




Chair of Mining Engineering and Mineral Economics

Master's Thesis



Safety in Small-Scale Underground Coal
Mining in Colombia

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A not-so-small mining issue

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Declaration of Authorship

„I declare in lieu of oath that this thesis is entirely my own work except where is otherwise indicated. The presence of quoted or paraphrased material has been clearly signaled and all sources have been referred. The thesis has not been submitted for a degree at any other institution and has not been published yet.”

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Preface, Dedication, Acknowledgement

To God, who has brought me to this point to improve as a professional and human being. To my family and friends, who always pushed me to overcome adversity and to thank all opportunities life gave me. To my brother Miguel Jaramillo, for his invaluable help in carrying out this work.

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Abstract

This thesis is a bibliographic review of occupational health and safety status regarding mining in Colombia through multiple studies. For this purpose, it is used the definition of key concepts such occupational safety and health, defining the types of risks in current mining as well. Also, a general reading on Colombian mining is carried out, including a classification according to methods, size, development, and legal status, adding statistics on accidents-fatalities within different categories.

Likewise, exploitation processes in small underground coal mining are defined, attempting to answer the research question: how is occupational safety carried out in underground coal mining in Colombia? Contextualizing good mining practices according to studies, this approach looks out for risk prevention, mitigation and control measures in the national panorama. In addition, a discussion around potential risk factors takes place, given the Colombian historic and current context, aside from those already exposed by occupational health and safety. Illegality and social dynamics around mining performed by vulnerable populations who subsist on said practice are also taken into account. To conclude, photographic material is presented to illustrate the current small mining conditions.

Zusammenfassung

Die vorliegende Arbeit gibt einen Überblick über den Status von Arbeits- und Gesundheitsschutz im kolumbianischen Bergbau. Zu diesem Zweck werden Definitionen aus Arbeitssicherheit und Gesundheitsschutz herangezogen, um die Risiken, welche die derzeit laufenden Bergbauaktivitäten mit sich bringen, einzuordnen. Zudem erfolgt eine allgemeine Zusammenfassung über den kolumbianischen Bergbau, einschließlich einer Klassifizierung der Abbaumethoden sowie der Größe, Entwicklung und des Rechtsstatus der betreffenden Unternehmen. Statistiken über tödliche Arbeitsunfälle werden ebenfalls beigefügt.

Ebenso werden Gewinnungsprozesse in kleinen untertägigen Kohlebergbauen beschrieben, um die Frage zu beantworten: Wie wird die Arbeitssicherheit im untertägigen Kohlebergbau in Kolumbien gehandhabt? Dieser Ansatz, der sichere Abbaumethoden mit diversen Studien in Kontext setzt, sucht nach Maßnahmen zur Risikovermeidung, -minderung und -kontrolle auf nationaler Ebene. Darüber hinaus findet angesichts des historischen und aktuellen Zusammenhangs in Kolumbien eine Diskussion über potenzielle Risikofaktoren statt, abgesehen von denjenigen, die bereits durch den Arbeitsschutz aufgedeckt und eliminiert worden sind. Illegal durchgeführte Bergbauaktivitäten finden dabei ebenfalls Berücksichtigung. Abschließend wird Fotomaterial präsentiert, um die aktuellen Abbaubedingungen im Kleinbergbau zu veranschaulichen.

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1 Introduction

Mining is a transcendental economic activity, since it provides the basic raw material for most industries. This work is developed under a complex environment since it is constantly in transformation and involves various risks reflected in the high rate of accidents, fatalities and affectations due to occupational diseases on the mining worker. Specifically, underground coal mining is considered one of the most dangerous activities, despite the many efforts to minimize its impacts. Within the cycle of coal extraction, transportation and processing, there are inherent hazards that put at risk the health and safety of the worker, leading to accidents, illness and even death. These risks are usually controlled in order to avoid such events, but the characteristics of underground coal mining, such as the shape of the deposit, lack of natural light, lack of air, among others, can and does complicate the objective (International Labour Office, 2009).

The present research refers to the issue of safety in small-scale underground coal mining in Colombia, looking up to describe the current situation and factors that affect occupational safety in said area under current available information, asking *how is occupational safety carried out in underground coal mining in Colombia*. To this effect, an overarching literature review about Occupational Safety and Health Administration – OSHA will be conducted; this also covers a characterization of the current mining situation in Colombia, its conditions, classifications, and accidents and fatalities statistics; and some definitions on Artisanal and Small-Scale Mining (ASM).

Although there are many researches developed on the subject, the mining problem does not show signs of improvement in the country. The extraction of minerals has been for decades the source of survival of many communities and even armed groups outside the law. Due to its value, gold is the second mineral with the most exploitation titles in Colombia, and although coal is the fourth, the latter is the most exported mineral (surpassed only by oil). For this reason, coal deserves the attention of the State, since it generates large royalties for national development. However, despite state efforts, coal extraction still has the highest rates of accidents and fatalities, with 77% and 73% respectively. Of these

statistics, underground method represents the 93% of the emergencies and 87% of fatalities (Grupo de Seguridad y Salvamento Minero, 2019).

The latter justifies the aim of this work: to investigate the possible causes of the high impacts on workers that underground coal mining generates annually in terms of safety. Coupled with the imminent mining illegality, the security problem becomes more complex, analyzing not only the risk factors related to mining, but also those external and implicit factors, such as the demographic conditions of the mining industry and mining population to fully understand its context.

This thesis aims to conceptualize the reader in the development of the research, where some figures about the accident rate and the production related to mining extraction methods and scaling will be exposed, highlighting the importance of small mining carried out mostly illegally and as a subsistence method in many regions. The research will also explore the different occupational risks that are often ignored by miners, either because of their empirical knowledge on how to extract coal, or simply ignorance, generating consequences such as health issues, economic losses and environmental damage. Next, the objectives of the research will be presented, which, as mentioned above, are to approach the factors that affect the occupational safety in the underground small-scale coal mining in Colombia, and perhaps, provide a reflection on why the mining problem is still latent at the national level.

Then the Theoretical Framework is defined. This is subdivided into three sub-chapters, seeking to develop the different basic concepts to understand what occupational safety is, how is mining in Colombia and how the Small-Scale Mining is understood. The first subchapter covers Occupational Safety and Health, a multidiscipline that is responsible for promoting workers welfare by minimizing and preventing occupational and health risks, and accidents at work (Arias, 2012).

In turn, the risks are classified in different ways, using as basis the Colombian Standards and Certification Standards - ICONTEC (Colombian Institute of Technical Standards and Certification), the International Labor Organization (ILO) and Pico (2004), forming risk groups divided into physical, chemical, biological, mechanical, ergonomic and locative.

On the other hand, the chapter presents a summary of Decree 1886 of 2015, by means of which the Safety Regulations for Underground Mining are established.

The second subchapter of the theoretical framework deals with mining in Colombia and its classifications according to different aspects. Firstly, it presents general aspects of Colombia, as its geography and hydrology, determining aspects in the extraction of minerals and the methods implemented. Colombian mining is also described in section 4.2.1, emphasizing coal, its potential, annual production and contribution to the national treasury. Likewise, the percentage of coal production is indicated by open pit and underground methods, according to the registered mines.

Section 4.2.2 shows the types of mining in Colombia according to compliance with legal requirements. According to the Ministry of Mines and Energy - Ministerio de Minas y Energía (2015b), Colombian mining comprises formal and informal mining; legal, illegal, traditional mining, 'de facto' and subsistence mining. Likewise, mining is classified according to scale (Small, medium and large) and the status of mining extraction. Thus, for exploration and construction and assembly stage, it is classified according to the number of hectares and, the exploitation stage, the mining method (Underground or Open Pit), and it is divided according to the tons of ore produced per year.

A key concept in this research is Small-Scale Mining, defined in subchapter 4.3 according to several authors. This activity represents 72% of the national mining, not being exclusive of Colombia, which is why it is difficult to find a conclusive definition. According to the Organisation for Economic Co-operation and Development – OECD (2016), Small-Scale Mining can be formal or informal, with low capital investment, using high manual labour and low level of technological development. The main processes implemented in small mining involve a great physical and psychological effort on the part of the miners since they must remain for hours under low lighting conditions, in bad ergonomic positions, with no ventilation and under stresses and loads of material. The less technified the mine is the more traditional or manual are its methods, which relates the lack of technification with the strong presence of risks.

Chapter 5 contains some figures for mining accidents in Colombia, the U.S. and China. Thanks to the legal mining registries, the ANM provides a compendium of emergency statistics according to the cause of the accident, the annual damages and

fatalities, the type of mineral, mining method (underground and open pit) and the legal aspect. There is also a discussion on risk factors, such as landslides, damaged atmosphere and explosions. These risks are constantly present in small-scale mining, especially if it is illegal, given the low technological level and, therefore, poor infrastructure and maintenance of tunnels and gas monitoring equipment.

International statistics are presented in order to contrast with the Colombian situation. Although each country has different mining demographic characterization, production, mining accident statistics and safety and occupational health models, the rate among production/accident-fatalities remains impressive. The American production exceeds the Colombian production by almost 10 times; while Colombia produces 87 million tons of coal with 106 fatalities and 64 casualties on average for 2015, the U.S. produces 896.9 million with eight fatalities. The figure is more scandalous when looking at China, with 38.7 billion tons of coal and 931 fatalities and 509 accidents.

Having this mining panorama, chapter 6 presents some good practices not without first defining them, allowing a discussion about the findings and facts identified in national mining. The "behaviors and interrelationships in the workplace that generate features of the decent work paradigm and respect for fundamental human rights related to work" are called best practices. Clearly, Colombia still struggles to achieve the implementation of these regulations that allow the development of secure praxis with the miner, the environment and the surrounding communities.

To conclude, the high accident rate is only one of the disastrous consequences of illegality, state weakness, limited state presence in the territories, and lack of decent work opportunities, among others. Human lives should be the priority of each miner, manager, inspector and public official, which is why any approaches to national mining security, cannot continue to be addressed from the perspective of the last century. These focuses clearly ignore the interrelations between the various sciences that might bring multidisciplinary solutions, respecting human rights, work conditions and the surrounding communities.

Keywords: Coal, occupational safety and health, small-scale mining, underground mining, working conditions.

2 Problem Statement

The use of better practices to improve occupational safety and health has ranged from technological improvements and capital investment to appropriate training of miners and understanding of unsafe work behaviours. In Colombia, the mining safety situation continues to be discouraging since accident statistics are not decreasing significantly, especially when it comes to coal mining. From the "Consolidated Accident Statistics 2005 – 2018" by the Agencia Nacional de Minería – ANM (National Mining Entity by its Spanish acronym) it is relevant the fact that, of the total emergencies by type of ore, coal represents 77% of emergencies and 73% of fatalities. Furthermore, by type of mining, underground mining accounts for 93% of emergencies and 87% of fatalities at national level. In the country, several factors influence the accident rate and mining fatalities, such as the illegality or informality of the miners, implying among many reasons, the oversight of their health and safety, ignoring the mechanisms of protection and management. Therefore, legislation and its correct compliance, timely mining inspection, productivity and the market conditions in which the mineral is commercialized are crucial aspects in the evaluation and understanding of the problems in matters of mining safety (Grupo de Seguridad y Salvamento Minero, 2019).

Worldwide coal mining is carried out at different scales: large, medium and small. Colombia is no exception, having one of the largest open pit coalmines in the world, Cerrejón, located in northern Colombia, a region from which 91% of coal production is extracted. The remaining 9% of the production corresponds to small and medium miners located in various areas of the country (Departments of Antioquia, Cundinamarca – Boyacá, Santander – Norte de Santander and Valle-Cauca) which extract coal by underground methods. Small and medium mining also represents the 98% of the mining titles (a power that grants the right to explore/exploit the national mineral resources) located in major quantity in Boyacá, and the remaining 2% is for large mining titles (Agencia Nacional de Minería, 2018; Escobar & Martínez, 2014).

Small and medium scale mining usually presents a breach of legislation and a lack of management on mining risks, generating eventually frequent calamities. It is remarkable that within the accident data presented by the Grupo de Seguridad y Salvamento Minero (2019), legal mining has the highest percentage of accidents and fatalities, surpassing the illegal: 73 and 70%, respectively. Although legal mining is staffed by only one UPM (Mining Production Unit) and many of the accidents and fatalities occurred in illegal mining are not reported to the competent authority, the latest figures are indeed alarming. This is why this research seeks to approach the Colombian mining labour context, specially small-scale mining, in order to examine, describe and understand its complexity and perhaps, elucidate the reasons that hinder the proper development of mining despite the existence of international standards of best practices and the efforts of several governmental entities and NGOs to improve the development of this activity.

There are many examples that can illustrate the situation, being one of this the Amagá, Antioquia municipality with a mining vocation where, according to Mercado (2016), mining is carried out by "close to 80 percent of the population..., its main economic activity". There, accidents and fatalities are frequent due to the informality and illegality of the activity, meaning that the problem is even more difficult to handle in terms of safety or the closure of those places considered dangerous. In 2010, an explosion in the San Joaquin mine, located in this municipality, caused the death to 73 workers and expenses of COP \$12.000 million (rough \$US 6 million) just in pension insurances (Jaramillo-Urrego, Molina-Escobar, García-Torrent, & Medic-Pejic, 2017).

Subsequently, the research question would be, how is occupational safety carried out in small-scale underground coal mining in Colombia?

3 Objectives

This project expects to review the current situation in small-scale underground coal mining in Colombia, as its overall objective is to analyse the factors that affect the occupational safety of said practice. In the same way, it is intended to provide if possible a reflection on why the mining problem is still latent at the national level, its causes, consequences and possible recommendations to advance towards the objective of the Colombian plan "National Mining Development Plan with a 2025 Horizon". This plan aims to advance "in the contribution of the mining sector to the economic, social and environmental development of the regions where it is produced and to increase the State's income from this activity" (Unidad de Planeación Minero Energética - UPME & Ministerio de Minas y Energía, 2017).

For this purpose, it is necessary to inquire into the mining reports about accidents and fatalities, as well as their possible causes and the type of mining in which they occurred. This task is difficult to accomplish by the fact that in Colombia there is not only mining at different scales, but also at diverse legal situations, ranging from legality and illegality to formality and informality. Colombia exploits around 211 minerals on a dense territory with topographical conditions that make even more difficult the state task to control all the territory and the activities that have been carried out on it. Although the country is currently under the disarmament process due to the armed conflict that prevailed for more than 50 years, this path of reconciliation is slow and the presence of the State cannot be guaranteed in all those areas previously dominated by the guerrillas. This exacerbates the problem of mining security, since the illegals have quicker access to those places forgotten by the State.

On the other hand, the lack of employment opportunities for a large part of the population aggravates the problem since illegal and informal miners often do not have the basic technical knowledge for mining exploitation and/or the investment capital necessary to meet all the requirements and safety elements.

General objective

To analyse the current situation and factors that affect occupational safety in small-scale underground coal mining in Colombia based on currently available information.

Specific objectives

- To conduct an overarching literature review to understand the generic framework for Occupational Safety and Health Administration – OSHA and its functionality in Colombia.
- To characterize the current mining situation in Colombia regarding to the accidents and fatalities in mining and their possible causes.
- To determine some of the best practices in mining according to the Colombian context that lead to an overall safer extraction and execution.

4 Theoretical Framework

In order to develop this thesis, it is necessary to determine the meaning of the key concepts implemented and to present the mining basic aspects in order to deliver a suitable reading and interpretation of the events recorded in the Colombian mining context.

4.1 Occupational Safety and Health

Since antiquity, man has been interested in occupational health, highlighting among the most important studies those of Hippocrates, Pliny and Paracelsus, and Bernardino Ramazzini, who in the Renaissance linked work with health, publishing in 1700 the book *De morbis artificum diatriba*. However, industrial safety was developed only until the First Industrial Revolution. W. H. Heinrich is considered the father of industrial safety thanks to his contributions to its consolidation as an independent science but linked to other disciplines. As mentioned above, there is occupational health and safety. Both concepts differ from each other, being usually used as synonyms since together they seek to guarantee "the minimization of labour risks and the prevention of accidents at work". Occupational health deals with the chronic effects of risks, while industrial safety deals with acute effects (Arias, 2012).

"Industrial safety concentrates on unsafe acts and conditions, while occupational health concentrates on health risks, and as a logical consequence, industrial safety studies accidents and occupational risks with a preventive and research approach, while occupational health studies occupational diseases based on early diagnosis and relevant treatment. Occupational health also encompasses industrial hygiene, occupational medicine and occupational mental health, while industrial safety encompasses ergonomics and environmental analysis." (Arias, 2012, p.45-46).

From Jilcha & Kitaw (2017), the integration of the concepts health and safety is occupational health and safety being the “total wellbeing of the employee at work”. As (Arias, 2012), Jilcha & Kitaw (2017) also declare in other words, occupational health is in charge of the “actions for occupational medicine, occupational hygiene, occupational psychology, safety, physiotherapy, ergonomics, rehabilitation, etc.” while safety covers the “protection of people from physical injury”. In Colombia, the term occupational health was used before the Law 1562 of 2012, which is changed by Safety and Health at Work (Ministerio de Minas y Energía, 2015a).

Within the world of safety, it is important to differentiate what is meant by an occupational risk, an accident and a danger. Occupational risk is understood as the combination of the probability and the consequence of not controlling the hazard, that is, "a combination of the likelihood of an occurrence of a hazardous event and the severity of injury or damage to the health of people caused by this event" (International Labour Office, 2009, p.25). According to (Arias, 2012), risk also includes any "damage to the environment or loss of processes and equipment within a work context". Instead, occupational accidents are "those injurious or fatal events that occur during the workday and that are characterized as violent and sudden, but preventable".

In terms of danger, it is defined as the situation or intrinsic condition that has the potential to cause harm such as injury or illness to personnel, equipment, facilities, environment, in addition to the paralysis of a process (Pico, 2004). Other important terms are "incident" which is "an unsafe occurrence arising out of or in the course of work where no personal injury is caused"; and "occupational disease" defined as a "disease contracted as a result of an exposure to risk factors arising from work activity" (International Labour Office, 2009, p.23).

Although occupational accidents can be avoided, the risks are always present in the working environment, being possible, with management and control, to identify them in order to "determine the level of risk of injury or illness associated with each identified hazard" and to take control measures to neutralize or minimize them. To this effect, a variety of tools is implemented, including the Occupational Safety and Health – OSH Management System, which is "a set of interrelated or interacting elements to establish OSH policy and objectives and to achieve those objectives" (International Labour Office, 2009, p.24). In other words, OSH tries to

promote and keep the physical, mental and social welfare of workers studying the possible damages that could affect the workers negatively, the surrounding communities and the environment by the recognition, evaluation and control of hazards arising in or from the workplace (Jilcha & Kitaw, 2017).

4.1.1 Risks factors

Several authors define risk types and hazards varying one from other just in some assumptions. Regarding to Colombia, the Instituto Colombiano de Normas Técnicas y Certificación – ICONTEC (Colombian Institute of Technical Standards and Certification by its Spanish acronym), is the national organization of standardisation. Its guide, *“Guía para la identificación de los peligros y la valoración de los riesgos en seguridad y salud ocupacional”* (Guide for hazard identification and assessment of occupational safety and health risks), tries to orientate how to identify hazards and assess occupational safety and health risks (ICONTEC, 2012). Likewise, Pico (2004) presents groups of risk factors divided into physical, chemical, biological, mechanical, ergonomic and locative. This classification is, in general, the most widespread, presenting some variations in the name of the groups and the factors they cover, just as presented in Table 1. These risks were selected to present the most common in mining, knowing that there are more than these.

In Colombia exists some decrees dedicated to regulate mining safety in both open pit and underground mines. For the last one, Decree 1886 of 2015 regularise this activity according to its objective, which is:

“To establish minimum standards for the prevention of risks in underground mining work, as well to adopt procedures for inspection, monitoring and control all underground and surface mining work that are related to them, for the preservation of safety and health conditions in the workplaces where such work is carried out” (Ministerio de Minas y Energía, 2015a).

The Decree specifies in its first section, General Provisions, that in abandoned or suspended fronts of exploitation the access of personnel should be restricted by means of protection works and preventive signs that guarantee the safety of the community. It also refers to the work of minors and women, which is forbidden for minors under 18, pregnant women, and it also mentions the entry of animals to work. This first section has eight chapters, being the first about technical definitions (except for Explosive Atmospheres) and references to safety standards such as MSHA, ANSI and ATEX for the certification of equipment, which are of voluntary adoption. Chapter 2 discusses the obligations and responsibilities of application and compliance with this Decree and other legal provisions by those involved (owners, operators, employers and authority, in this case the ANM), as well as the determination of protocols that include inspections and monitoring of mining work, taking into account the parameters of a management system in occupational safety and health. Decree 1443 of 2014 better determines the aspects of this chapter.

Chapter 3 deals with the provisions on training before the competent entities, the retraining of workers to be carried out at least once a year, and defines the content of safety and health training programs for underground mining operations. For its part, chapter 4 determines the measures in terms of Personal Protective Equipment (PPE). These include training in the use of the elements and PPE, their certification, maintenance, replacement and storage, such as equipment for detecting toxic, asphyxiating or explosive gases, equipment for controlling noise and lighting, and equipment for obtaining and analysing dust particles suspended in the atmosphere.

In relation to the competent authorities that carry out the inspection, surveillance and control of the regulations, chapter 5 indicates that it is the competence of the mining authority and that "the personnel responsible for the safety visits must have training and be related to the activities to be inspected and the regulations in force". Chapter 6 deals with the content of the plans and records regarding the progress of the operation, measurements and presence of risks. With regard to preventive and occupational medicine, chapter 7 establishes that the provisions of Resolutions 2346 of 2007 and 1918 of 2009 of the Ministry of Social Protection must be followed. In addition, each mine must have an emergency plan, shelter(s)

inside, necessary elements for first aid, and a trained emergency brigade made up of at least thirty percent (30%) of the mine's workers. In the event of fatal accidents, chapter 8 determines the composition of the committee of experts that will develop the mandatory investigations.

Section 2 refers to aspects of ventilation, such as the ventilation plan, monitoring systems, recording of measurements, qualification of mining work according to the amount of methane present and airflow values according to personnel number, mine elevation above sea level, contaminant Threshold Limit Values (TLV) and machinery used. In section 3, the mines are classified by the coal dust content, factors to be avoided to prevent a coal dust explosion and the determination of their propagation control. It also establishes that control mechanisms must be determined to reduce emissions in operations that generate particulate matter, chemical compounds and biological agents.

Section 4 addresses the generalities of mine support, type of support, inspection and maintenance plans, and defines that the minimum free area of a mine excavation must be 3 m² with a minimum height of one point eighty meters (1.80 m). Section 5 deals with the requirements for transport in galleries, track dimensions and speeds, as well as preventive measures for transport in inclined planes, communication systems, characteristics of locomotives, conveyor belts, panzers, explosion-proof protection measures for equipment, transport of personnel, signalling and handling of silos and/or hoppers.

The measures regarding the handling and control of explosives are indicated in section 6. This indicates how to carry out storage, marking, transport, trade and usage requirements (including permissible safety explosives). The construction, operation and maintenance of underground electrical installations are regulated by the Technical Regulations for Electrical Installations, RETIE, as indicated in section 7. It also prohibits the use of machinery or electrical equipment that is not RETIE certified in underground coalmines. For the machines, section 8 stipulates that there must be an operating protocol and maintenance technical sheet as well, along with a maintenance program for the equipment, machinery and tools, including safety conditions and installation of the winch.

With regard to the presence of fires, section 9 states that measures must be taken to detect and reduce the possibility of fires, to avoid the storage of combustible

materials inside the mine and to have extinguishing equipment. Section 10 deals with provisions related to hygiene and working conditions, such as lighting, use of individual and safety lamps, permissible noise levels, temperature and permanence in work fronts, signalling and demarcation of preventive, prohibitive and informative warnings. The management of surface and groundwater and its drainage is stipulated in section 11. Section 12 takes up prevention, training and attention to mining emergencies from the owner and mining employer to the competent authority, which must train the auxiliary rescue workers and mining rescuers and fulfil the functions established in the corresponding Decree. The mining authority, must provide support services, issue regulations and guidelines concerning the Prevention and Attention of Mining Emergencies and coordinate rescue activities.

Finally, the Decree presents a series of prevention and safety measures in section 13, which include technical surveillance and control visits by the mining authority, registration of the conditions encountered and compliance with the observations, recommendations and measures imposed, and the application of imposed sanctions and fines.

RISK GROUP	Physical	Chemical	Biological	Psychosocial	Mechanical	Ergonomic	Locative	Safety conditions	Natural
RISK FACTOR	<ul style="list-style-type: none"> • Noise • Vibrations • Illumination • Heat and cold stress • Atmospheric pressure • Ionizing radiation (x-rays, gamma, beta and alpha) • Non-ionising radiation (laser, infrared ultraviolet) 	<ul style="list-style-type: none"> • Chemicals in the workplace • Inhalable agents <ul style="list-style-type: none"> - Dust - Gases - Vapours - Fumes - Fibres 	<ul style="list-style-type: none"> • Viruses • Bacteria • Fungus • Parasites • Insects • Fluids or excrement • Animals • Plants 	<ul style="list-style-type: none"> • Organisational management • Characteristics of the organization of work • Characteristics of the social work group • Task Conditions • Working day • Workplace violence 	<ul style="list-style-type: none"> • Faulty tools • Machinery without protection 	<ul style="list-style-type: none"> • Static charge • Dynamic charge • Workplace design • Manual load handling • Repetitive movement 	<ul style="list-style-type: none"> • Lack of signalling • Lack of order and cleanliness • Inadequate storage 	<ul style="list-style-type: none"> • Fire and explosion generating factors • Falling materials • Electrics • Personal safety • Basic sanitation • Confined spaces • Working at heights 	<ul style="list-style-type: none"> • Earthquake • Windstorm • Flooding • Landslide

Table 1: Risk factors.

Source: Own elaboration according to (ICONTEC, 2012; International Labour Office, 2009; Pico, 2004).

4.2 Mining in Colombia

Colombia is a country located in South America which capital is Bogotá C.D. (See Figure 1) with a population around of 50 million of inhabitants. The country bases its economy on four sectors: Agriculture and livestock; industry, construction, mining and energy; foreign trade and tourism.

Made up of 33% by mountains and 67% by low plains, Colombia is divided into three sectors according to its topography. The first is the Andean mountain system, located to the west and formed by the three mountain ranges in which the Andes divide when arriving in Colombia from the south. The second sector corresponds to the low plains that include the eastern plains (Amazonian and Orinoco regions), Pacific and Caribbean coasts. Finally, the independent mountain systems correspond to the third sector or peripheral systems, which have no geological connection with the Andes. In general, the western mountain range has an average height of 2000 m and an extension of 1095 km. The central one is the highest with an average height of 3000 m, the shortest with an extension of 1000 km and morphologically characterized by the high presence of volcanoes and paramos. The most extensive mountain range is the Eastern one with 1200 km, being at the same time the widest one (Mundo Litográfico, 2010).

In terms of hydrography, Colombia has great potential as it counts with an extensive water network that covers the country. Thus, in the mentioned mountain ranges you can find water springs, lagoons, swamps, streams and rivers. In the Andean region, where the largest area of the mountain ranges is located, 70% of the population resides, covering an area that covers one third of the country. The center and west of the country tends to be seismic and various faults cross them, such as the Falla Romeral, crossing almost the entire central mountain range of SE-NW (Mundo Litográfico, 2010). It is precisely this region where the coal deposits are located (See Annex 1), exploited mostly by small miners through tunneling, even when the thickness of the layers can be as thin as 0.40 m.



Figure 1. Geographical position of Colombia.

Source: (Tareas-facil.com, 2018).

4.2.1 Mining Characterization

The mining sector participates on average with 2.2% of GDP (Gross Domestic Product), within which coal extraction is the most important subsector with an annual participation in the national GDP of 1.3%, followed by the contribution of metal ores and non-metallic minerals (each representing 0.4% of total GDP). Colombian mining deposits include coal, vein gold and alluvial gold, nickel, iron ore, nickel ore, and copper (metalliferous minerals); as well as sulphur, construction minerals and industrial minerals, sea salt, land salt and emeralds (non-metallic minerals). By 2016, the mining sector accounted for 21.7% of the country's exports, of which 68% were coal and 23% were non-monetary gold, ferronickel and emeralds (Unidad de Planeación Minero Energética - UPME & Ministerio de Minas y Energía, 2017).

Coal leads the world supply of minerals, being produced mainly in developed countries (such as the United States and Australia) and emerging economies (such as China and Russia). Although Colombia has a high volume of coal production at national level, it only stands out at global level for the extraction of gold. Colombia has more than half of the (high quality) coal reserves in South America and represents the 10% of world trade in this mineral, being the main producer in Latin America and the eleventh of the world. Also, Colombia exports more than 90% of its production, which makes it the fourth largest exporter worldwide (Agencia Nacional de Minería, 2017; Unidad de Planeación Minero Energética - UPME & Ministerio de Minas y Energía, 2017). Potential coal resources and reserves are estimated at 16,569 million tons, 84% of thermic coal and 16% of metallurgic and proved ore reserves at 4,881 million tons, which exploited at the current annual rate, allows extraction for another 183 years (Agencia Nacional de Minería, 2018).

The national economic growth and the collection of royalties are mainly due to the extraction of oil and not to the exploitation of minerals. Even so, according to the Contraloría General de la República - Office of the Comptroller General (2017), Colombia managed to collect \$ 40.3 billion between 2012 and 2016, \$ 32.42 billion thanks to hydrocarbons and \$ 7.84 billion to mining, with its largest contributor being coal with 77%, having an increase in production in more than 1.3 million tons in that period (See Figure 2). The annual production of coal determines the payment of royalties, which are distributed nationally among the departments and municipalities for the financing of investment expenses and their operation, among other sectors of the National Development Plan such as Science and Technology, Health and Housing (Contraloría General de la República, 2017b).

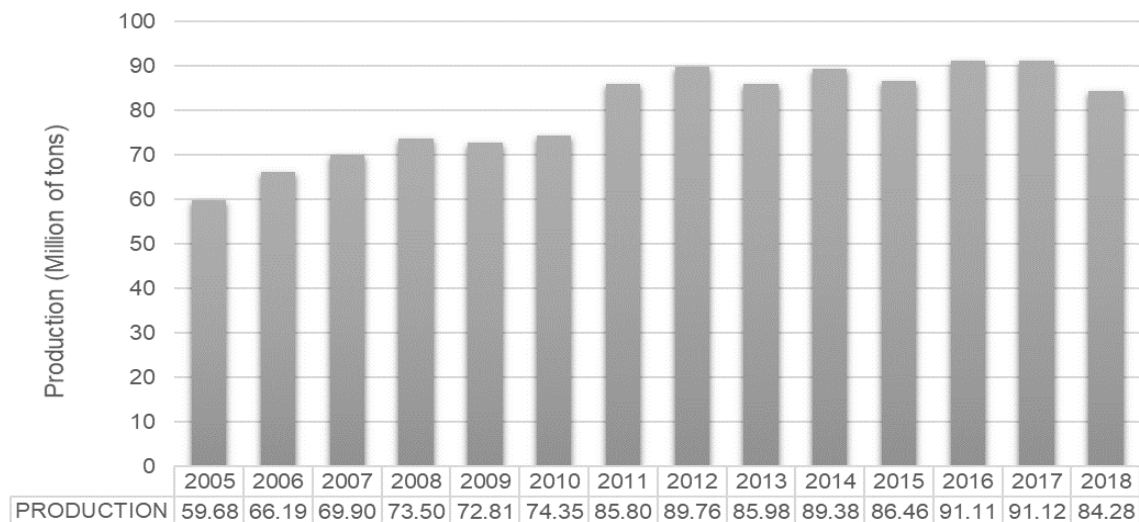


Figure 2. Coal production between 2005 and 2018.

Source: (Agencia Nacional de Minería, 2019).

Coal mining in Colombia is performed by both open pit and underground methods at different scales. The large mining is developed mainly by open pit while the medium and small mining by underground, being the latter the one with the most legal breaches and security problems. Thus, 8.86% of the national coal is extracted by underground from 91.14% of the registered coal mines in force (Agencia Nacional de Minería, 2018). As for unregistered (illegal) mines, there is no exact knowledge of their quantity or status as the number of workers and accidents they present annually.

In order to guarantee the compliance of mining regulations, determine the effective production and apply good practices in the exploration and exploitation of non-renewable natural resources according to technical, environmental, social and operational aspects, the ANM has undertaken the task of supervise the mining titles, which is carried out in two phases. The first is a documentary review of the file of each mining title to verify compliance with the contractual requirements according to the mining stage (exploration, construction and assembly stage, and exploitation). The second phase is a comprehensive inspection visit or field inspection to determine the correct application of mining practices according to technical aspects: safety, hygiene and health; legal, environmental and social (Escobar & Martínez, 2014).

The Government has invested efforts in the realization of mining legalization programs already developed, primarily, since 2001, and programs for traditional mining formalization since 2010. These programs are immediate antecedents to the current control program that aims to finish the problematic of mining illegality that, in general, addresses the aspects of ownership, compliance with mining safety standards and environmental protection, accounting management and compensation payment, introduction of clean technologies and development of business and associative structures among miners (Contraloría General de la República, 2017a).

However, these programs have not had the expected success, incurring great costs for the State without achieving the desired results. The official balance after eight years of implementation of the first legalization program of the new century (in 2001) was: 158 legalized mines (on average 20 mines / year) with a cost per unit of COP 88.6 million without taking into account indirect costs, for a total of current COP 14 billion. Although it is true that the management of the ANM "cannot be measured in terms of contracts signed because the rejections have arisen as a result of non-compliance with the requirements by the interested parties" (Contraloría General de la República, 2017a, p.24), the Legalization Program was only effective at 3.7%.

The above can be an indicator that government programs focused on legalizing mining are not enough to generate a significant change in the sector. As a support to this, the characterization of mining in Colombia is presented below, according to different entities, programs and studies carried out in recent years, which could be helpful to visualize the persistence of negative mining impacts in small mining.

According to UPME's plan "National Mining Development Plan with a 2025 Horizon" (2017), the extractive sector (mining and hydrocarbons) contributes on average 0.6% of the jobs concentrated mostly in rural areas. Of these, the coal industry generates approximately 130,000 legal direct jobs, 30,000 correspond to large open-pit mining and 100,000 to small and medium-sized mining. It is estimated that the sector benefits indirectly almost half a million Colombians through productive linkages, support to the local industry, and purchases of goods and services demanded from other economic sectors for around COP 6 billion (US\$ 1,779,750,000) (Agencia Nacional de Minería, 2017).

From the total of employees, only 9% have higher education, 33% have secondary education, 46% have primary education and 12% have no education at all. The foregoing indicates that mining in Colombia employs about 90% of unskilled or unprofessional labour. Figure 3 shows that this situation did not change in eight years (period between 2008 and 2015) which is important to consider how the Government face the mining problems and its way of planning the mining improvement programs. Of those employed, 97% are self-employed and employees of private companies, and 30% of them contribute to pensions, which is an indicative of a high level of labour informality. This informality, along with the illegality in the sector, limits the exact measurement of the employment generated and the companies destined for this sector (Unidad de Planeación Minero Energética - UPME & Ministerio de Minas y Energía, 2017).

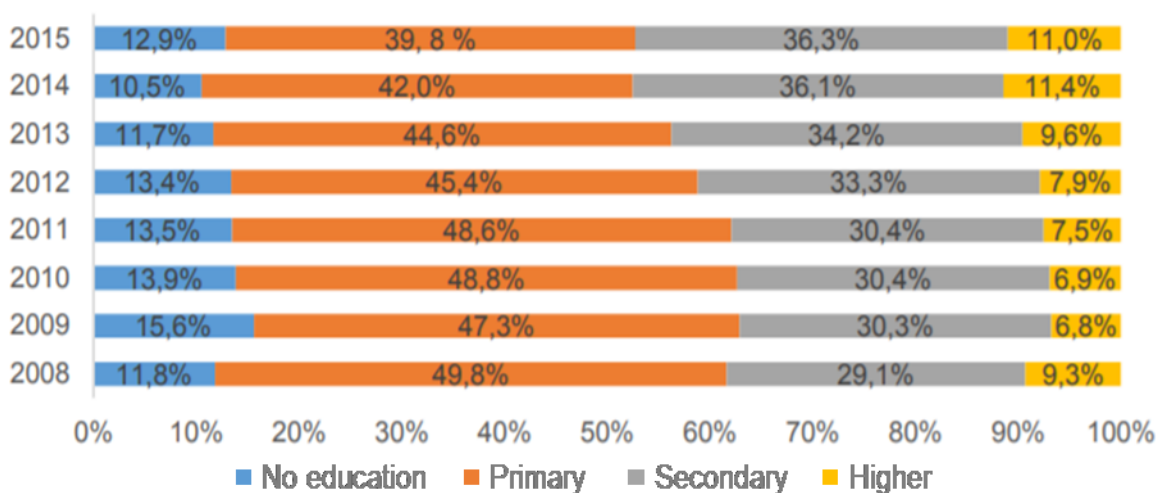


Figure 3. Percentage of population employed at each level of academic education.

Source: (Unidad de Planeación Minero Energética - UPME & Ministerio de Minas y Energía, 2017).

The last Departmental Mining Census was made for the Ministerio de Minas y Energía (2012) conducted in the country in 2011. Its objective was to know the current technical, environmental, socioeconomic, organizational and administrative conditions of each of the UPMs, which serve as a basis for the formulation of projects by government entities for the improvement of the activity and regional development.

For this, 102,742 miners were interviewed to determine their socioeconomic conditions, and following the previous educational description it was noted that those with higher educational level (professional and technician / technologist) work in mines with mining titles while those without education or basic education (primary and secondary) work in illegal mines (See Figure 4). In addition, of the total number of miners, 4.3% (4,439) are foreigners, that is, people from other departments with less than 5 years in the region. Although child labor is illegal in Colombia, 239 children work in mines, 25 in mines with a mining title and 214 in mines without a title.

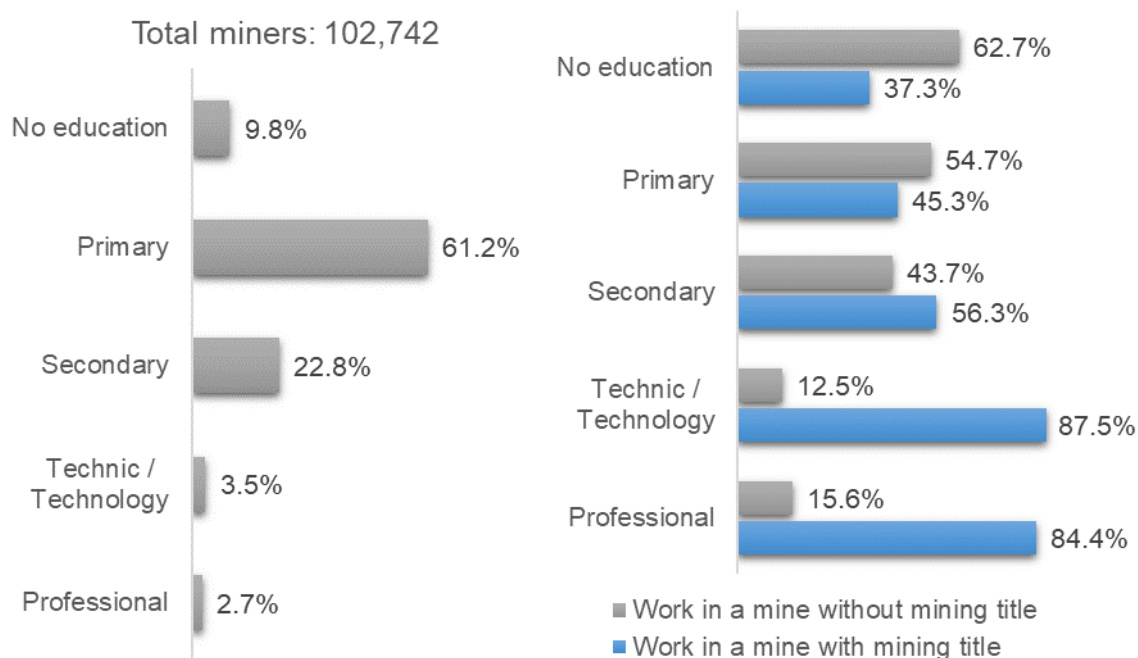


Figure 4. Educational level of the miners.
Source: (Ministerio de Minas y Energía, 2012).

On the other hand, the most frequent contracting modalities are a fixed-term employment contract and an indefinite term employment contract (69.1% and 63.3%, respectively) for units with a mining title, while for those without a mining title, the modalities of piecework, service provision and temporary contracting are dominant (65.7%, 57.9% and 57.0%, respectively) as seen in Figure 5. The days worked per month, as well as the shifts per month and the hours worked per shift do not differ between UPMs with title and without title (See Figure 6). Regarding

the affiliation to social security, Figure 7 clearly shows that those mines without a mining title tend to have a subsidized social security system, and those with title to have a contributory system. The above supports the fact that poor working conditions are linked to illegality.

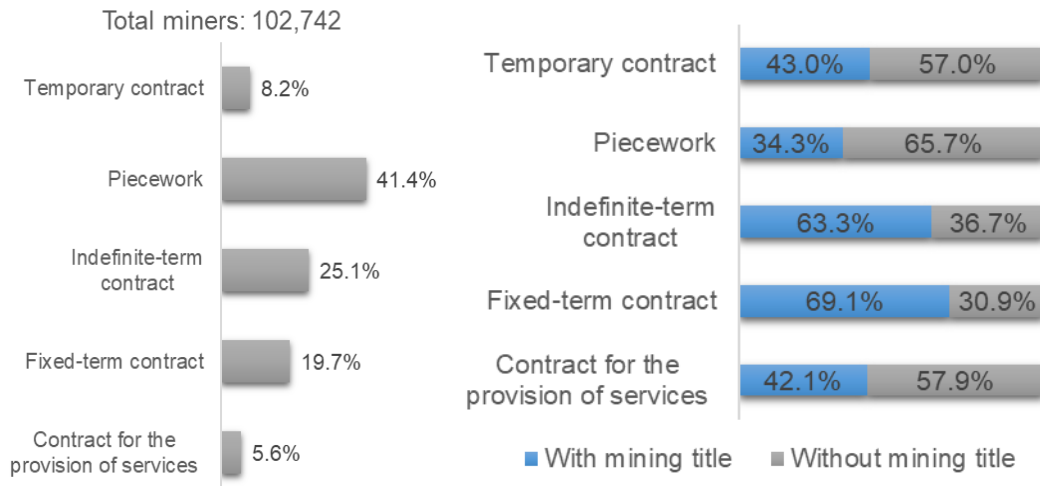


Figure 5. Contracting modalities.
Source: (Ministerio de Minas y Energía, 2012).

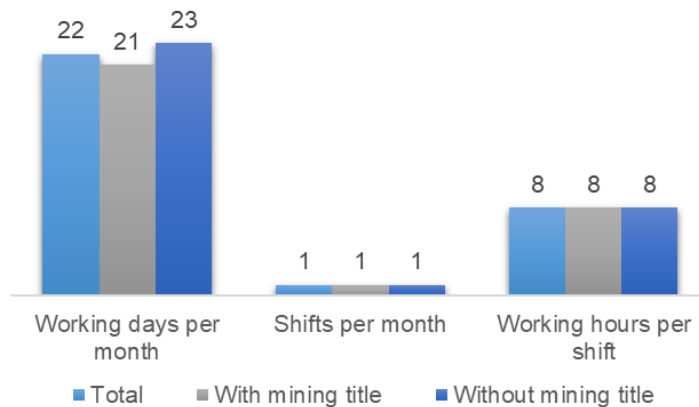


Figure 6. Working hours.
Source: (Ministerio de Minas y Energía, 2012).

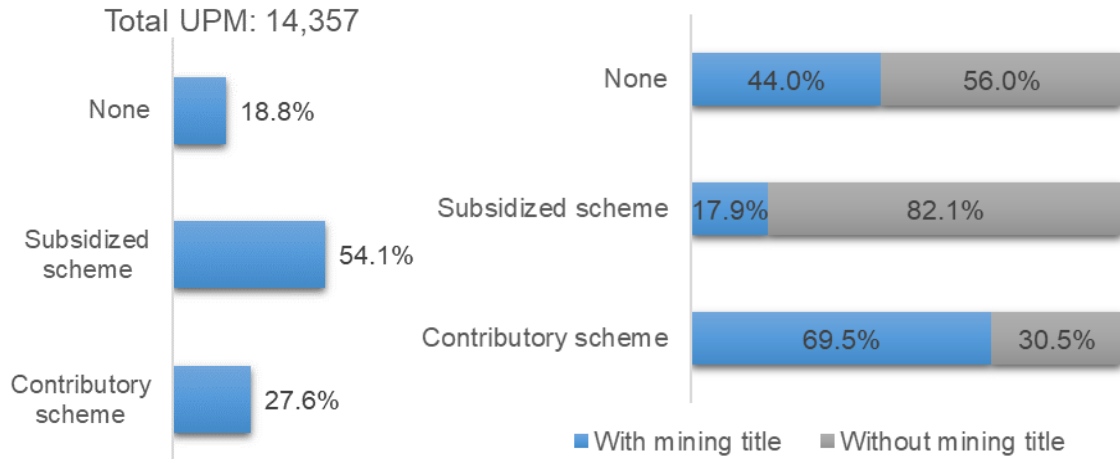


Figure 7. Affiliation to social security.
Source: (Ministerio de Minas y Energía, 2012).

In the census, 14.357 UPM were identified in 23 departments of 31 planned to be registered (Colombia has in total 32 departments), from which 63% of the total have no mining title. From the same census, it was also obtained that, only 60.1% of the UPM that exploit coal had a mining title, 13.6% for metallic minerals, 41.3% for non-metallic minerals and 84.4% for precious stones. Furthermore, the sizes of UPM can vary according to the generation of employment as shown in Table 2. It can be said that 72% of the total UPM have less than 6 employees, 15% have between 8 and 21 employees, 7% of the units with 6 and 7 employees, and the rest (6%) have 22 employees or more. This can sign that mining in Colombia is, in majority (94% has less than 22 employees), made in small scale. According to this census then, it was noted that “the larger the UPM in terms of employees, the more likely it is to have a mining title, but small mines are still predominant” (Escobar & Martínez, 2014; Ministerio de Minas y Energía, 2012).

Regarding the level of administrative development and management of UPMs, 66.5% do not have any type of managerial tool, 30.3% keep an accounting and 19.8% an inventory control. The 55.7% of the UPMs with mining title have a structured accounting while those without title the percentage is 15.4%. Those controlling their inventories are 37.8% and 9.2% for UPM with title and without title, respectively. Finally, of those UPMs with title, only 41.5% do not implement any business tool and for those without title the figure reaches up to 81.2%, indicating

a link among illegality, level of organization and administrative development. In the same way, the census evaluated the state of mining regarding the implementation of safety, hygiene and occupational health actions (See Figure 8). From there, it is noted that 72% of the UPMs do not implement any security, hygiene and occupational health action, as do 50% of the units with mining title and 84% of the UPMs without title (Ministerio de Minas y Energía, 2012).

Quantity of employees	Total		With title		Without title	
	UPM	%	UPM	%	UPM	%
Total	14,357	100%	5,316	37.0%	9,041	63.0%
Less than 6 employees	10,384	72.3%	3,572	34.4%	6,812	65.6%
Between 6 and 7 employees	1,013	7.1%	398	39.3%	615	60.7%
Between 8 and 21 employees	2,201	15.3%	893	40.6%	1,308	59.4%
Between 22 and 28 employees	271	1.9%	132	48.7%	139	51.3%
Between 29 and 100 employees	373	2.6%	236	63.3%	137	36.7%
More than 100 employees	98	0.7%	81	82.7%	17	17.3%
No report	17	0.1%	4	23.5%	13	76.5%

Table 2. UPM census regarding the quantity of employees.

Source: (Ministerio de Minas y Energía, 2012).

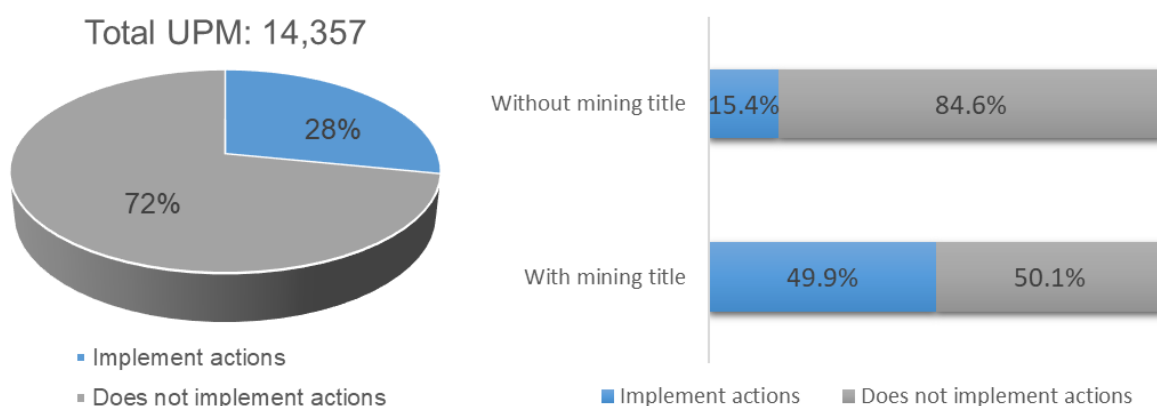


Figure 8. Percentage of UPMs implementing safety, hygiene and occupational health actions.

Source: (Ministerio de Minas y Energía, 2012).

In terms of environmental aspects, it is alarming that of the UPMs with mining title, 47.1% do not have environmental authorization and 81.5% do not have any environmental permits, causing low levels of formality that generate regional negative impacts. Of the UPMs without mining title, 92.6% do not have environmental authorization and 95.8% do not have any environmental permits. Figure 9 and Figure 10 show in detail the percentages of UPMs with and without title that have or do not have any environmental authorization and environmental permits.

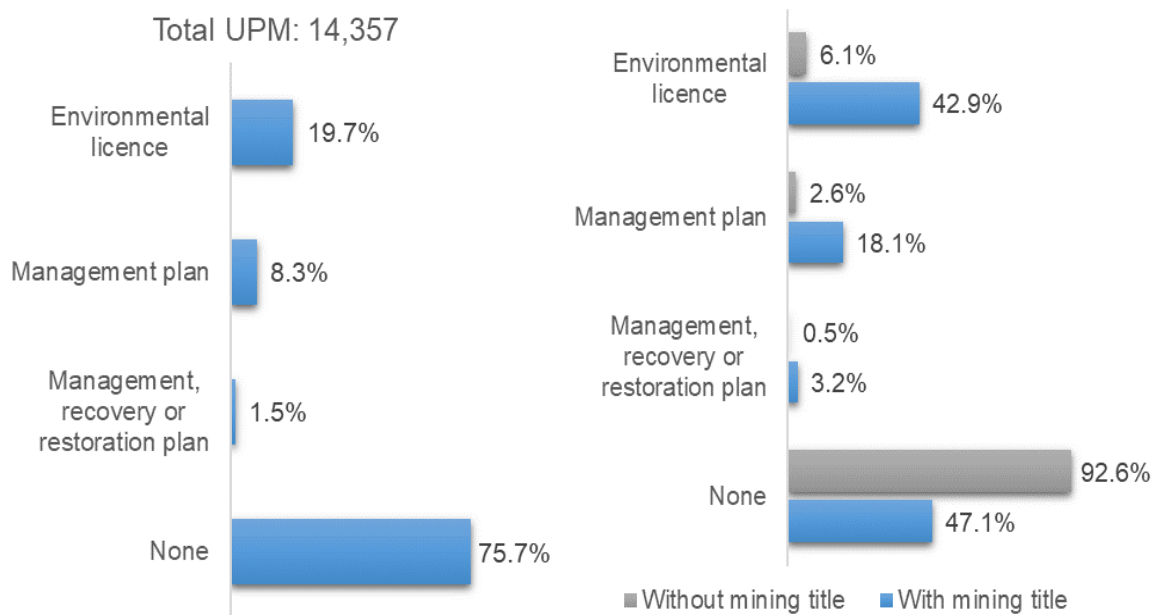


Figure 9. UPMs with environmental authorisation.

Source: (Ministerio de Minas y Energía, 2012).

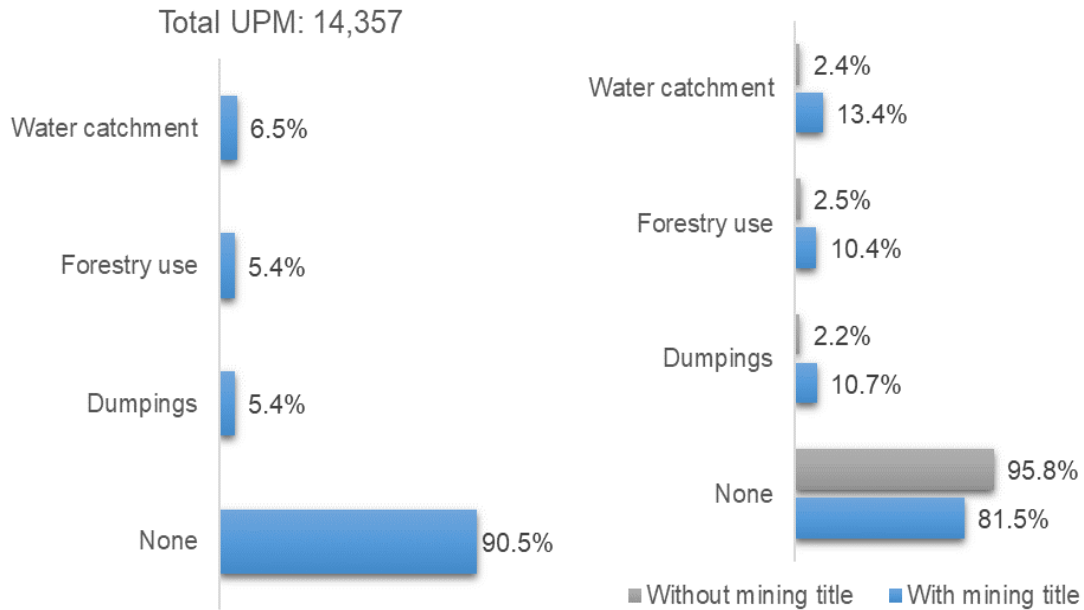


Figure 10. UPM with environmental permits.
Source: (Ministerio de Minas y Energía, 2012).

By 2016, Colombia had 8,866 mining titles, 7,996 in force and 870 temporary authorizations, which represent 3.8% of the country's total area (4,377,993 Ha of 114,218,901 Ha). Of the titles, 1,127 are in the exploration stage, 1,014 are under construction and assembly, and 6,725 are being exploited. Construction materials represent the most exploited mineral with 40% of the mining titles, followed by gold and precious metals (22%), other materials (18%), coal (16%) and emeralds with 4% (ANM, 2016). Around 68% of the ownership of mining titles is at hands of natural persons and the rest at hands of holders with legal personality (ANM, 2015a). Besides, the extraction methods implemented are heavy machinery (63%), drilling and blasting (15%), artisanal (14%) and pneumatic hammers (9%) (ANM, 2013).

The extraction of minerals is an activity that demands the execution of different tasks and occupations such as transportation, construction and maintenance of infrastructure and equipment, the use of telecommunications, among others. With this, a wide chain of supplies is necessary, invigorating the economy around minerals directly and indirectly as consequence. In Colombia, the aim is to reinforce a mining productive chain, since this task articulates different economic sectors, generating jobs and royalties directly, and demanding goods and services

indirectly that in turn stimulate employment. (ANM, 2015b). Thus, the analysis of mining safety is not limited exclusively to the activity of extracting the ore or developing the mine. Mining safety goes back and forth in the life cycle of the product, being important to consider aspects such as the acquisition of safe tools or the sale of legal coal extracted with good practices.

4.2.2 Mining Types in Colombia

In Colombia, there are different types of mining in terms of compliance with the requirements of the law. These include formal, informal, legal, illegal, traditional, 'de facto' and subsistence mining. The majority are defined in the Technical Mining Glossary (See Table 3) from the Ministerio de Minas y Energía (2015b), but the legislation in Colombia has multiples definitions for mining, which are used interchangeably, preventing a single classification of small-scale mining. For example, the mentioned glossary does not present the concept of 'de facto' mining, an illegal practice where the miners exploit the lands without the mining title but are in formalization process.

As stated, this study is focused on small coal mining presenting the different types of mining mentioned throughout the Colombian territory, as well as the three types of mining according to the scale of production and the mining method that may have any of the legal figures mentioned, which are defined in the following section.

TYPES OF MINING	DEFINITION
Artisanal or subsistence	<p>Mining type exercised since before Law 685 of 2001, in a specific area on a continuous or discontinuous way, by natural persons or groups of natural persons or associations without mining title registered in the Registro Minero Nacional – RMN – (National Mining Registry), in mineral deposits owned by the State and which, due to the socioeconomic characteristics of these and the location of the deposit, constitute the main source of maintenance and income generation for these communities, in addition to be considered a source of regional supply extracted minerals. This mining is also informal and may be subject to formalization processes.</p> <p>It is the mining activity developed to open pit of sands and gravel of river destined to the construction industry, clays, precious metals, precious and semiprecious stones, performed by manual tools, without the use of any type of mechanized equipment or machinery for its exploitation, reason why it will not include the mining activities developed in underground mining.</p> <p>It is performed by people who dedicate their work force to extract some mineral by rudimentary methods, such as 'barequeros'¹ and the occasional extraction of clays in their different forms and construction materials.</p>
Legal	<p>Mining covered by a mining title, which is the written administrative that grants the right to explore and exploit the mining soil and subsoil of national property, according to the Mining Code. The mining title must be registered in the RMN.</p>

¹ Barequero: Miner who extracts gold through the barequeo procedure.

Barequear: To extract the gold of the deposits washing in a pan the sand in which the mineral is found to separate it of this one.

Asociación de Academias de la Lengua Española. (2010). Diccionario de americanismos. Retrieved from <http://lema.rae.es/damer/>

Illegal	Mining developed without being registered in the National Mining Registry and, therefore, without mining title. It is developed in an artisanal and informal way, outside the law. It also includes works of exploration without mining title. It includes mining covered by a mining title, but where the extraction, or part of it, is done outside the area granted in the license.
Formal	Formed by exploitation units of variable size, operated by legally constituted companies that comply with the permits to operate and have titles.
Informal	Consisting of small and medium sized operating units, individually owned without any kind of accounting records.

Table 3: Classification of types of mining in Colombia.

Source: (Ministerio de Minas y Energía, 2015b).

4.2.3 Mining Classification According to the Scale and Stage

According to the stage, exploration, construction and assembly stage, and exploitation, mining in Colombia can be classified in small, medium or large. For the first two stages, classification depends on the area conferred to every mining title and for exploitation is related to the production.

CLASSIFICATION	N° HECTARES
Small	Less or equal to 150
Medium	Greater than 150 but less or equal to 5,000
Large	Greater than 5,000 but less or equal to 10,000

Table 4. Classification of mining to small, medium and large scale in exploration or construction and assembly stages.

Source: (Ministerio de Minas y Energía, 2016).

The volume of maximum annual mining production determines the classification of mining titles in the exploitation stage into small, medium or large mining and according to the mining method (Underground –UG– and Open Pit –OP–). In the event that a mining title presents both methods of exploitation, the one that generates the greatest volume of production will be taken for classification.

MINERAL	SMALL		MEDIUM		LARGE	
	UG	OP	UG	OP	UG	OP
Coal (ton/year)	<60,000	<45,000	>60,000 to 650,000	>45,000 to 850,000	>650,000	>850,000

Table 5: Classification of mining to small, medium and large scale in exploitation stage.

Source: (Ministerio de Minas y Energía, 2016).

In Colombia, major coal production becomes from the north with the 90% of the total national production. This region owns large open pit mines legally registered. Small and medium miners exploit the remaining 10%, especially by underground

methods and in an informal and illegal way. Escobar & Martínez (2014) indicate that approximately 54% of mining titles have an area of less than 100 hectares, that is, they are small titles, and 44% of the titles are of medium scale, representing a total of 98% of the titles. Also, 47% of coal mining titles are less than 100 hectares, indicating that formal mining is far from being mature. Regarding the informal, the information is imprecise because the mining control by the ANM is only performed on legal units, making it difficult to account and characterize illegal mining. However, the Departmental Mining Census obtained information on both formal and illegal mining. From there, it is highlighted that 63% of the sites did not have a mining title, that is, they are illegal, which is an index of the size of informal mining in the country. Of the total of the registered UPM (14.357) 19% correspond to coal exploitations, of which 40% do not possess a title (Ministerio de Minas y Energía, 2012).

4.3 Small-Scale Mining

Small-scale mining in Colombia, as has been said, represents 72% of the country's mining, being an activity carried out with less than 6 employees in an area less than 150 hectares, with a production for the case of coal, lower at 60,000 ton / year for Underground and less than 45,000 tons / year for Open Pit (See Chapter 5.2). This activity is present worldwide, covering countries such as Canada, China, Bolivia, England and Peru. The general and international definition for Artisanal and Small-Scale Mining (ASM), according to the Organization for Economic Co-operation and Development - OECD (2016), describes the practices as:

“Formal or informal mining operations with predominantly simplified forms of exploration, extraction, processing, and transportation. ASM is normally low capital intensive and uses high labour intensive technology. ASM can include men and women working on an individual basis as well as those working in family groups, partnerships, or as members of cooperatives or other types of

legal associations and enterprises involving hundreds or even thousands of miners. For example, it is common for work groups of 4-10 individuals, sometimes in family units, to share tasks at one single point of mineral extraction (e.g. excavating one tunnel). At the organisational level, groups of 30-300 miners are common, extracting jointly one mineral deposit (e.g. working in different tunnels), and sometimes sharing processing facilities". (p.65).

According to Chaparro Avila (2003), the main characteristic of small mining is the impossibility of defining it universally, because as mentioned in the Colombian case, there are different meanings according to different parameters. Even so, some of its qualities are presented in Table 6.

<ul style="list-style-type: none"> • Intense use of manpower • Low level of technological development • Supplying local markets • Wide range of products • Environmental damage • Employment option in poor areas 	<ul style="list-style-type: none"> • Precarious safety and health conditions • Social and legal conflicts • Low production costs • Many stakeholders involved • Variable volume and size according to the mineral and the region • Encourages larger projects • Stimulates local economies 	<ul style="list-style-type: none"> • Takes place worldwide • Generates local production chains • Encourages geopolitical development • Explores new deposits • Widespread geographical distribution
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Table 6. Characteristics of small-scale mining.

Source: (Chaparro Avila, 2003).

In addition, small-scale mining presents high levels of legal informality, low business management, poor working conditions and low fiscal profitability to the states (Chaparro Avila, 2003). ASM provides ten times more jobs than large-scale

mining, being 20-30 million of the world's poorest people that works in these mines, and five times said quantity that support their lives by this mean. From this number, 10.9-12.5 millions are from Latin America and in total they generate the 15-20 % of minerals and metals globally (Buxton, 2013; Chaparro Avila, 2003). These activities are carried out in vulnerable, remote areas with high levels of poverty, becoming in many cases the only opportunity for subsistence for some populations.

Since mining is conditioned by market conditions and thus, by demand and supply of its products, many unemployed miners in times of low demand turn to the exploitation of old mining areas or the invasion of legal areas in order to obtain some product for its survival. Also and unfortunately for them, small mining is usually stigmatized as criminal mining, which, although it causes social damages in many cases and leaves environmental liabilities that the State must solve, it often stands for the economic source that energizes regions.

4.3.1 Unitary Processes

Usually, small miners implement unitary processes to extract coal. According to Cardona Trujillo & Carmona García (2017), these processes can be defined, roughly, as:

- *Barroteo or piquero*: It is the action of extracting coal from the mantle that, in turn, can be executed in three ways: manual, with dynamite or with rotary hammer.
- *Drag*: It refers to the action of carrying coal from the working front to a main road within the mine, which is equipped with rails and can be accessed by car or trolley. This activity is carried out using one of three different elements: tow, plastic can or plastic can with PVC (Polyvinyl chloride) coating on the base.
- *Carriage and winch*: the car or transporting car is filled with the coal that has been transferred from the work front; once full, the car is taken out of

the interior with the help of a winch, which consists of an electric motor that collects a metallic cable attached to the car.

- *Selection or patiero*: Once the coal has been extracted from the interior of the mine, it is selected according to its diameter.

In Jiménez-Forero, Zabala, & Idrovo (2015) other work functions are defined on the surface and in depth, such as the *frentero*, which is responsible for creating access to the coal mantle and installing the tunnel support, either using a pneumatic hammer and / or explosives. According to Figure 11, these processes can be executed manually or mechanically depending on the availability of equipment.

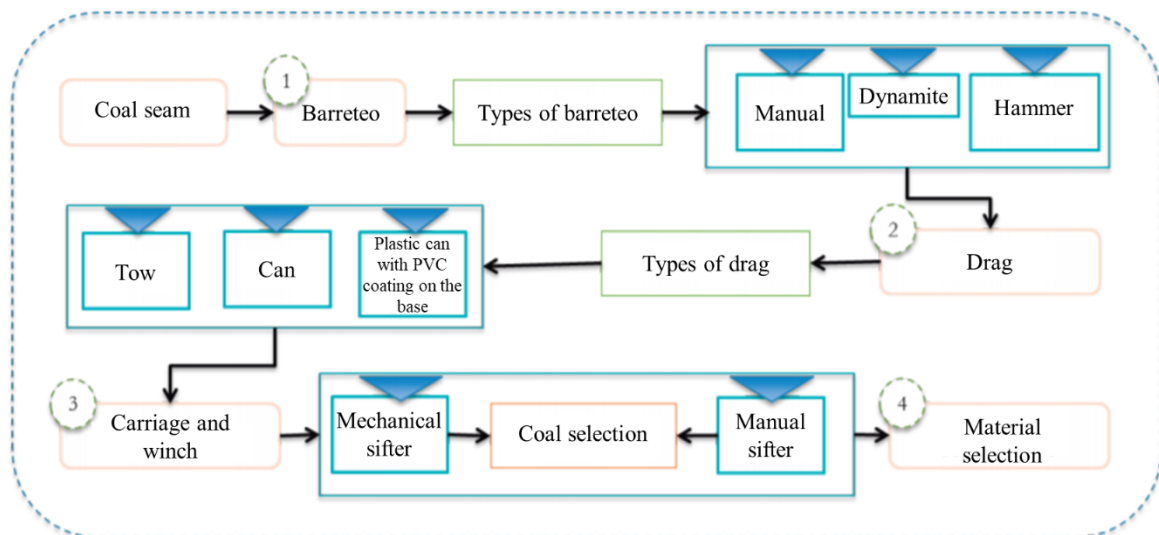


Figure 11. Basic process of coal extraction (ROM) from the small and artisanal enterprises in the Sinifaná basin.

Source: (Cardona Trujillo & Carmona García, 2017).

As mentioned, open-pit mining predominates in the north of the country, which is usually highly technical and large-scale, while underground mining and low-tech mining prevail in the interior of the country. According to the degree of technification, the *Unidad de Planeación Energética - Mining and Energy Planning Unit* (2012) defines each type of mining as:

- *Technological or large-scale mining*: Characterized by having a strong technological infrastructure that allows the efficient development of mining activities (exploration, exploitation, transport and shipping), as well as managing their control and monitoring thanks to high investments.
- *Moderately technified mining*: With lower investments that allows to have technology, knowledge about the exploration and exploitation of the mineral and a certain degree of environmental control.
- *Small scale and subsistence mining*: This activity is developed by hand, without technology and with manual starting. Given the lack of exploitation designs, it is associated with pollution, deterioration, erosion and destabilization of the land.

The efficiency of the mining processes depends among other things on the geological environment of the productive unit and the extraction method implemented. Thus, technical mining is associated with economy of scale, which reduces the competitiveness of small-scale mining since it must face the same challenges as large-scale mining with a weak economic support. As an example, transportation, an expensive activity that increases the price of exploitation and trade of the mineral, compel small miners to associate in order to face said investments.

On the other hand, productive efficiency is affected by illegal extractions that negatively affect the social, environmental and economic landscape. Several aspects that hinder the eradication of this type of mining: the lack of opportunities and training in other vocations in rural areas, the management given by local authorities to this activity, and the support of legal producers and traders who often trade with illegal miners, seeking to achieve their sales goals. This point is crucial in mining safety, since these practices encourage unsafe activities linked to illegality (Unidad de Planeación Minero Energética, 2012).

In illegal mining, it is common to implement inefficient, unsafe and polluting materials, such as mercury in gold amalgamation, homemade explosives in production fronts and wood in support pillars. The use of these materials has a negative impact on the environment, affecting not only the health and safety of the

mining workers, but also the surrounding communities. Although the technological development in mining has advanced, allowing having efficient methods and equipment that reduce or mitigate emissions, the human factor and environmental responsibility are still commonly neglected, despite being crucial in the efficient coal production.

Thus, large-scale mining faces optimally responsible production, addressing risk prevention, mitigation and control. The contrary occurs in small-scale mining, where due to its low profitability, commercialization and management, it does not include an environmental assessment within its work. Although there are other alternatives to promote responsible and efficient extraction, such as "green coal", an export of clean coal through the certification of emission reduction by implementing reforestation programs, small-scale mining in Colombia continues to be very far from a significant change or said implementations (Unidad de Planeación Minero Energética, 2012).

5 Mining Safety in Figures

The duty of each mining operation is to keep records of its different activities and create quality indicators to achieve the proper functioning of the work. In terms of occupational safety, different factors are recorded, such as the number of employees, hours worked per shift, number of accidents (daily, weekly, monthly, annual), number of fatalities, occupational diseases, among others. Given the focus of this research, it is important to show and understand accident statistics, since they are indicators of the correct (or incorrect) functioning of mining activity in Colombia and provide support for the attention and prevention of accidents to in terms of responsible mining.

5.1 Colombia

In Colombia, the Agencia Nacional de Minería – Nacional Mining Agency (ANM) is the responsible institution to manage the state mineral resources through the granting of titles, monitoring and control of mining exploration and exploitation. Within the ANM, the Mining Safety and Rescue Group was created to carry out inspections in mining operations, training and education programs, monitor and control mining safety and hygiene, and manage emergency response (Grupo de Seguridad y Salvamento Minero, 2019). Likewise, it has also instructed more than 2,500 rescue workers and assistants for the Sistema Nacional de Salvamento Minero - National Mining Rescue System, but as indicated by the statistics, greater efforts are required by the State to change the situation.

The “Consolidated Accident Statistics 2005-2018”, presents the figures on accidents and fatalities in mining, classifying them according to cause, mineral, type and scale. Figure 12 is a review of the main causes of mining emergencies in which landslides, explosions and damaged atmosphere for the presence of toxic gases by absence of sufficient oxygen are predominant. Between 2005 and 2018 in Colombia occurred 1,202 emergencies encompassing underground and surface

mining as well as several minerals and mining scale. The same situation is presented in Figure 13 for the fatalities in the mining sector.

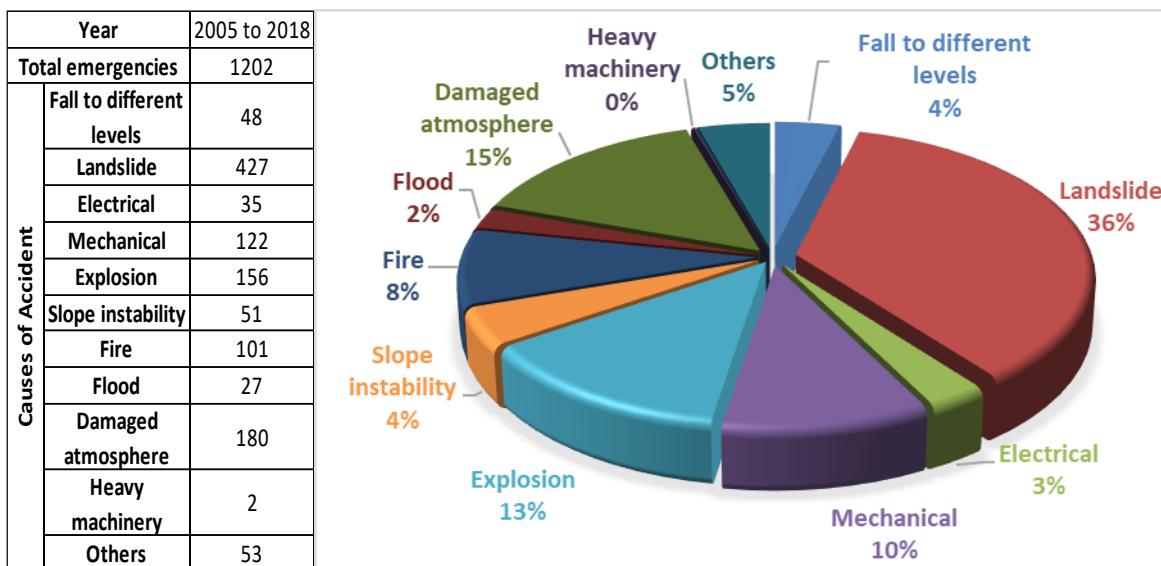


Figure 12. Causes of mining emergencies occurred between 2005 and 2018.

Source: Own elaboration according to (Grupo de Seguridad y Salvamento Minero, 2019).

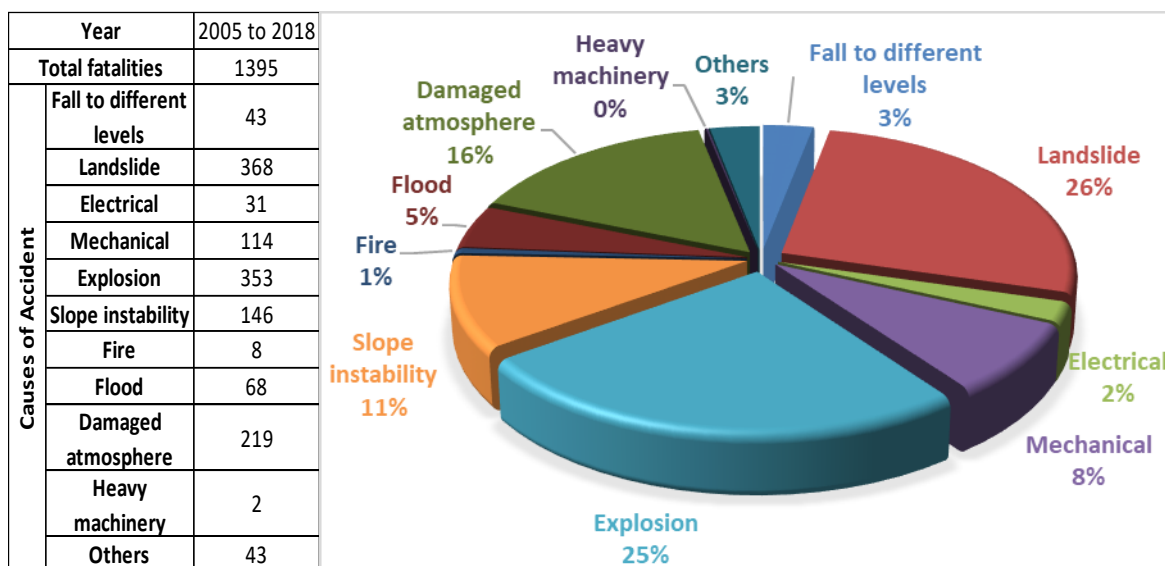


Figure 13. Causes of mining fatalities occurred between 2005 and 2018.

Source: Own elaboration according to (Grupo de Seguridad y Salvamento Minero, 2019).

Every year, mining in Colombia takes the lives of dozens of miners and triggers the loss of machinery and infrastructure due to the associated risks to this activity,

including the limited control and management in the exploitation. Figure 14 resumes the emergencies between 2005 and 2018, classifying them in *unharm*, *casualties* and *fatalities results*. For example, in 2010 an emergency caused by an explosion at the San Fernando mine in Amagá, Antioquia, left 73 miners dead, the biggest catastrophe that year (Jaramillo-Urrego et al., 2017).

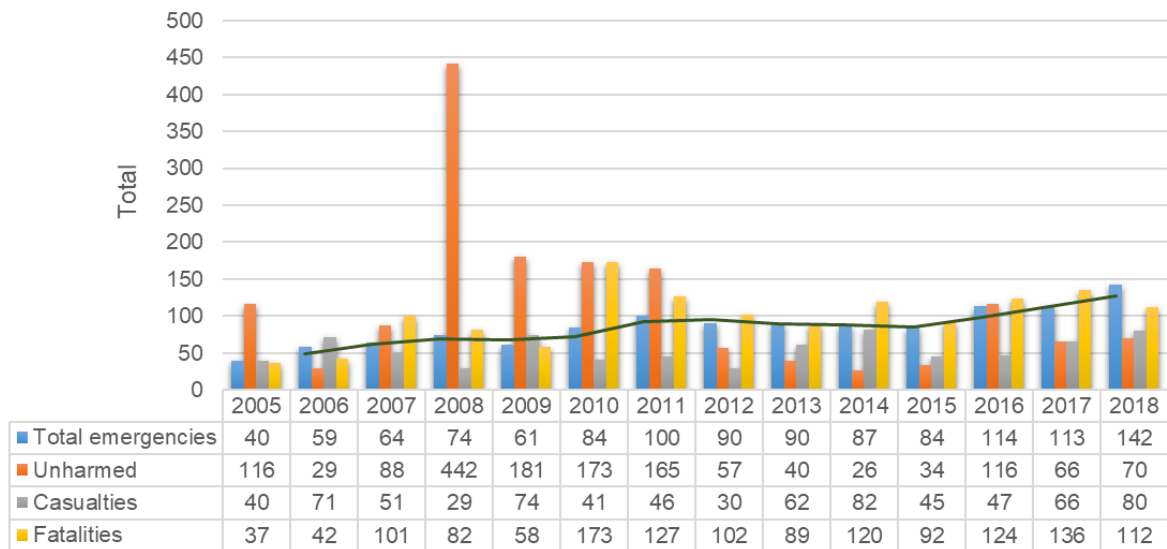


Figure 14. Yearly mining emergencies occurred between 2005 and 2018.

Source: Own elaboration according to (Grupo de Seguridad y Salvamento Minero, 2019).

The ANM also categorised the emergencies and fatalities by type of mineral. Reports indicates that coal mining is the most dangerous activity with 77% of the emergencies and 73% of fatalities, followed by vein gold with 16% and 13% respectively (See Figure 15). Knowing the predominance of illegal mining in Colombia, the ANM registers the emergencies and fatalities in two categories, legal and illegal, as presented in Figure 16, which at first sight depicts legal mining with the largest values, resulting this odd despite the regulations and compliances. The last figure corresponds to the emergencies and fatalities by mining method, *open pit* or *underground*. The last method represents the 93% of the emergencies and 87% of fatalities, as represented in Figure 17.

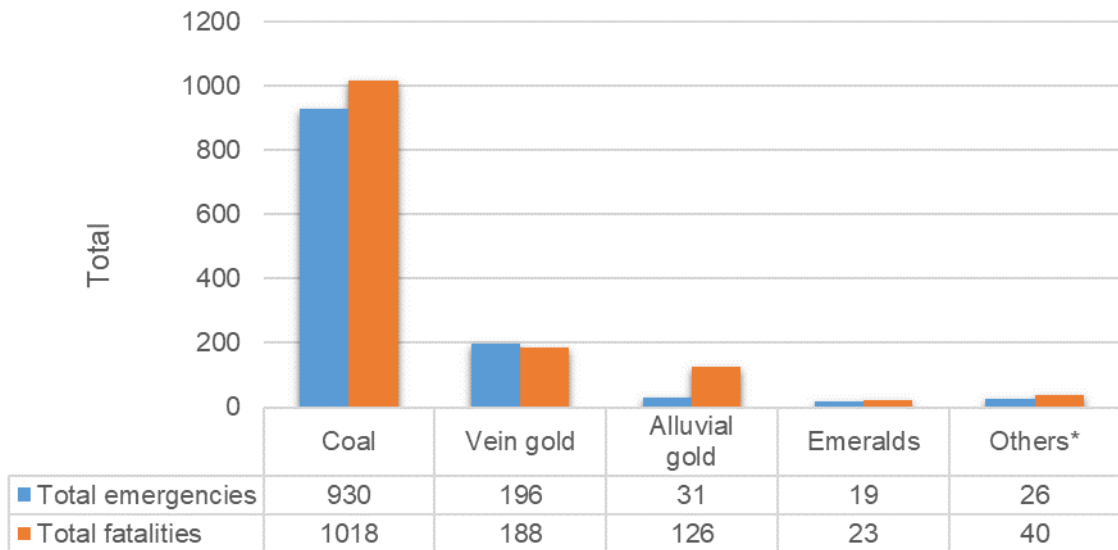


Figure 15. Mining emergencies and fatalities occurred between 2005 and 2018 by type of mineral.

Source: Own elaboration according to (Grupo de Seguridad y Salvamento Minero, 2019).

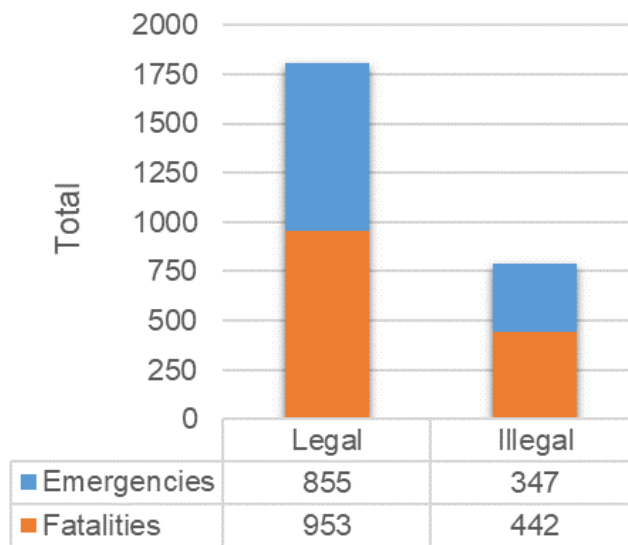


Figure 16. Personnel affected in mining emergencies occurred between 2005 and 2018 by mining type.

Source: Own elaboration according to (Grupo de Seguridad y Salvamento Minero, 2019).

*: Others include limestone, salt, sulphur, sand, hydrocarbons, construction materials, etc.

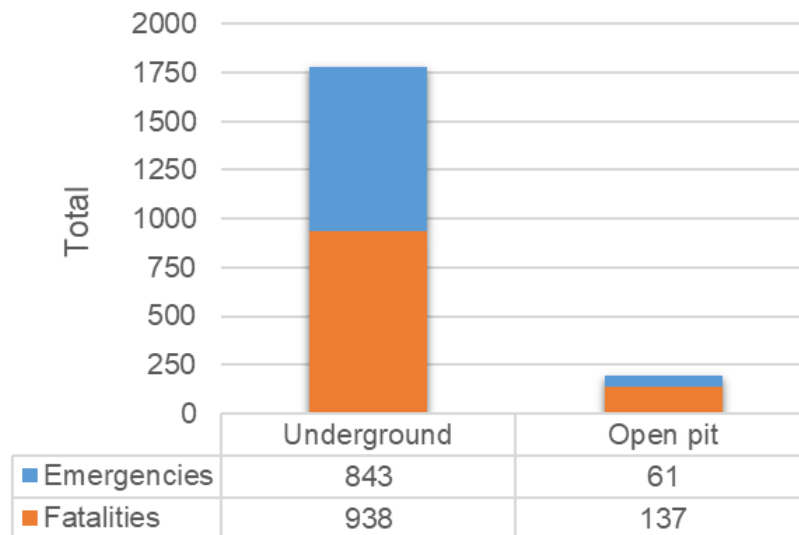


Figure 17. Personnel affected in mining emergencies occurred between 2005 and 2018 by mining method.

Source: Own elaboration according to (Grupo de Seguridad y Salvamento Minero, 2019).

5.2 USA

The National Institute for Occupational Safety and Health (NIOSH) is a federal agency, part of the Centers for Disease Control and Prevention from the United States with almost 50 years working on research for prevention of work-related injury and illness. According to MSHA (Mine Safety and Health Administration), there were 13,294 mining operations by 2015, classified as surface (95.1%) and underground (4.9%), 11% are coal (1,460 mining operations), 9.3% metal and non-metal (1,239) and 79.7% stone and sand & gravel (10,595) (Centers for Disease Control and Prevention, 2017a). U.S. is one of the biggest coal producers with an amount of 774.6 million of short tons (MMst) by 2017, representing an increase of 6.4% (See Figure 18); 273.129 short tons extracted from 367 underground mines and with a total of 31.487 employees (U.S. Energy Information Administration (EIA)., 2018).

There are 349,847 employees, of which 292,790 are full-time equivalent (FTE) employees, 82% work on surface and 18% in underground work locations. The 68% are mine operator employees and their numbers of hours worked comprised 81% against 32%, being these independent contractors with a numbers of hours

worked of 19%. As Figure 19 shows, the mine operators by sector were divided by 2015 in 19.6% for coal, of which 48% work at underground locations and the remaining 52% at surface. The 19.3% for metal and non-metal, and 29.1% for stone and sand & gravel; contractors are distributed in 9.8% for coal and 22.2% for non-coal (Centers for Disease Control and Prevention, 2017a).

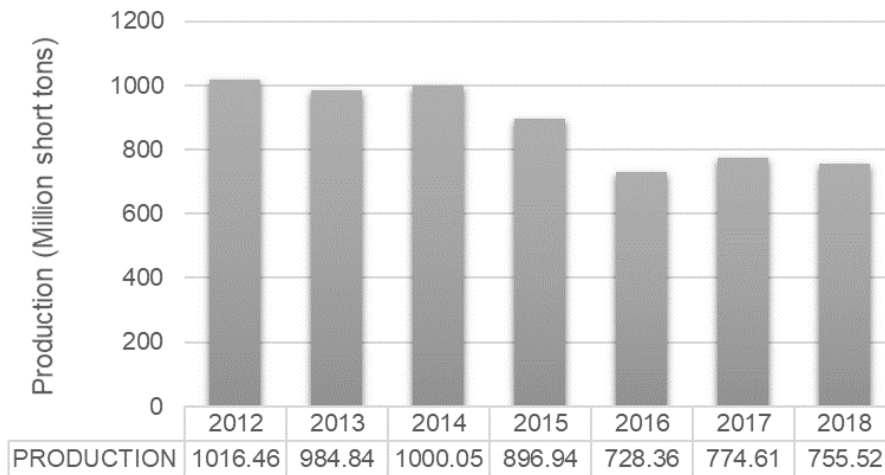


Figure 18. U.S. coal production, 2012 – 2018.

Source: (U.S. Energy Information Administration (EIA), 2018).

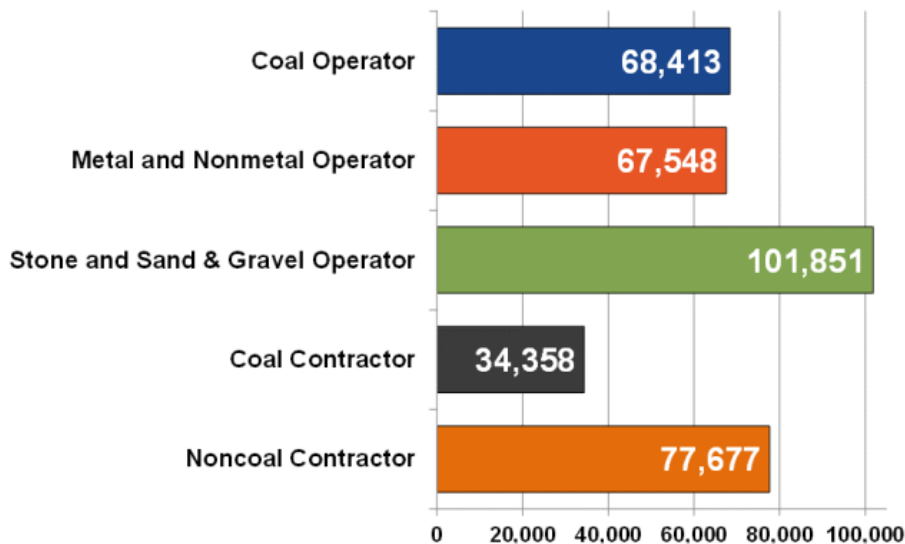


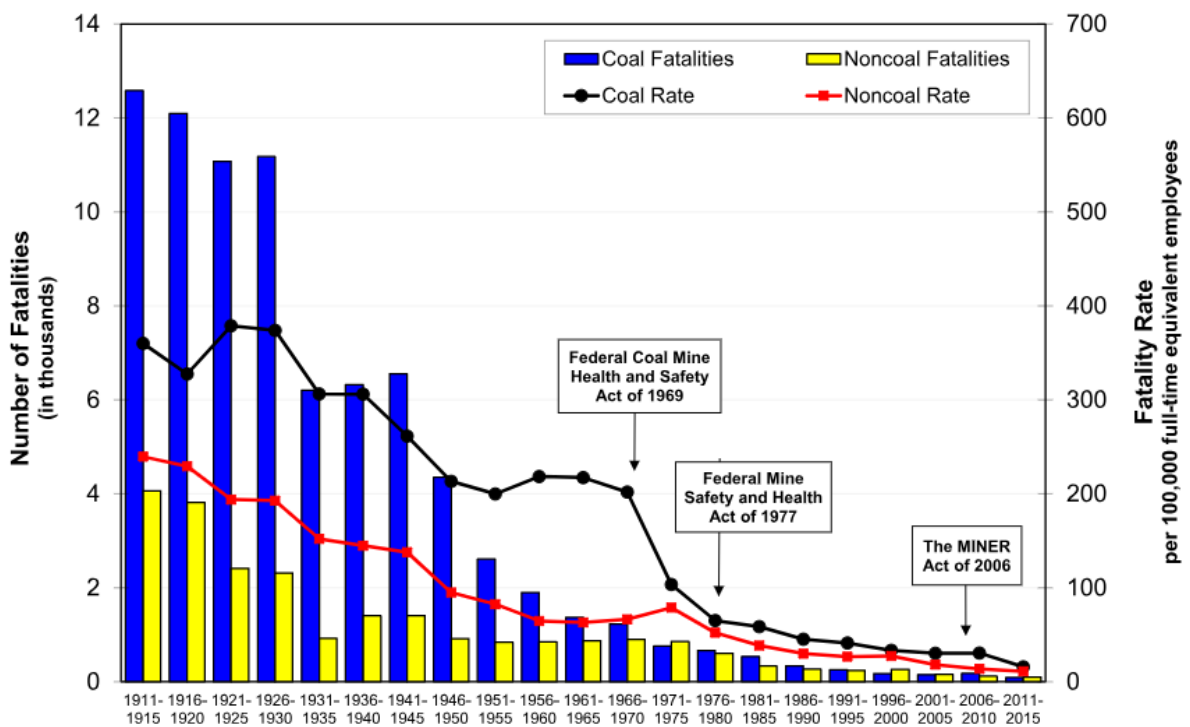
Figure 19. Employees by industry sector, 2015.

Source: (Centers for Disease Control and Prevention, 2017a).

Regarding fatalities, 57.7% occurred at surface and 42.3% at underground work locations, presenting the coal industry the highest number with 42.3%, followed by

the stone and sand & gravel (30.8%) and the metal and nonmetal (26.9%). The overall fatality rate for 2015 was 9.8 per 100,000 FTE employees, 20.8 for underground workers, and 7.0 for surface. In 2015, 9 occupational fatalities were reported in coal mines, 8 of them in underground facilities. The fatality rate was 12.8 per 100,000 FTE employees, which has presented a decrease over the years, reaching similar numbers to other minerals, how is presented in Figure 20 (Coal fatalities include underground and surface locations).

According to an accident classification, by 2015 the coalmine operator fatalities occurred specially due to fall of ground (n=3); powered haulage (n=2); machinery (n=2); falling, rolling, or sliding rock or material (n=1); and slip or fall of person (n=1). In the same way, the nonfatal lost-time injuries were 1,643 at underground 1,210 and 433 at surface (See Figure 21), principally for handling materials and slip or fall of person, presenting also bigger figures at underground workings (Centers for Disease Control and Prevention, 2017a).



NOTE: Excludes office employees. Noncoal includes metal, nonmetal, stone, and sand & gravel operations. Sand & gravel miners included starting in 1958. Hours for 1911-1923 computed on assumption that weighted average length of workday was 9.36 hours. Full-time equivalent employees (2,000 hours = 1 FTE employee). Data source: USBM and MSHA

Figure 20. Number of fatalities and fatality rates (5-year aggregates) in the mining industry by sector, 1911 – 2015.

Source: (Centers for Disease Control and Prevention, 2017b).

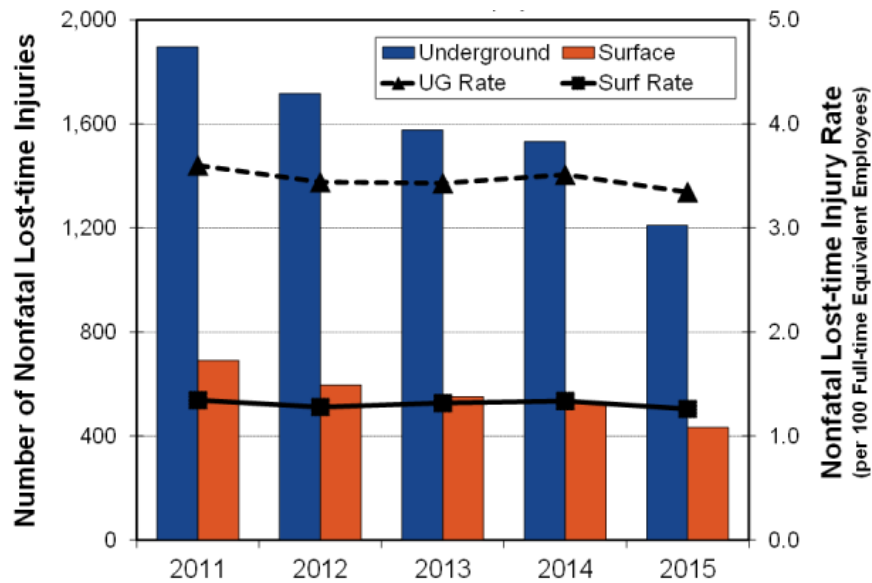
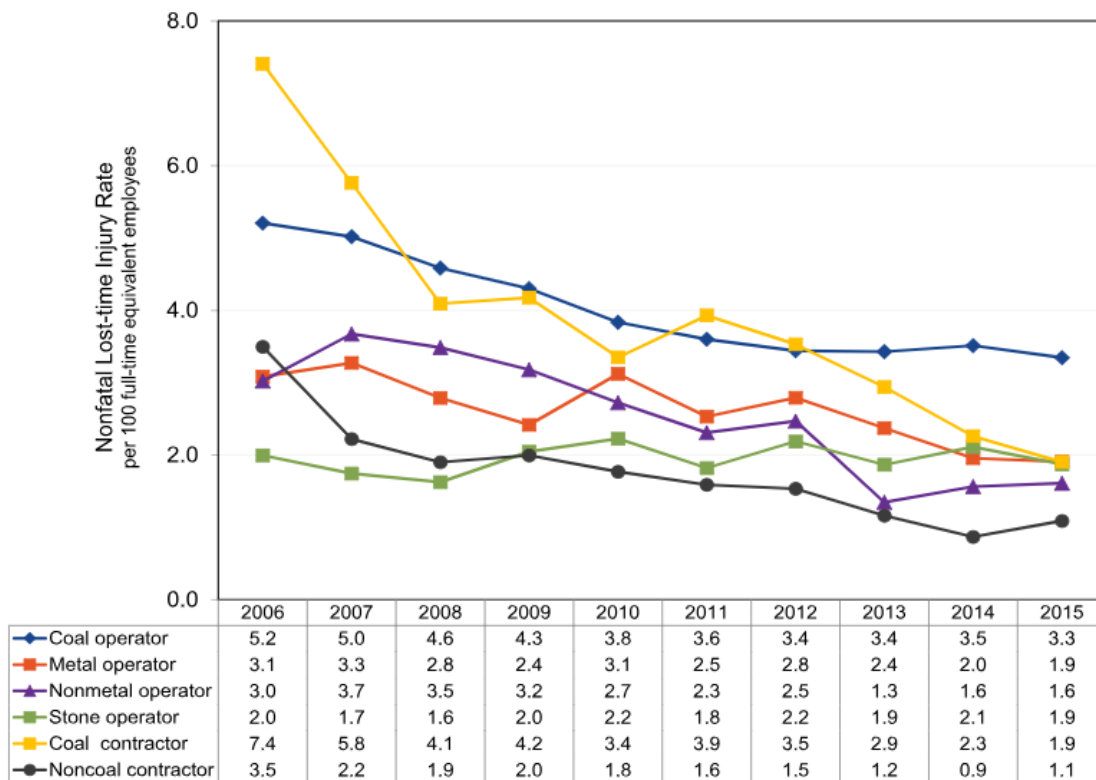


Figure 21. Coal mine operators' nonfatal lost-time injuries by work location and year, 2011-2015 (excludes office employees).

Source: (Centers for Disease Control and Prevention, 2017a).

Figure 22 portrays nonfatal lost-time injuries rates variation according to the mineral and employees (operators and contractors), presenting coal the greatest values. By Centers for Disease Control and Prevention (2017a):

“Injury rates were computed using employment estimates as derived from total hours worked. Full-time equivalent workers (FTE) were calculated by dividing total hours by 2,000 hours/worker. Nonfatal injury rates were constructed per 100 FTE, and fatal injury rates per 100,000 FTE. Of note, MSHA publishes both fatal and nonfatal injury rates based on 200,000 hours, which is equivalent to 100 FTE”.



NOTE: Full-time equivalent employees (FTE) computed using reported hours worked (2,000 hours = 1 FTE).
Data source: MSHA

Figure 22. Rate of nonfatal lost-time injuries at underground work locations by commodity, 2006 – 2015.

Source: (Centers for Disease Control and Prevention, 2017c).

5.3 China

With a production of 3,523 million metric tons of coal for 2017, China is the world's largest coal producer. This is the 46% of the world coal production and is the largest consumer worldwide with the 51% (Coyne, 2018). Despite advances in mining science and technology have allowed reducing the number of fatalities and injuries, the number of economic losses and people still remains worrying, added to the fact of the negative social view. China is responsible for approximately 70% of the global coal fatalities due to different causes, being the most dangerous one the accidents caused by gas explosions, as it occurred in Baoma Mine, Inner Mongolia Province on 3 December 2016, leaving 32 human losses (Meng, Liu, Luo, & Zhou, 2019; Yang et al., 2016) (See Figure 23).

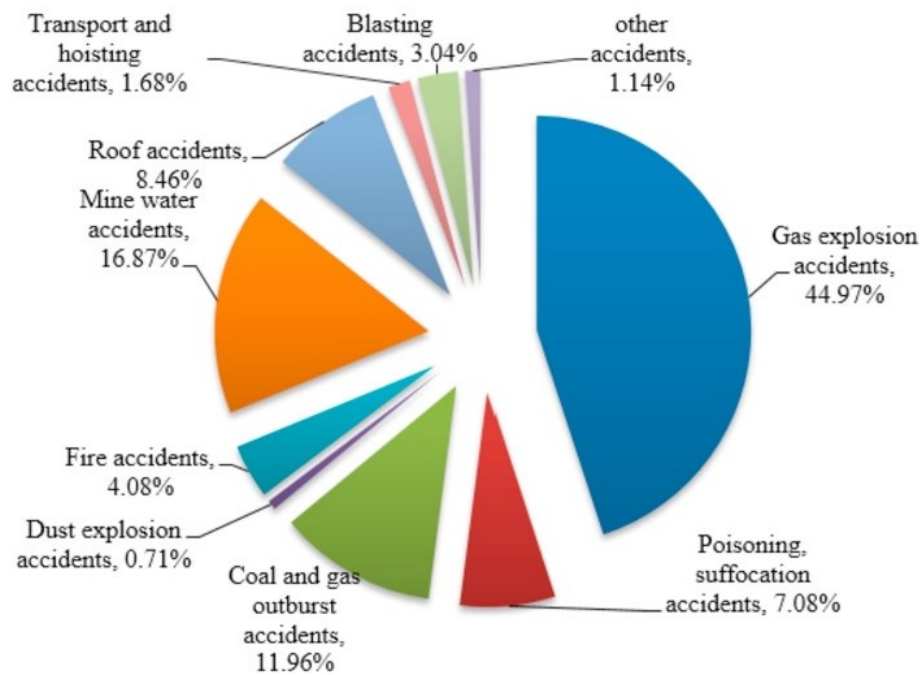


Figure 23. Percentage of casualties associated with different types of accidents in 2001–2015.

Source: (Meng et al., 2019).

The Chinese government and academics have destined efforts in reform coal mining safety through the implementation of advanced equipment, internal safety management of the enterprises, and external supervision systems and risk management tools among others, improving the safety performance as is shown in Figure 24. However, this also depends on the internal and external related industries (as electric power enterprises, railway sectors, and coal transportation) that could affect the safety investment decisions of the mine (Liu et al., 2017; Meng et al., 2019) and the human safety behaviour as, according to literature, more than 90% of accidents can be attributed to unsafe conducts (Yang et al., 2016).

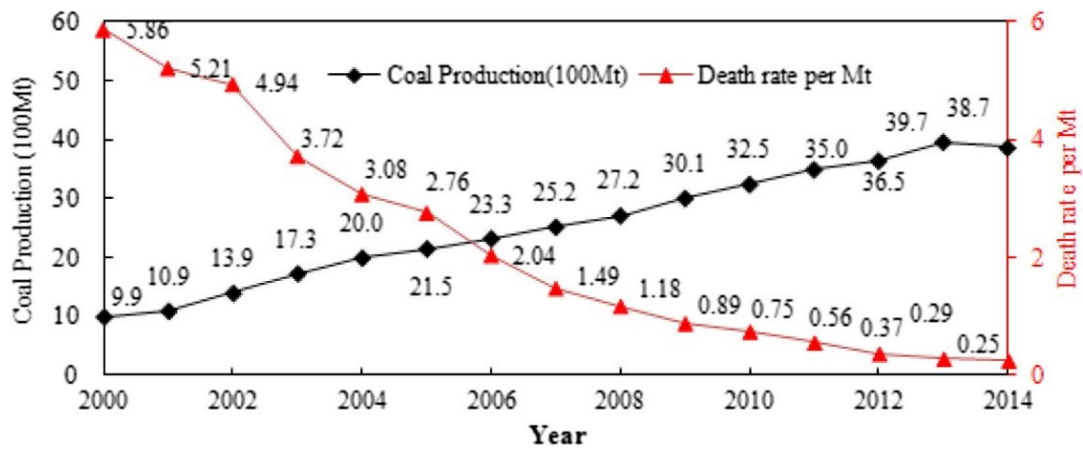


Figure 24. China's fatality rate per million tonnes in coalmines from 1949 to 2015.

Source: (Yang et al., 2016).

6 Best Practices in Mining – Discussion

Many studies have been conducted on mining risks as well as proposals to minimize, mitigate, control or eliminate them as ideal. Although each risk factor has its particularities and each mine is different from the other, the solutions posed by different authors tend to be similar and applicable in different contexts. Therefore, a summary of some measures implemented on mining risks will be presented, emphasizing those that strongly affect Colombian mining. Firstly, the discussion will refer to the concept of good practices as a guide.

Best practices are "technical instruments that consolidate models for the improvement of the management, managerial and environmental performance of the productive sectors" and "includes community participation and the linking of industry with the population, care for the environment and the creation of new development opportunities" (Chaparro Avila, 2007, p.16).

Similarly, according to the European vision of best practices, it refers to "individual actions, both in professional activity and in other vital areas, carried out based on criteria of respect for the environment" (Chaparro Avila, 2007, p.12). Thus, good practices are subject to international standards, the result of experience and the repetition of the same according to successful cases, and takes into account the nature and specific conditions of each work environment being of voluntary application.

In addition, the implementation of these good practices not only reinforce the risk avoidance due to social and labour conflicts, but also promotes the efficiency of the activity by managing and planning any possible unforeseen production, that is, ensuring the sustainability of the project.

This is important because it tends, as defined, for the proper management of the mining work, protecting the natural and social environment. In addition to this, within a healthy social environment, health and safety are immersed as transcendental factors. The (Superintendencia de Riesgos de Trabajo, 2016) defines the best labour practices and gives some actions to prevent and mitigate the risks, being:

“The behaviours and interrelationships in the workplace that generate features of the decent work paradigm and respect for fundamental human rights related to work, being important to highlight those experiences or practices related to health and safety ... They contribute to achieving the goal of reducing precarious work and, on the other hand, that companies can be effective promoters of decent work. The most important thing to bear in mind is that these practices not only refer to compliance with regulations, but also cover all aspects of the labour relationship within organisations.” (p.12).

Implementing safety standards can be considered as a good practice, such as the ISO 45001 standard for Occupational Safety and Health Management Systems. However, it is not the objective of this research to describe and list a series of existing recommendations rather than to bring them up and analyze aspects not considered yet (standards, standards, laws). Table 7 shows some control measures for some risks within the many actions that can be taken.

The existence of risk in small mining as mentioned in Table 1 is constant and its sources are poorly controlled or, in many cases, unidentified. Thus, Ospina Díaz, J., Manrique Abril, F., & Guío GARZÓN (2010), present in their study a brief yet complete depiction of the traditional small mine in Colombia and its working conditions.

“Some mines are found in suitable houses as camps; the three-wire electrical service is deficient (220 V); in times of rain, the work is considerably affected as the mine walls do not have an adequate infrastructure. In general, the maintenance of the mining works is in ordinary condition, presenting risks of accidents in some mines; natural ventilation, through communication with neighboring mines; auxiliary fans with plastic ventilation duct are used for the advance of blind fronts; the main evacuation path of the material is inclined. The load extracted in the fronts with manual spout is evacuated with shovel to a car with an average capacity of 1,000 kg, with tire wheels. Electric pumps and discharge pipes are used In the drainage of accumulated water, the waters are taken to the surface and discharged to pipes and gutters,

without any treatment. For the purposes of operating the machinery and lighting, there is a network of community transformers throughout the area; all mines have electric lighting installed, personal lighting is not used, but in some cases carbide lamps are available. The connections are disorganized and lack of adequate installation; cables of different diameters and brands are all damaged. 72.4% of respondent employees work under the surface, performing tasks as coachman or picador; the average time of work experience is 10.2 years. The average duration of the workday is 7.44 hours (SD = 2.2). The work envelope is usually an overall, gloves and helmet "(Ospina Díaz, J., Manrique Abril, F., & Guío GARZÓN, 2010, p.110-112).

Like the PDCA cycle (Plan-Do-Check-Act), good practices aim to improve existing ones, which will depend on the time, place and actors involved. Thus, a community of miners will have a criterion on what is best for them, perhaps very different from that of an occupational safety technician, based on their experience and perception on how to protect themselves from the risks to which they are exposed in their workplace.

A very important concept when assessing occupational health and safety in mining is perception. This is usually relegated to the humanities and social sciences, as it is not a technical approach. The perception of risk by the exposed population and their control mechanisms are key factors in the determination of policies and proposals to improve mining work. Perception is very important, as it depicts the general understanding of the mine situation through the sensory signals, specifying the flaws and virtues of the workplace. The way miners perceive, live and see their reality may or may not differ from the rest of the population, constituting certain social relationships, languages and, in the labor context, behavior and safety standards according to the individual and social perception of risk. This perception is influenced by the experience, tradition, education, culture and communication received from the daily environment. As indicated by (Jiménez-Forero, Zabala, & Idrovo, 2015), said risk perception is related to:

"The definition of risk, its potential to cause harm, the time between exposure and the manifestation of harm, the anthropogenic or natural origin, the equitable distribution of risks and benefits in society, its potential effects on future generations, the ability to control, its familiarity, habituation, voluntary exposure or not, and environmental values, among others ". (p.78).

As example, in order to investigate the relationship between the perception of working conditions and labor morbidity in the coal mines of Guachetá, Colombia, (Jiménez-Forero et al., 2015). They decided to approach their study from the perspective of the subject, that is, they accepted the knowledge of the miner about their safety and occupational health as valid, being complementary to traditional study. Among the results, they highlight the fact that the miners recognize as risky activities those that generate immediate negative effects, such as musculoskeletal disorders, and do not perceive as risky those whose effects require a period of extensive latency, such as respiratory diseases.

Thus, the implemented security actions may or may not be accepted according to the level of importance that the miner places on risk. The study reveals that 22.1% of the surveyed sample do not have knowledge or perceive safety in their work, while 29.9% perceive safety in a medium to low range. Clearly, the fact that a miner feels healthy despite not being it will influence the protection measures taken, along with how they perceive what protects or bothers them. For example, a miner who has been exposed to coal dust for years may not yet have the symptoms of pneumoconiosis and may feel that the mask hinders him from working, which is why he does not use it. Therefore, the interventions intended in terms of improving mining safety should be differentiated according to the problem without forgetting the vision of the miner, in order to raise awareness.

The characteristics of mining have been presented and described, with special emphasis on small-scale mining, the mining situation in Colombia, the working conditions and some demographic aspects of the miners. The reader has also been contextualized in occupational health and safety, types of risks prevailing in mining and some good practices to minimize or control them. Clean technologies are a reality implemented in several countries, as well as administrative and management tools, legislation and sustainable methods of exploitation

documented in large databases. However, this information becomes important as, despite all this, the mining problem in Colombia persists on showing insignificant improvement indexes. Aside, the Government and some NGOs have carried out various mining legalization and formalization programs, with the purpose of training miners in the use of best practices. Proof of this are the programs carried out by institutions such as the Ministerio de Minas y Energía - Ministry of Mines and Energy; UPME; ANM; Servicio Nacional de Aprendizaje - National Training Service (SENA) and the Ministry of Labor, as well as different public and private universities and NGOs, such as Alliance for Responsible Mining - ARM and USAID. Among the calls, there are trainings, diplomas, and legalization and formalization projects with small formal, informal and artisanal miners.

Regarding the role of the State, one of its functions is to periodically inspect mines and ensure that they comply with current legislation correctly. In Colombia mines should be visited at least once a year, however, taking into account the number of mining titles (14,357) it is clear that this goal cannot be met, not even satisfactorily, this meaning an exhaustive review of each aspect considered in the inspection: infrastructure, administration, production, among others.

Unfortunately, in Colombia the inspectors are miners who often do not have the fundamental experience nor the basic knowledge of each mining area to evaluate the singularities of each mine. In USA, the MSHA must inspect each underground mine four times per year, and even more often those mines with high levels of explosive or toxic gasses. Likewise, the MSHA is strict with inspectors, who must be trained in all aspects of mining and meet other requirements, such as an electrical capacitation test in case of wanting to occupy an Electrical Inspector position. In the Colombian case, it could be an alternative to focus the inspection, without neglecting the others, on those titles presenting the most problems, in order to support them rather than sanction them.

Although the Colombian standard describes different practices in each activity and sector of the mine, its content and applicability is poorly executed and explored, which makes it necessary to consider complementary rules, such as ATEX for Explosive Atmospheres. Although Decree 1886/15 of Colombia indicates that standards such as ATEX should be implemented, it only recommends them since they have a non-mandatory applicability. As example, the lack of gas measuring

equipment leads the miners not to measure concentrations or to do so not as often by means of the loan of devices. This, along with the use of natural ventilation and a single access tunnel with adequate infrastructure, makes the work environment even more unsafe.

In China, gas explosion accidents are the foremost threat to safety, as is shown in Figure 23, while in Colombia it represents one of the main causes of accidents and the main cause of fatalities in coal mining. Jaramillo-Urrego et al. (2017) declares that Colombian legislation mentions aspects as “safety for infrastructure, communities, environment, equipment, and workers in mining facilities [...] but in a shallow manner, having a more administrative approach perceived as a regulatory lack, since it belongs to a more industrial scheme that does not have the appropriate analysis for mining-associated risks and prevention mechanisms.” China, meanwhile, although it has reduced its figures, is still struggling to eliminate mining accidents.

For this purpose, the *risk management* was widely adopted, which “coordinates activities to direct and control an organization with regard to risk” (Meng et al., 2019) based on the *risk assessment* that assesses the probability and the consequences of the mining hazards to cause any harm. In risk assessment, it was recognized that most of the gas explosion accidents are triggered by the unsafe behaviours of human action, such as underground smoking, mishandled gas emissions and omission of gas monitoring. In order to reduce them, a persistent risk management of unsafe behaviours is highly recommendable, if not mandatory.

In Colombia, the training given to the miners addresses the issue of safe behaviors and personal care, yet accidents and casualties are still happening. As the pictures in Annex 2 show, small-scale miners carry out their activity in an insecure environment, plagued by risks that constantly endanger their integrity; bad postures, precarious signaling, incompetent infrastructure and scarce usage of PPE are just some of the notable risks in Annex 2.

Many miners recognize the importance of self-care. However, in practice they tend to neglect its importance, sometimes mentioning the discomfort generated by using PPE or carrying tools as the self-rescuer. Then, the issue is not merely of technical knowledge, but a persistent inherited cultural heritage that could perhaps

be altered by the smart articulation of disciplines as social sciences and engineering. For example, of the different risks triggered by socially accepted behaviors in the small-scale mining sector, there is the consumption of alcoholic beverages, which are consumed frequently and, since there is no strong control over the health conditions and habits of the worker, is easy and common to enter the mine under the influence of alcohol.

On the other hand, the main cause of mining accidents in Colombia are landslides, which corresponds to the geological conditions and methods of exploitation implemented. Not only Colombia is crossed by several geological faults, but it also is a hydrologically rich region that, along with the rainy seasons, can generate multiple landslides per year on the main roads. As small-scale mining is based on empirical knowledge and the lack of rigorous climatological measures, accidents are highly expected yet not forewarned.

Coal mantles up to 40 cm are usually exploited in completely insecure ergonomic positions and under little or no sustained/fortified structures. Likewise, knowing that mining generates high environmental and social impacts, its development under illegality and informality can magnify them at scales out of control. The need to obtain daily subsistence income means that territorial zoning rules are also violated, illegally exploiting areas declared reserves or banned for exploitation given their geological risks. Although the government often identifies and closes some illegal mines, small miners are knowledgeable about their territories and therefore create new accesses from other points of the mountains, seeking access to the precious mineral. This creates a network of abandoned yet re-exploited tunnels that contribute to the instability of the massif, as the illegal do not have a mining plan that includes cartographies and work mapping.

On the other hand, armed and organized groups outside the law profit from mining to finance their practices, contributing to the problem of public insecurity. Thus, the degree of accidents and fatalities could be much underestimated given the large unreported informality. Besides, although the trade of coal extracted from conflict or reserve areas is not very large (since the largest amount of coal comes from mines belonging to multinationals) it is important that the State takes control over those areas, since part of the smaller production (small and medium-sized miners) is illegally traded.

However, the responsibility also falls on those traders who encourage illegality by not buying legal coals. This has an impact on mining safety, since illegal and informal workers are encouraged to continue with their illegal practices in the market that allows them, although poorly paid, to sell their products.

The Colombian coal potential will allow the country to exploit this mineral for dozens of years, which requires a strengthening in the sector of both state institutions and their regulations, as well as exploitation in the regions, their methods and social dynamics. The Government's proposals to achieve this have not shown the desired success and impact, so it is worth asking what else could be done and how. Hence, when looking at the mining statistics on production and accidents in other countries such as the U.S. and China, it is concluded that in Colombia the backwardness and negligence when it comes to the normative and application of good practices is indeed serious.

By 2015 the coal production in USA was 896.9 million of short tons, from which 306.8 million of tons were extracted from 405 underground mines (Centers for Disease Control and Prevention, 2017a), having only nine occupational fatalities as already stated. According to Figure 24, China produced 38,7 billion tons of coal by 2014 and in the same period the fatality rate per Mt was 0.25. (Yang et al., 2016) indicate that for this year China had 931 fatalities and 509 accidents regarding coalmines. Although they do not differentiate accidents in coal mining by open pit and underground, the figure contrasts with Colombian mining data. Colombia produced on average 87 million tons of coal per year between 2014 and 2015 and had 106 accidents and 64 casualties. By looking at the data, it could be affirmed that mining in China generates many more accidents than in Colombia. However, just by looking at the production/accidents-fatalities rate, the ratio of fatalities in Colombian mining due to bad practices results even more worrying.

In Colombia, coal is the most exploited mineral that generates accidents and fatalities, surpassing underground mining to the open pit modality, with 93% of the emergencies and 87% of fatalities. Added to this, underground mining only produces 9% of coal. Then, it is not intended to imply that underground coal mining should be restricted or banned in Colombia, but rather to encourage the State to strengthen this activity by safe and contextual means, reducing the accident rates and taking into account the involved communities.

As a possible solution, models of *associativism* among miners could be implemented so that they can supply economically high cost activities for a small miner, such as the geology and management of SISO.

Geological-mining information is dispersed and divided according to government institutions. Even so, the existing information is insufficient and highly questionable since, for example, many geological mappings are outdated and their access is complicated. It also happens with the knowledge of informal mining and its magnitude. The last mining census occurred in 2011 and, to date, the figures could be very different from those presented in the absence of continuous monitoring. This makes it difficult to control and monitor the mining activity and therefore its improvement in the short and medium term.

To conclude, the study carried out by (Ospina Díaz, J., Manrique Abril, F., & Guío GARZÓN, 2010), asserts that 93% of the miners perform this activity as a means of subsistence rather than vocation. Demographic aspects, such as those developed in this research, mining techniques (illegally or legally), marketing and world view or mining culture are directly related to occupational health and safety. This anthropological and sociological factors are rather important and worthy of an intensive study.

Physical	Chemical	Mechanical	Ergonomic	Locative	Safety conditions
<p><i>Temperature and humidity</i></p> <ul style="list-style-type: none"> • Rotation of jobs • Resting periods • Adequate ventilation system <p><i>Vibrations</i></p> <ul style="list-style-type: none"> • Periodic maintenance of vehicles and equipment • Seat cushioning systems • Padded gloves (PPE) <p><i>Noise</i></p> <ul style="list-style-type: none"> • Auditive protectors • Periodic maintenance of machinery • Noise combat at its source • Barriers of noise isolation • Increasing the distance between the worker and the source 	<p><i>Gases</i></p> <ul style="list-style-type: none"> • Monitoring concentrations • Adequate ventilation system • Use of self-rescuer • Work schedule (determine exposure times). <p><i>Dust</i></p> <ul style="list-style-type: none"> • Adequate ventilation system • Wear PPE and appropriate work clothes. • Perform periodic medical exams 	<ul style="list-style-type: none"> • Use safety glasses, gloves, safety shoes and helmet • Training • Define the operation areas of the machines 	<ul style="list-style-type: none"> • Adjustment of the workplace • Implement work engineering • Redistribute assigned tasks and take breaks 	<ul style="list-style-type: none"> • Clean, dry and well-marked pedestrian and vehicular traffic surfaces • Use safety boots and helmet • Pumping • Adequate illumination system 	<ul style="list-style-type: none"> • Identify combustible materials and sources of ignition • Have equipment and protection systems; breathing equipment and/or self-rescuers • Audible and visual alarm signals • Have temporary shelters in the mine

Table 7. Risks and their proper control.

Source: (Superintendencia de Riesgos de Trabajo, 2016).

7 Conclusions

The purpose of this thesis was to analyse the current situation regarding occupational safety in small-scale underground coal mining in Colombia and the factors that contribute to its fatal consequences. The foregoing was analyzed as the result of the alarming statistics on mining safety in the country, since the decrease on accidentally rate has not been significant over the years. In fact, according to the Mining Rescue and Safety Group - Grupo de Seguridad y Salvamento Minero (2019), the figures have been increasing since 2015.

In order to define the panorama and its impacts, as well as its reflective purpose, it was strictly necessary to explore the occupational safety and health universe, as understood by international organizations and the definition of occupational risks and its classification according to ICONTEC, the Colombian Standardization Institute. It was found that in Colombia the current legislation addresses the priority topics of occupational safety. However, said normative is ambiguous to imply the use of international standards of non-mandatory compliance. This creates a gap in the mining security field, which may be affected by the provisions acquired in each mining unit according to the studies.

Although mining in Colombia is not the main economic activity, it does represent a strong income in terms of royalties for the State and exports, especially coal. Geology places Colombia as a country rich in non-renewable natural resources, although its geography is complex given its topography and hydrology, leading to complications not only on accessing the minerals, but also on controlling the extractive activity by the state. Additionally, the isolation of communities and their status of state abandonment are factors that feed the phenomenon of illegality and as consequence, the promotion of bad practices in mining and lack of guarantees and/or training.

It can also be concluded that, in Colombia, 9% of the coal is extracted by small and medium underground mining, having this sector the most emergencies and fatalities reported annually with 77% and 73% respectively by type of mineral, and 93% and 87% by method of mining. The figures may be higher if one takes

into account that illegal mining is not quantified accurately in the country, since the last mining census occurred in 2011, and although many illegal UPMs were recognized, many others remain unregistered. In the same way, accident reports in illegal mining are scarce and doubtful given the conditions of work and the workplace, the legal consequences to be faced and the possible closure of the mines once they are identified.

In order to eradicate mining illegality, the Colombian State has accomplished several mining legalization and formalization projects. However, the impact generated has been minimal compared to government costs for this purpose. Hence, to indicate that official efforts should focus on investing more in small and medium-scale mining is not a suitable solution to the issue, at least not in the traditional way that has been implemented, as it does not resolve the illegality problem. Similarly, many NGOs have put their efforts in the same task, generating local changes that often do not transcend or vanish, given the social dynamics and demographic conditions of the populations. The lack of decent employment opportunities, low educational levels, state abandonment, violence by illegal groups outside the law, unsatisfied basic needs, among others, are the real factors that lead the miner to risk his integrity on a daily basis; to subsist without considering the negative impacts on the environment, their communities and their own well-being.

It is not responsible to affirm that the problem of mining safety lies exclusively in illegality, although this field presents the most losses. The issue of mining in Colombia has no clear causes and consequences, or at least that indicates the figures. However, factors such as the low schooling of the miners or inherited perceptions in the workplace could result in the execution of bad practices in mining. Still, these are consequences of the lack of opportunities for the miners and, as well as the few opportunities on professional or technical trainings that they can access. The lack of a legal mining title reproduces the marginalization of mining, as well as its unacceptable quality standards. Even so, mining legalization demands, among other things, significant investments that small miners cannot afford given their economic disadvantages, disabling them to meet the minimum work requirements established by law.

As long as mining continues to be carried out in a fortuitous and uncontrolled manner, the large numbers of emergencies and fatalities will continue to appear in the annual records, as well as the environmental damages and liabilities that incur in risks for the miners and their surrounding communities. Since the State cannot guarantee its constant presence in the vulnerable areas where illegal mining has its core, and although following the formalization programs is indispensable, those approaches to the problem must be reconsidered, especially from a focus that encompasses the miner, their microcosm, human relations and work in the mine.

As a response to this issue, models such as *associativism* and cooperation among miners could promote, in first instance, the legalization of small units before official and state dynamics. In addition, it could be considered a communal reinforcement of the good practices acquired from governmental and NGOs training, without any need of a vigilant entity monitoring the correct extractive operation, but rather from an awareness approach.

Additionally and to close, it is necessary a greater articulation between the different sciences that have interference in this matter. Studies and multidisciplinary approaches that cover the social and environmental spheres of the mining community, and that study their conditions and guarantee their rights will allow mining security not only to improve, but also to maintain its exercise in good conditions and to become ingrained in the culture of the workers and their good practices in the mining workplace.

**Uno escribe a base de ser un minero de sí mismo
One writes on the basis of being a miner of oneself**

(José Luis Sampedro)

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11 List of Abbreviations

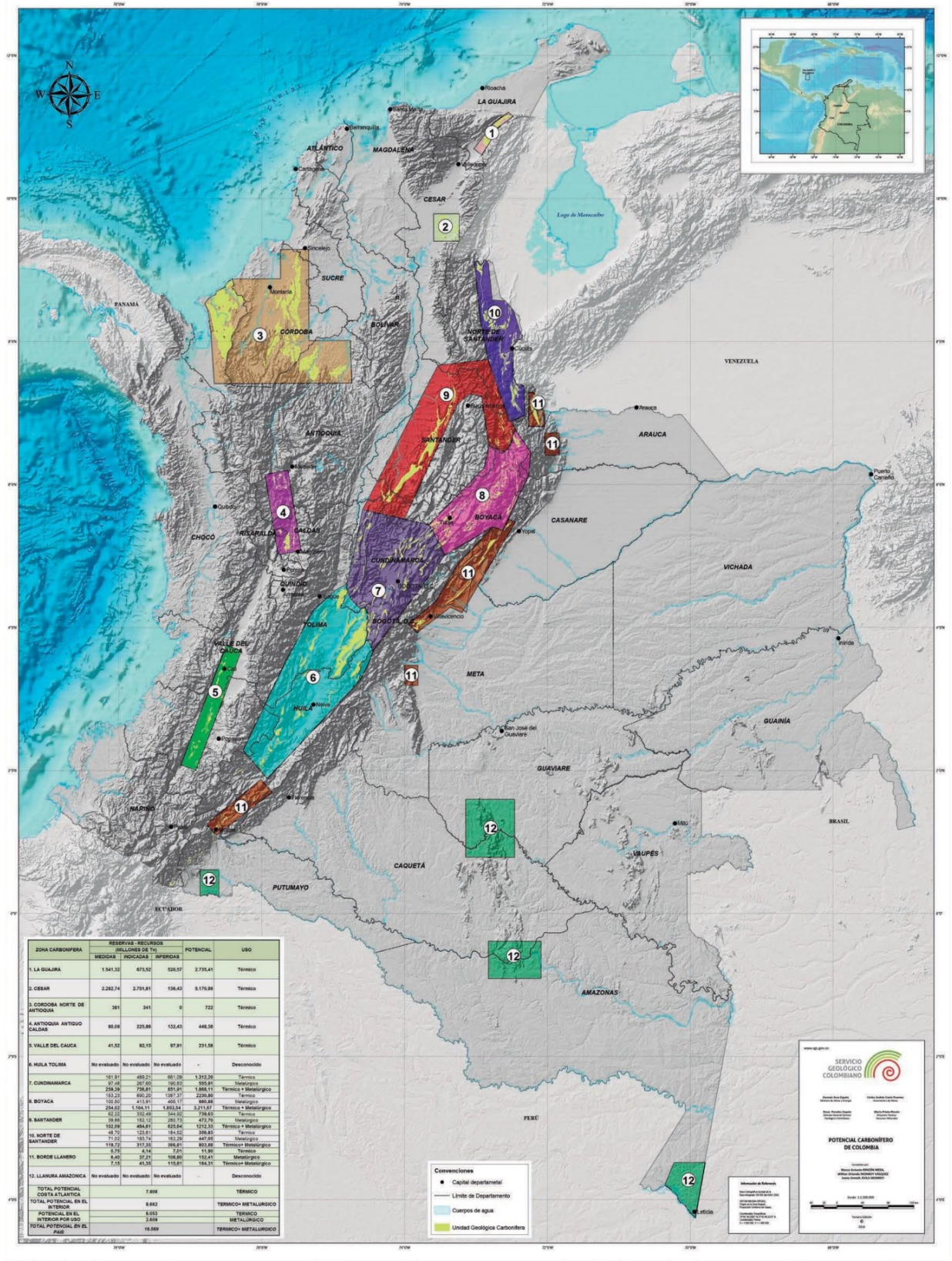
ANM:	Agencia Nacional de Minería – National Mining Agency
ANSI:	American National Standards Institute
ASM:	Artisanal and Small-Scale Mining
ATEX:	Atmósferas Explosivas – Explosive Atmosphere
COP:	Colombian peso
FTE:	Full-Time Equivalent
GDP:	Gross Domestic Product
ICONTEC:	Instituto Colombiano de Normas Técnicas y Certificación – Colombian Institute of Technical Standards and Certification
ILO:	International Labour Organization
ISO:	International Organization for Standardization
MinMinas:	Ministerio de Minas y Energía
MMst:	Millions of Short Tons
MSHA:	Mine Safety and Health Administration
NIOSH:	National Institute for Occupational Safety and Health
OECD:	Organisation for Economic Co-operation and Development
ONG:	Non-Governmental Organisation
OSH:	Occupational Safety and Health
OSHA:	Occupational Safety and Health Administration
PDCA:	Plan-Do-Check-Act Cycle
PPE:	Personal Protection Elements
RETIE:	Reglamento Técnico de Instalaciones Eléctricas – Technical Regulations for Electrical Installations
RMN:	Registro Minero Nacional – National Mining Registry

ROM: Run Of Mine
TLV: Threshold Limit Values
UPM: Unidad de Producción Minera – Mining Production Unit
UPME: Unidad de Planeación Minero Energética – Mining Energy Planning Unit

Annex Table of Contents

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Annex 1



Map of coal potential in Colombia
 Source: (Agencia Nacional de Minería, 2018).

Annex 2

The following material depicts the mining activity performed in La Hornilla sector, village of Minas, in the municipality of Amagá, Antioquia, Colombia. They reflect the illegal activity in underground coal mining.



Main access to the mine.



Manual discharge of the wagon.



Signaling.



Coal storage.

Next, some photographs displays the way that miners extract coal by underground methods.



Miner carrying coal.

Source: (El Nuevo siglo, 2018).



Miner in the tunnel.

Source: (Avendaño & Sánchez, 2015).



The winches are found in strategic points to accelerate the transportation of the mineral to the exterior.

Source: (Avendaño & Sánchez, 2015).