

# CHARACTERISTICS OF THE 3 MOST COMMON TYPES OF OCCUPATIONAL ACCIDENT IN SPANISH SUB-SURFACE AND SURFACE MINING, FROM 2003–2008

## CARACTERÍSTICAS DE LOS 3 TIPOS DE ACCIDENTES MÁS FRECUENTES EN LA MINERÍA DE INTERIOR Y EXTERIOR ESPAÑOLA EN EL PERÍODO 2003-2008

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**ABSTRACT:** The rate for work related accidents in Spanish mining has decreased during recent years. However, the incidence rate per 100,000 workers in the Spanish mining sector in 2007 was significantly higher than the ones reported in the mining industry of other countries. This result implies that studies and research should be carried out in order to reveal the nature of the factors influencing the high incidence rates of the Spanish mining sector. Thus, this article offers features of the 3 most common types of accident of the Spanish mining industry during the period of 2003–2008. For each type of accident, the analysis proceeds as follows: 1) Modeling of the adjusted exponential distribution in terms of workdays lost; 2) Calculation of the risk index adjusted by age group of injured workers; 3) Identification of the 3 main deviations or immediate causes.

**KEYWORDS:** Labor Risk Prevention Act, accident types, deviation, immediate cause

**RESUMEN:** Los índices de siniestralidad laboral en la minería española han disminuido en los últimos años. Sin embargo, la incidencia por cada 100.000 trabajadores en el año 2008 era considerablemente mayor que la de la minería de otros países. Ello implica que deban realizarse estudios e investigaciones que pongan de manifiesto la naturaleza de los factores que influyen en la alta incidencia de siniestralidad laboral del sector minero español. Así, en el presente estudio se presentan las características más importantes de los 3 tipos de accidentes más frecuentes de la minería española en el período 2003-2008. Por cada tipo de accidente se realiza lo siguiente: 1) Modelización de la distribución de los accidentes en función de los días perdidos; 2) Cálculo del Índice de Riesgo por grupos de edades de los trabajadores accidentados; 3) identificación de las 3 principales desviaciones o causas inmediatas de los accidentes.

**PALABRAS CLAVE:** Ley de prevención de riesgos laborales, Forma de accidente o contacto, desviación o causa inmediata

### 1. INTRODUCTION

The incidence rate of occupational accidents in Spain is to a large extent higher than the average of the European Union (EU). During the last 10 years [1], the Spanish Government has promoted the Labor Risk Prevention Act and has undertaken different actions. In this sense, more than fifteen complementary Royal Decrees have followed the enactment of Law 31/1995, and a National Work-related Accidents Plan containing 74 measures and a Shock Plan for the 3,000 Spanish companies that have accounted for half the

accidents registered, have been approved. The Foundation for Occupational Risk Prevention and the National Commission for Health and Security at Work have been constituted, and the figure of Public Prosecutor coordinator of occupational accidents has been introduced. Also, the Spanish National Commission for Health and Security at Work has approved a National Occupational Health and Security Strategy formulated for the period of 2007–2011.

In the mining sector, the Bureau of Mine Safety has been established to promote studies, training, and subsidies for

the improvement of the safety levels of mining workers. In Spain, occupational accidents are classified into minor, severe, and fatal accidents on the basis of the injuries suffered. This classification is determined by the doctor of the mutual health insurance of the company of the injured worker. In 2008, the total number of Spanish economic sectors recorded an incidence rate of 5,069 accidents with workdays lost per 100,000 workers (the lowest value since the peak reached in year 2000); whereas the value registered in EU-15 in 2007 was about 3,782. In 2008, the incidence rate recorded in the Spanish mining sector was 17,721 (3.5 times higher than the value recorded in the all economic sectors together). This result fits with the conclusions of different studies conducted in other countries [2–4], which state that mining activities have a major influence on the number and seriousness of occupational accidents compared to the other economic sectors. Therefore, occupational health and security is especially important in mining activities due to their particular characteristics (e.g., dangerous work posts, powerful work equipment and machinery, environmental conditions with the presence of high levels of dust and humidity, etc.), and it should be integrated in the whole productive process of companies. On the other hand, the low prices assigned to mineral resources and the principles of sustainable mining could limit in the short term the exploration and extraction of these resources [5], and that would also imply the reduction of occupational incidence rates in the mining sector.

## 2. STUDY POPULATION

This paper attempts to contribute to the health and safety literature by analyzing the occupational accidents in the Spanish mining industry. In 2007, approximately 4,281 mining explorations were active in Spain. Around 6,724 (17.2%) direct workers were employed in sub-surface mines and 32,304 (82.8%) in surface mines. The study population is constituted by the occupational accidents recorded in the Spanish mining sector during 2003–2008. The research conducted differentiates between sub-surface mining and surface mining. Data was obtained from the annual digital database on accidents of the Spanish Labor and Immigration Ministry, using the ArcGis 9.3 software. The accidents considered in the study are those that took place in mining work centers, within regular work hours (the so-called *in itinere* accidents are not taken into account), and that caused the injured worker to miss at least one workday.

## 3. METHODS

The methodology used by the Spanish Labor and Immigration Ministry to feed the accidents digital database was adopted for the purpose of this research to classify and codify both the type of accident and the immediate causes (or deviations). Different studies published elsewhere about occupational accidents in the mining industry have employed the average lost workdays as a measure to determine risk indexes of work posts and tasks, among groups of workers, and types of mines [6–8]. This measure enables one to evaluate the overall safety performance within a specific mine, since it can reflect factors such as the use of personal protective equipment, the effective use of first aid and rapid access to medical care, and a company's policies concerning return-to-work practices [9]. Other studies have modeled the annual incidence rate of the mining sector to compare different groups of accidents and to study the incidence of accidents throughout a specific period of time [10].

In this paper, the distribution that was more closely in accordance with the number of accidents considering the number of workdays lost, both in surface and sub-surface mining, was modeled using the exponential distribution and software MINITAB version 15. The exponential distribution has the probability density function described in (1), where “b” represents the scale parameter and “θ” represents the threshold parameter.

$$f(x) = \frac{1}{b} e^{-\frac{(x-\theta)}{b}}, \quad x > \theta, \quad b > 0 \quad (1)$$

Values  $\theta = 0$  and  $b =$  “average mean of lost workdays per frequency of accidents” were used in this study. To facilitate the fitting, values on the lost workday axis (the X-axis) were divided by 6,000, resulting in a range of 0 to 1 for the transformed values (workdays lost). To determine the validity of the adjustment, the Kolmogorov-Smirnov D-statistic test (K-S D statistic) was used. This test indicates whether or not a statistically significance resemblance exists between both sectors, sub-surface and surface mining. The analysis proceeded as follows: First, an adjusted exponential function was modeled for each of the sectors considered and for each of the most common types of accident. Then, the validity of the adjustment with K-S D statistic test was analyzed; and finally, the cumulative form of the fitted curve  $F(x)$  was calculated. For convenience in representing the adjustment functions so that a given value in the Y-axis indicates the probability of an accident with more than one lost workday, the form  $1-F(x)$  was used for plotting.

The risk index adjusted by age group for the 3 most common types of occupational accident in the Spanish mining sector was also calculated. For the age variable, 6 groups were established: 16–24, 25–29, 30–39, 40–49, 50–59, and 60 years old. The risk index is indicative of the incidence of accidents among different groups or subpopulations [11], and it is defined as the ratio of percentage of injured workers of a given subpopulation to the percentage of the total workforce represented by this subpopulation (2).

$$\text{Risk index} = \frac{\% \text{Accidents}}{\% \text{Workers}} \quad (2)$$

A risk index = 1.0 corresponds to an average incidence rate of work-related accidents, whereas a value greater than 1.0 indicates a higher risk for the group, and a value smaller than 1.0 means a lower incidence. The percentage of occupational

accidents for the 6 age groups considered was obtained from the annual digital database on accidents of the Spanish Labor and Immigration Ministry, using ArcGis 9.3 software. The percentage of workers by age group was obtained from the annual statistics on active population published by the Spanish National Institute of Statistics (INE).

## 4. RESULTS

### 4.1. Most frequent types of accidents

The 3 most common types of occupational accident in sub-surface and surface mining in Spain during 2003–2008 (Table 1) was determined from the analysis of data sources. The main characteristics of these accidents are detailed in Table 2.

**Table 1.** Distribution per type of accident recorded in sub-surface and surface mining in Spain (2003–2008)

<b>Sub-surface mining (25,362 accidents)</b>	
#71: Physical over-exertion on the muscular-skeletal system	(21.7%)
#42: To be hit by a falling object or one that is detached	(20.3%)
#50: Contact with a cutting, piercing, hard or rough agent–non-specified	(15.4%)
<b>Surface mining (28,094 accidents)</b>	
#71: Physical over-exertion on the muscular-skeletal system	(28.3%)
#31: Blows or hitting something as a result of a fall	(8.6%)
#42: To be hit by a falling object or one that is detached	(8.3%)

**Table 2.** Severity (expressed as an average duration index) of accidents by accident code in sub-surface and surface mining in Spain (2003–2008)

ACCIDENT CODE	Total number of accidents	Number of accidents $\geq 30$ lost workdays	Number of fatal accidents	Average Duration Index
<b>Sub-surface mining</b>	25,362	3,733 (14.7%)	23	23.8
71	5,508	743 (13.5%)	0	23.8
42	5,140	943 (18.3%)	5	25.0
50	3,910	354 (9.1%)	0	20.9
<b>Surface mining</b>	28,094	5,528 (19.7%)	86	26.1
71	7,939	1,242 (15.6%)	0	22.5
31	2,419	681 (28.2%)	7	34.4
42	2,337	539 (23.1%)	5	27.0
<b>Total</b>	53,456	9,261 (17.3%)	109	25.0
71	13,447	1,985 (14.8%)	0	23.0
42	7,477	1,482 (19.8%)	10	25.6
50	5,777	620 (10.7%)	0	21.0

**Table 3.** Adjusted parameters of the exponential distributions of number of accidents-workdays lost in sub-surface and surface mining in Spain (2003–2008)

<b>Sub-surface mining</b>	<b>code #71 accidents</b>	<b>code #42 accidents</b>	<b>code #50 accidents</b>
Average	22.192	23.397	19.146
Number of accidents	5,481	5,115	3,891
K-S D-statistic	0.09	0.06	0.08
Critical value for p = 0.05	0.02	0.02	0.02
<b>Surface mining</b>	<b>code #71 accidents</b>	<b>code #31 accidents</b>	<b>code #42 accidents</b>
Average	21.112	32.803	25.462
Number of accidents	7,900	2,407	2,326
K-S D-statistic	0.05	0.08	0.04
Critical value for p = 0.05	0.02	0.03	0.03

The most common type of fatal accident recorded in sub-surface mining during the period considered was code #42 (to be hit by a falling object or one that is detached) with

5 fatal accidents, followed by code #62 (to be trapped, flattened, or forced under) and #90 (heart attack, brain hemorrhage and other non-traumatic pathologies) with

4 fatal accidents each. In surface mining, the first-place fatal accident was code #44 (crash or blow against an object in movement, including vehicles) with 14 fatal accidents, and the second was code #32 (blows as the result of a fall, or crashing into an immovable object), and #62 (to be trapped, flattened, or forced under) with 10 fatal accidents each.

**4.2. Modelling**

Table 3 lists the fundamental characteristics of the modeled distributions of the number of accidents considering the number of workdays lost in the 3 most common types of occupational accident, both in sub-surface and surface mining. The values obtained from

the K-S D statistic test are higher than the critical value with a significance level of 0.05. This result indicates a possibly poor fit of the exponential distributions. The best fit corresponds to code #42 and #71 accidents in surface mining.

Table 4 shows the probability of an accident involving more than 10, 20, 30, and 60 days away from work, for both mining sectors (sub-surface and surface mining). Accident code #31 in surface mining registered the most severe consequences, whereas accident code #50 in sub-surface mining accounted for the least severe consequences. On the other hand, accident code #71 had worse consequences in sub-surface mining than in surface mining. The contrary was observed in accident code #42.

**Table 4.** Probability of an accident involving more than 10, 20, 30, and 60 workdays lost in sub-surface and surface mining in Spain (2003–2008)

<b>Sub-surface mining</b>	<b>code #71 accidents</b>	<b>code #42 accidents</b>	<b>code #50 accidents</b>
≥ 10 lost workdays	63.7%	65.2%	59.3%
≥ 20 lost workdays	40.6%	42.5%	35.2%
≥ 30 lost workdays	25.9%	27.7%	20.9%
≥ 60 lost workdays	6.7%	7.7%	4.4%
<b>Surface mining</b>	<b>code #71 accidents</b>	<b>code #31 accidents</b>	<b>code #42 accidents</b>
≥ 10 lost workdays	62.3%	73.7%	67.5%
≥ 20 lost workdays	38.8%	54.4%	45.6%
≥ 30 lost workdays	24.1%	40.1%	30.8%
≥ 60 lost workdays	5.8%	16.1%	9.5%

**Table 5.** Risk index per age group code #71 in Spanish mining (2003–2008)

<b>Year</b>	<b>Risk Index, code #71 accidents</b>					
	<b>Age group</b>					
	<b>16–24</b>	<b>25–29</b>	<b>30–39</b>	<b>40–49</b>	<b>50–59</b>	<b>≥60</b>
<b>2003</b>	0.79	0.82	1.10	1.29	0.56	0.40
<b>2004</b>	0.58	0.92	1.08	1.33	0.60	0.75
<b>2005</b>	0.80	0.82	1.67	0.99	0.41	0.50
<b>2006</b>	0.81	1.04	1.23	1.31	0.44	0.31
<b>2007</b>	1.02	0.89	1.12	1.35	0.52	0.25
<b>2008</b>	0.68	0.80	1.35	1.23	0.51	0.28
<b>Total</b>	0.76	0.91	1.15	1.26	0.54	0.36

**Table 6.** Risk index per age group code #42 in Spanish mining (2003–2008)

<b>Year</b>	<b>Risk Index, code #42 accidents</b>					
	<b>Age group</b>					
	<b>16–24</b>	<b>25–29</b>	<b>30–39</b>	<b>40–49</b>	<b>50–59</b>	<b>≥60</b>
<b>2003</b>	0.53	1.00	1.30	1.16	0.28	0.19
<b>2004</b>	0.61	1.20	1.35	0.94	0.41	0.23
<b>2005</b>	0.83	0.85	1.90	0.89	0.26	0.27
<b>2006</b>	0.89	0.95	1.42	1.22	0.31	0.21
<b>2007</b>	1.18	0.74	1.24	1.41	0.25	0.23
<b>2008</b>	0.53	0.67	1.48	1.32	0.32	0.18
<b>Total</b>	0.71	0.94	1.33	1.17	0.32	0.21

**Table 7.** Risk index per age group code #50 in Spanish mining (2003–2008)

<b>Year</b>	<b>Risk Index, code #50 accidents</b>					
	<b>Age group</b>					
	<b>16–24</b>	<b>25–29</b>	<b>30–39</b>	<b>40–49</b>	<b>50–59</b>	<b>≥60</b>
<b>2003</b>	0.33	0.26	1.24	1.70	0.24	0.22
<b>2004</b>	0.44	0.48	1.26	1.56	0.20	0.40
<b>2005</b>	0.53	0.48	1.75	1.28	0.19	0.21
<b>2006</b>	0.76	0.54	1.38	1.59	0.21	0.14
<b>2007</b>	0.84	0.46	1.07	1.78	0.29	0.61
<b>2008</b>	0.49	0.55	1.30	1.49	0.29	0.23
<b>Total</b>	0.55	0.45	1.27	1.58	0.22	0.21

### 4.3. Risk Index

The risk index of the 3 most common types of occupational accident identified was analyzed considering the pre-established age groups. The percentage of workers per age group in sub-surface and surface mining separately is unknown; thus, for the purpose of this analysis, the mining sector was considered globally. Results are listed in Tables 5, 6, and 7.

### 4.4. Deviations and other characteristics

Tables 8 and 9 show the main deviations (immediate causes) attributed to the 3 most common types of occupational accident.

Finally, the physical activity of injured workers in accidents of code #71 (the most common type of occupational accident in both surface and sub-surface mining) was analyzed in order to extract more information about deviations #70–79 (Tables 10,11).

**Table 8.** Deviations of code #71, #42, and #50 accidents in sub-surface mining in Spain (2003–2008)

<b>Sub-surface mining (25,362 accidents): deviation or immediate cause</b>
<b>code #71 accidents (21.7%; n = 5,508)</b>
#70-79: An abnormally high physical effort is required, and it causes injuries to the worker. An external material agent may be the source of the required supplementary physical effort, or an external material agent may not exist (74.2%)
#52: The worker slips, trips or falls on the same level (the worker has impact with either the surface or an object at the same level or above the surface on which he/she was standing before the occurrence of the deviation) (6.2%).
#44: Loss of control (total or partial) of an object (shipped, displaced, handled, etc.) (6.1%).
<b>code #42 accidents (20.3%; n = 5,140)</b>
#33: Slip, fall, or collapse of an upper material agent (that falls onto the worker injured) (61.8%),
#32: Break or burst in fragments (wood, crystal, glass, metal, stone, plastic, others) (8.7%),
#44: Loss of control (total or partial) of an object (shipped, displaced, handled, etc.) (7.9%),
<b>code #50 accidents (15.4%; n = 3,910)</b>
#30: Break, fracture, burst, slip, fall, or collapse of a material agent (52.2%).
#40: Loss of control (total or partial) of machines, vehicles, loading equipment, hand-tools, objects, or animals (22.3%).
#52: The worker slips, trips, or falls on the same level (the worker impacts either the surface or an object at the same level or above the surface on which he/she was standing before the occurrence of the deviation) (5.8%).

**Table 9.** Deviations of accident code #71, #31, and #42 in surface mining in Spain (2003–2008)

<b>Surface mining (28,094 accidents): Deviation or immediate cause</b>
<b>code #71 accidents (28.3%; n = 7,939)</b>
#70–79: An abnormally high physical effort is required, and it causes injuries to the worker. An external material agent may be the source of the required supplementary physical effort, or it may not exist (68.9%).
#60: Body movements without physical effort (generally they provoke an external injury) (18.9%).
#52: The worker slips, trips, or falls on the same level (the worker impacts either the surface or an object at the same level or above the surface on which he/she was standing before the occurrence of the deviation) (2.4%).
<b>code #31 accidents (8.6%; n = 2,419)</b>
#52: The worker slips, trips, or falls on the same level (the worker impacts either the surface or an object at the same level or above the surface on which he/she was standing before the occurrence of the deviation) (34.1%).
#51: Different level falls while working from heights (heights of over 2 meters) (23.7%).
#50: Falls of workers, non-specified (12.7%).
<b>code #42 accidents (8.3%; n = 2,337)</b>
#33: Slip, fall, or collapse of an upper material agent (that falls on the worker injured) (27.3%).
#44: Loss of control (total or partial) of an object (shipped, displaced, handled, etc.) (15.2%).
#32: Break, burst in fragments (wood, crystal, glass, metal, stone, plastic, or others) (9.6%).

**Table 10.** Physical activity of injured workers in sub-surface mining in Spain, deviation #70–79, code #71 accidents (2003–2008)

<b>Sub-surface mining (25,362 accidents): Physical activity</b>
<b>code #71 accidents and deviation #70–79 (74.2%; n = 4,086)</b>
Handling objects (picking up, grabbing, pulling, fixing, opening, closing, screwing on,...) (46.9%)
Jobs with hand-tools (with or without a motor) (21.4%)
Manual load transportation (18.6%)
Worker movements (walking, running, jumping, standing up, sitting down,...) (7.2%)
Operations with machines (pulling off, stopping, keeping watch over... a machine) (2.5%)
Driving a vehicle or loading equipment/to be put on board (1.9%)



**Table 11.** Physical activity of injured workers in surface mining in Spain, deviation #70–79, code #71 accidents (2003–2008)

<b>Surface mining (25,362 accidents): Physical activity</b>	
<b>code #71 accidents and deviation #70–79 (68.9%; n = 5,466)</b>	
Handling objects (picking up, grabbing, pulling, fixing, opening, closing, screwing on,...)	(39.3%)
Manual load transportation	(17.1%)
Worker movements (walking, running, jumping, standing up, sitting down,...)	(16.3%)
Jobs with hand-tools (with or without a motor)	(15.7%)
Operations with machines (pulling off, stopping, keeping watch over... a machine)	(7.0%)
Driving a vehicle or a loading equipment/to be on board	(3.7%)

## 5. DISCUSSION

It is important to indicate the limitations of the database on accidents of the Spanish Labor and Immigration Ministry. Many of these limitations could be attributed to the overcomplicated design of the accident report form and its subsequent procedures [12]. Moreover, another factor could be the confusing definition and classification of some variables. In this sense, one of the most affected variables is the number of workdays lost in severe and fatal accidents.

## 6. CONCLUSIONS

### 6.1. Most frequent types of accidents

The most common type of accident recorded in sub-surface and surface mining in Spain throughout the period of 2003–2008 was code #71 (physical over-exertion on the muscular-skeletal system) with 21.7% and 28.3%, respectively. The second most common type of accident was code #42 (to be hit by a falling object or one that has become detached) with 20.3% in sub-surface mining, and code #31 (blows or hitting something as a result of a fall) with 8.6% in surface mining. Code #42 was the third most common type of occupational accident registered in Spanish surface mining.

When considering fatal accidents, codes #42 and #31 were the only ones recorded. On the other hand, these two types of accidents provoked 30 or more workdays lost and accounted for 18.3% and 28.3% of the total number of accidents registered in sub-surface and surface mining, respectively.

Code #71 accident occurred in sub-surface mining in Spain had slightly more severe consequences (in number of workdays lost) than the ones registered

in surface mining during period 2003–2008. The probability of suffering a code #71 accident with 10 or more workdays lost was 63.7% in sub-surface mining and 62.3% in surface mining (according to the adjusted exponential distributions calculated). The opposite was observed in code #42 accidents, in which the probability of occurrence was higher in surface mining than in sub-surface mining. Thus, the probability of suffering a code #42 accident with 10 or more workdays lost was 65.2% in sub-surface mining and 67.5% in surface mining.

### 6.2. Modeling

The type of accident with the least severe consequences was code #50 in sub-surface mining in Spain, with a 59.3% probability of involving 10 or more workdays lost. This value, although it is a low percent, is slightly higher than the losses recorded in the coal sub-surface and metal/non-metal mining of United States during 2000–2004. The probability of an accident involving 10 or more workdays lost in the mining industry of United States was 35% and 50% in metal/non-metal and coal sub-surface mining, respectively, according to adjusted beta distribution [9].

The type of accident that recorded the most severe consequences in Spanish surface mining was code #31, with a 73.7% probability of having 10 or more workdays lost.

### 6.3. Risk Index

The workers who suffered the most accidents were the ones aged 30–39 and 40–49 years old, with a risk index of 1.15 and 1.26, respectively, in code #71 accidents; 1.33 and 1.17 in code #42 accidents; and 1.27 and 1.58 in code #50 accidents. On the other hand, the age groups that recorded the least number of accidents were the

50–59 year-olds and the  $\geq 60$  year-old group, with a risk index of 0.54 and 0.36, respectively, in code #71 accidents; 0.32 and 0.21 in code #42 accidents; and 0.22 and 0.21 in code #50 accidents. These results fit with the ones obtained by Groves [13] when considering all the accidents occurred within the mining sector in the United States during period 1995–2004. Ural [14], in a study of the Turkish surface mining, concluded that the more accident prone workers were the ones younger than 40. This latter result partially coincides with the results of the study presented in this paper, that show the highest incidence rates in the age groups 40–49 year-old for code #71 and #50 accidents, and 30–39 year-old for code #42 accidents.

#### 6.4. Deviations and others characteristics

The most common deviation or immediate cause in code #71 accidents, both in sub-surface and surface mining in Spain, was group #70 (in which an abnormally high physical effort is required, and it causes injuries to the worker). It includes the injuries resulting from worker movements (standing up, ducking, turning, moving forward, etc.), handling a load or not. When no load is manipulated by the injured worker there is no clear cause for the injuries suffered. It also includes the situations when a worker (with or without a load) trips over (without falling) and suffers a muscular-skeletal lesion.

The most common physical activity of injured workers at the time of accident (code #71 accidents, deviation group #70) was related to the handling of objects (see Tables 9 and 10). Moreover, the percentage of occurrence was higher than the percentages recorded in the other physical activities (i.e., manual load transportation). This is a surprising result as it seems more logical that this type of accident would have occurred when workers performed some manual load transportation (picking up, pushing, taking down, or pulling a load). In spite of that, manual load transportation activities accounted for the second highest percentage of accidents in Spanish surface mining and the third in sub-surface mining (code #71, deviation group #70).

Workers with less than two years of experience sustained 26.4% of accidents #71 (deviation group #70) in sub-surface mining in Spain and 49.3% in Spanish

surface mining. These results may indicate that workers did not have enough experience in objects handling and in manual load transportation activities.

The most common deviation or immediate cause in code #42 accident, both in sub-surface and surface mining in Spain, was #33 (slipping, falling, or collapsing of an upper material agent that falls onto the injured worker). Specifically, deviation #33 was attributed to 61.8% of the 5,140 accidents #42 recorded in sub-surface mining and attributed to 27.3% of the 2,337 accidents #42 registered in surface mining. This result seems logical considering that sub-surface mining activities are more conducive to accident #42 with deviation #33. Hence, it is especially important that occupational health and safety prevention services take this into account and that mining companies adopt accurate preventive measures to minimize this type of accident.

The second main deviations or immediate causes that were attributed to code #31 accident in Spanish surface mining were #52 (the worker slips, trips, or falls on the same level) and #51 (falls of workers on different levels), with 34.1% and 23.7% of the 2,419 accidents #31 registered. These two deviations may be indicative of inappropriate workplace conditions (a slippery floor, inappropriate cleaning, untidiness, and inappropriate protection against falls from heights).

Studies on occupational accidents recorded in the Spanish mining industry reveal that approximately 51% of the severe and fatal accidents occurred in surface mining and 67% of the accidents registered in sub-surface mining had an immediate cause that was directly linked to workplace conditions [15]. Another study on fatal electrical accidents in Australia [16] determined that 70% of these accidents had immediate causes that were attributable to workplace conditions. The results of the study presented in this paper reveal that only 49.9% ( $n = 12,650$ ) of the accidents occurred in sub-surface mining in Spain and 37.9% ( $n = 10,639$ ) of the accidents recorded in Spanish surface mining were based on workplace condition deficiencies. The difference in percentages can be attributed to the fact that the analysis described in this paper considered both the minor accidents and the severe and fatal accidents, whereas the aforementioned two studies only considered fatal accidents [16] or severe and fatal accidents [15]. If the calculations are only computed

with severe and fatal accidents data, the percentages are nearly the same, with 66% (n = 95 of the 144 severe and fatal accidents) in sub-surface mining and 50.9% (n = 279 of the 548 severe and fatal accidents) in surface mining.

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