground/ Salt	Falling, Rolling, or Sliding Rock or Material of Any Kind	1
38	26/01/2010	Tehachapi Plant, California	Facility/ Cement	Powered Haulage	1
39	22/01/2010	Abner Branch Rider, Kentucky	Underground/ Coal (Bituminous)	Fall of Face, Rib, Side or Highwall	1
40	09/01/2010	Freeport McMoRan Miami Inc, Arizona	Surface/ Copper Ore NEC	Falling, Rolling, or Sliding Rock or Material of Any Kind	1
41	02/01/2010	Bull Mountains Mine No 1, Montana	Underground/ Coal (Bituminous)	Powered Haulage	1

3- China

Number of Accident	Date	Location	Mine Type	Type of Accident	Number of Fatalities
1	05/01/2010	Tanjiashan, Xiangtan, Hunan	Underground/ Coal	Cable Fire	34
2	05/01/2010	Chongqing Dazu	Underground/ Coal	Gas Suffocation	3
3	08/01/2010	Jiangxi Xinyu	Surface/ Coal	Cable Fire	12
4	19/01/2010	Hunan Linwu	Surface/ Coal	Gas Explosion	3
5	20/01/2010	Guizhou Bijie	Surface/ Coal	Gas Explosion	7
6	22/01/2010	Ningxia Wuzhong	Surface/ Coal	Flooding (Inundation)	7
7	22/01/2010	Cili County, Zhangjiajie , Hunan	Surface/ Coal	Gas Explosion	4
8	23/01/2010	Gansu Zhangye	Unknown	Mine Collapse	3
9	16/01/2010	Liupanshui, Guizhou	Coal	Gas Explosion	5
10	31/01/2010	Sichuan Liangshan Ganluo	Unkown	Gas Suffocation	8
11	07/02/2010	Tongliang County, Chongqing	Coal	Gas Explosion	5
12	08/02/2010	Yuxi, Weinan County, Chongqing	Unkown	Natural Gas Leakage	3
13	15/02/2010	Hunan Huaihua China Flower Town	Coal	Gas Suffocation	3
14	15/02/2010	Yunnan Zhaotong Shigeo black peak	Waste Mine	Gas Suffocation	6
15	18/02/2010	Shanxi Xinzhou Yuanping long beam Town	Coal	Gas Suffocation	5
16	24/02/2010	Lupo Guanpo Town, Sanmenxia, Henan	Iron	Gas Explosion	4
17	01/03/2010	Inner Mongolia Wuhai	Surface/ Coal	Flooding (Inundation)	32
18	03/03/2010	Shuyang County, Yongzhou, Hunan	Coal	Gas Explosion	7
19	05/03/2010	Xinjiang Manas	Coal	Roof Fall	3
20	05/03/2010	Hegang, Heilongjiang	Coal	Gas Explosion	4
21	07/03/2010	Sichuan Guang'an	Coal	Gas Suffocation	3
22	08/03/2010	Wusu City, Tacheng , Xinjiang	Coal	Roof Fall	4
23	09/03/2010	Sichuan Neijiang Weiyuan County	Coal	Other	3
24	10/03/2010	Hunan	Non-ferrous	Gas Suffocation	8
25	12/03/2010	Chongqing	Coal	Gas Leakage	3
26	12/03/2010	Nayong County, Bijie, Guizhou	Coal	Coal & Gas Explosion	7
27	15/03/2010	Zhengzhou Xinmi, Henan	Surface/ Coal	Cable Fire	25
28	16/03/2010	Shilin, Kunming, Yunnan	Coal	Gas Explosion	5
29	19/03/2010	Anhui Chizhou Guichi	Quarry	Collapse	4
30	19/03/2010	Anlong County, Southwest Guizhou	Coal	Flooding (Inundation)	6
31	21/03/2010	Fuyuan County, Qujing , Yunnan	Coal	Gas Suffocation	5
32	21/03/2010	Fuquan County, Buzhou, Guizhou	Coal	Gas Suffocation	3
33	21/03/2010	Fenghuang County, Xiangxi Prefecture, Hunan	Asphalt	Roof Fall	2
34	22/03/2010	Henan Zhumadian Biyang	Iron	Flooding (Inundation)	9
35	23/03/2010	Boli County, Qitaihe, Heilongjiang Province	Coal	Machinery	3
36	25/03/2010	Gejiu City, Honghe Prefecture, Yunnan	Tin	Suffocation	5
37	25/03/2010	Hebei Chengde	Coal	Gas Explosion	11
38	25/03/2010	Xinglong Town, Fengjie, Chongqing	Coal	Gas Explosion	7
39	28/03/2010	Wangjialing Mine, Shanxi	Surface/ Coal	Flooding (Inundation)	38
40	30/03/2010	Yichuan, Henan	Coal	Gas Explosion	44
41	30/03/2010	Xinjiang Tacheng area	Coal	Gas Explosion	10