Comparison of the occupational hazards in the Spanish mining sector based on the type of workplace in the period 2003-2012

RESUMEN / ABSTRACT

Methods and background: This review has done a comparison of the 3 types of workplace in the Spanish mining sector. The 3 workplaces considered are: mines, quarries and mineral processing plants. The 10 most frequent accidents and deviations have been obtained for each one. It has also been calculated the annual incidence, frequency, average duration and severity indexes as well as the risk index for each one. Besides, the accident distribution has been modelling, based on exponential distribution function of the lost days in the 3 workplaces mentioned. Results: The main sort of accident is due to physical overexertion and the principal deviation is the material collapsing from the roof of the mines, no coordinate movements in quarries and body movements because of physical overexertion in mineral processing plants.

PALABRAS CLAVE / KEYWORDS

Type of Accident; Deviation; Risk Index; Exponential Function; ORP Conference

AUTORES / AUTHORS

Lluís Sanmiquel Pera
Iberpotash Chair in Sustainable Mining / Polytechnic University of Catalonia (UPC)
sanmi@emrn.upc.edu

Modesto Freijo Álvarez
Iberpotash Chair in Sustainable Mining / Polytechnic University of Catalonia (UPC)
freijo@ee.upc.edu

Josep Maria Rossell Garriga
Department of Business Organization / Polytechnic University of Catalonia (UPC)
josep.maria.rossell@upc.edu

Marc Bascompte
Iberpotash Chair in Sustainable Mining / Polytechnic University of Catalonia (UPC)
marc_bascompte_massanes@hotmail.com

Introduction

The occupational hazard indexes in the mining sector have decreased during the last years. The table 1 shows the annual statistic of occupational accident extracted from the Ministry of Labour and Social Security and the Ministry of Industry, Energy and Tourism. The figures from 2005 to 2011 display how the occupational accident incidence decrease in the Spanish mining sector of 41,3%.

Accident rate	Total
2005	19070,8
2006	16980,5
2007	17218,4
2008	15382,6
2009	13877,5
2010	12656,2
2011	11189,2

Table 1: Annual incidence index of the mining sector in Spain from 2005 to 2011.

In spite of a positive evolution in the indexes, the mining accidents incidence is still slightly higher than in the other economic sectors. In 2011, while the accident incidence in the overall accident incidence was 2831,2 per 100.000 employees in the mining sector it was 4 times higher, 11189,2. These figures coincide with several studies undertaken in other countries [1], [2], [3], aiming this fact to the characteristics of the mining sector, such as: hazardous work places, work equipment, environment conditions like dust, high rate of humidity, etc. All these factors cause a higher number of serious accident injuries than in the other economic sectors. In addition, their accidents are among the most expensive due to the severity and frequency of the mining injuries, illnesses, and fatalities [4].

Doing a comparison between the Spanish indexes in the mining sectors and other western countries, the Spanish ones are much higher. For instance, the incidence indexes in USA and the state of Queensland, Australia, were 5,8 and 17,3 times lower, respectively. Thereby, the investigations in this field should keep on because there is a huge margin to improve the Spanish figures. The preventive measures can only be implemented properly and enhance the indexes and ratios when there is a deep knowledge about the origin, the causes, the characteristics and the consequences of the accidents.

Once the accident has taken place, the investigation of what has happened is a very important source of information. Normally, the genesis of an accident involves more than one cause. An adequate investigation of accident allows us to determine all its causes and influences. Thus, if the causes of the accident are known, methods of prevention and protection can be designed and applied to eliminate them, and in this way the possibility of recurrence would be none to very low [5].

Another important aspect that gives information about the sort of accident is the number of days lost. Some articles focused on accidents in the mining sector have used the number of lost days per accident in order to get a risk index based on the work place, type of task, type of mine, among different team's work…. [6], [7], [8].

The data used in this article, extracted from the Spanish Ministries, is from the annual database. The information about the sort of accident and their causes is stored in the database. Analysing all the information together allows knowing what kind of accidents are the most frequent and the principal causes of them.

An article based on 212 serious and mortal accidents in the Spanish mining sector in 2010 [9], determined that the majority of the accidents: 51,1% in open pit mining, and 67,1% in underground mining were caused for a lack of a proper work place. The second most important factor was the behaviour of the employees. Agreeing with other survey that took into account more than 1000 fatal accidents from all the economics sectors in Australia [10]. Other article [11] pointed out the huge influence of the hygienic and ergonomic conditions as a source of occupational accidents.

The prevention management is the process that the company uses to plan its different actions: executing, checking out the result based on the expectations and defining and developing the proper actions to achieve the requirements and the policy of the company [12]. According to some authors, the prevention management is considered as an essential tool in order to prevent the accidents [13], [14]. The Regulation of Prevention Services was done through the Royal Decree 39/1997 of 17 January 1997. The prevention services, within the different branches, were in charge to the prevention management in any economic activity from that moment. One of the most important issues entrusted to these services is the occupational hazard training programs for the employees. Several articles have pointed out the formation as a key factor in order to prevent the accidents [15], [16], [17]. Hence, the lack of a prevention service is, most probably, a sign of having employees with a low level of knowledge of preventive measures against occupational hazards. The Spanish law describes four different types of possible prevention services: The manager of the company assumes the duties of the prevention, only if he has been trained adequately before. The manager gives the responsibility to an employee, only if he has been trained adequately before. Creating a prevention service as a department inside the company. Contracting an external prevention service which is entrusted of all the prevention matters. For small companies, with less than 20 employees, the 2 first options are very common, whereas companies between 20 and 100 employees often contract external prevention services. On the other hand, the big companies with more than 100 employees use to have its own prevention service.

In Spain, the occupational accidents are classified as light injuries, serious injuries and fatalities, depending on the degree of injury. The degree suffered in an employee is determined by the doctor of the company's health insurance.

Methodology

Data

The study population comprises the accidents suffered in the workplace, also mentioned mining centre along this article, of the mining sector from 2003 to 2012. These accidents have been suffered during working hours ("in itinere" accidents have not been taken into account) and with at least one day of work lost by the employee. The data of the annual accidents have been obtained from the Ministry of Labour and Social Security through the ArcGis software, version 10. Some other information obtained from the Ministry of Industry, Energy and Tourism has also been necessary, such as number of employees, hours worked… for the three types of mining centres (quarries, underground mines and mineral processing facilities).

Methods

The four occupational fatalities standard indexes (incidence, frequency, average duration and severity) have been used as a basis to compare the three types of mining centres. These indexes were recommended by the XVIª International Conference of Labour Statisticians from the OIT in 1998. Except the average duration index, the other ones have been calculated until 2011 because the data from 2012 had not been released. In addition, the indexes have taken into account the data since 2005 because previously, there was no information about the mineral processing facilities.

The risk index has been calculated for each index previously mentioned. This index is a very useful statistic value to compare the incidence and severity of the occupational hazards in a group or sub-population [18]. The risk index is a ratio between the chosen index (incidence, frequency, average duration and severity) of a certain sub-population and the total index of all the considered sub-populations. In this article the different sub-populations are the three types of mining centres (quarries, mines and mineral processing facilities) for every one of the analysed years.

$$Risk\ Index = \frac{Subpopulation\ Index\ of\ quarries, underground\ mines, processing\ facilities}{Total\ Index}$$

A risk index with a value of 1 is equal to an average severity or incidence (depending on the considered index) compared to the rest of the sub-populations. Meanwhile, a value greater than 1 points out an important incidence or severity of the sub-population analysed. On the other hand, a value less than 1 means low incidence or severity.

The accidents have been classified depending on the type of mining working centre (quarries, mines and mineral processing plants), the type of accident and the cause thanks to the software ArcGis 10. In addition, information concerning the lost working days, the consequences of the accidents in each working centre has been possible to obtain as well.

As it was mentioned previously, the analysis of the lost days due to accident gives important information about different characteristics of the accidents. This information can be used to evaluate the security system of the company and the effectiveness of factors like first aid, policies of the company, safety and health matters, personal protective equipment utilization or health assistance could be defined [19].

In this review a modelling distribution of the accidents based on the lost days due to accidents in quarries, mines and processing plants, has been done using an exponential distribution function through MINTAB version 16.

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

Where b= Scale parameter and = Threshold parameter.

The value of each parameter is = 0 and b = average of the lost days weight with the accident frequency. In order to make easier the adjustment, the lost days, which are within the function as abscissa axis (X) values, have been divided per 6000, giving o the lost days a range between 0 and 1. The adjustment done in the exponential distribution function has been undergone to the Kolmogorov-Smirrnov (K-S) test so that it will indicate if the lost days distribution adjustment is good enough or not. Hence, the exponential function must be obtained for each type of mining centre to analyse (quarries, mines and processing plants) and then check the suitability of the adjustment with the K-S test. The adjusted function 1-F(x), in the ordinate axis, indicates the probability of and accident to have more than certain lost days.

Results

Statistic index of occupational accidents

The first phase of the review displays the annual occupational accident indexes of the three types of mining centre and their risk indexes (tables 2 and 5).

Incidence Index					Incidence Risk Index		
Year	Mines	Quarries	Processing Plants	Total	Mines	Quarries	Processing Plants
2005	52265.8	4479.7	33101.0	19070.8	2.74	0.23	1.74
2006	47728.8	4446.4	26879.7	16980.5	2.81	0.26	1.58
2007	53881.6	6167.1	19653.3	17218.4	3.13	0.36	1.14
2008	52168.3	5983.7	13709.2	15382.6	3.39	0.39	0.89
2009	48890.7	4803.5	10061.4	13877.5	3.52	0.35	0.73
2010	45576.2	4857.8	7014.0	12656.2	3.60	0.38	0.55
2011	39287.7	4240.2	6679.7	11189.2	3.51	0.38	0.60
Average					3.24	0.34	1.03
Standard deviation					0.35	0.06	0.47
95% CI					2.92-3.57	0.28-0.39	0.60-1.47

Table 2: Incidence index and annual risk index of the mining sector in Spain from 2005 to 2011for each mining centre.

Frequency Index					Risk Frequency Index		
Year	Mines	Quarries	Processing Plants	Total	Mines	Quarries	Processing Plants
2005	367.7	29.2	199.3	124.6	2.95	0.23	1.60
2006	334.8	29.2	160.9	110.9	3.02	0.26	1.45
2007	369.7	41.9	118.2	114.1	3.24	0.37	1.04
2008	360.6	41.6	94.4	106.6	3.38	0.39	0.89
2009	346.0	35.3	64.8	98.2	3.52	0.36	0.66
2010	345.5	35.6	43.7	89.4	3.86	0.40	0.49
2011	281.9	32.3	41.7	79.8	3.53	0.40	0.52
Average					3.36	0.35	0.95
Standard deviation					0.32	0.07	0.44
95% CI					3.06-3.65	0.28-0.41	0.54-1.36

Table 3: Frequency index and annual risk index of the mining sector in Spain from 2005 to 2011for each mining centre.

According to the two previous tables, the accident incidence, considering the employees (incidence index), and the number of working hours (frequency index) have a very similar pattern. Thus, in both cases the incidence in the mines is much higher than in quarries and processing plants. Besides, the processing plants suffer a slightly higher index compared to the quarries during the first three years. The average period is between 10 and 3 times higher than in quarries and processing plants in the tables 2 and 3, respectively

Other important aspect to take into account is that all the mining centres have decreased the accidents incidence from 2005 to 2011. A small increase of the frequency index has been produced in the quarries sector, but keeping much lower figures compared to the mines sector. The drop is very important in the processing plants sector around 80%, either the incidence or the frequency index.

Average duration index					Average duration risk index		
Year	Mines	Quarries	Processing Plants	Total	Mines	Quarries	Processing Plants
2003	27.1	28.5	25.8	27.0	1.01	1.06	0.96
2004	21.7	26.8	24.3	23.0	0.94	1.16	1.06
2005	24.0	29.1	23.2	24.5	0.98	1.19	0.94
2006	22.1	26.0	23.2	23.1	0.96	1.13	1.00
2007	24.2	29.4	23.5	25.2	0.96	1.17	0.93
2008	21.2	27.6	24.1	23.3	0.91	1.19	1.03
2009	22.9	32.7	25.4	25.4	0.90	1.29	1.00
2010	24.1	32.5	28.1	26.5	0.91	1.23	1.06
2011	29.3	35.7	29.7	30.7	0.95	1.16	0.97
2012	37.2	43.3	34.0	37.9	0.98	1.14	0.90
Average					0.95	1.17	0.99
Standard deviation					0.03	0.06	0.06
95% CI					0.93-0.98	1.13-1.22	0.95-1.02

Table 4: Average duration index and annual risk index of the mining sector in Spain from 2003 to 2012 for each mining centre.

Severity index					Severity risk index		
Year	Mines	Quarries	Processing Plants	Total	Mines	Quarries	Processing Plants
2005	8.8	0.9	4.6	3.1	2.89	0.28	1.51
2006	7.4	0.8	3.7	2.6	2.89	0.30	1.46
2007	9.0	1.2	2.8	2.9	3.12	0.43	0.97
2008	7.7	1.1	2.3	2.5	3.08	0.46	0.91
2009	7.9	1.2	1.6	2.5	3.19	0.46	0.66
2010	8.3	1.2	1.2	2.4	3.51	0.49	0.52
2011	8.3	1.2	1.2	2.5	3.37	0.47	0.51
Average					3.15	0.41	0.93
Standard deviation					0.23	0.09	0.42
95% CI					2.94-3.36	0.33-0.49	0.55-1.32

Table 5: Severity index and annual risk index of the mining sector in Spain from 2005 to 2011for each mining centre.

The indexes from the tables 4 and 5 indicate the severity of the accidents depending on the lost days. The average duration index displays the average of accident leaves meanwhile the severity shows the number of lost days every 1000 worked hours. These differences could explain, up to a certain point, the different figures between both indexes in the tables. Thus, while the duration of the accident leaves is similar among the three mining centres, the severity index varies considerably. Having the mines a much higher severity index than quarries and processing plants. Moreover, the severity index decreases in mines and processing mines, while the quarries increase it a bit during the period analysed. On the other hand, the average of accident leaves has increased substantially, 37% in mines, 52% in quarries and 32% in processing plants.

A non-parametric test (Kruskal-Wallis) was used to determine if there was a statistically significant difference between Incidence, Frequency, Average Duration and Severity Index for every mining centre (quarries, mines and processing plants). The results of the statistic test (H=17,8 for Incidence Index, H=6,3 for Frequency Index, H=20,1 for Average Duration Index and H=17,6 for Severity Index) had a critical value lower than all the H values calculated. Therefore, it can be said with a statistic significance level of 0,05 that the occupational hazard indexes are reasonably different depending on the type of working mining centre during the period analysed.

Type of accident and immediate causes

The table 6 displays that the most frequent accident in any type of mining centre in Spain is the “physical overexertion” (code = 71) with a wide difference compared to the others. In quarries the physical overexertion reach the 30,8% of 10180 accidents, while in mines is 24,2% of 34348 and in processing plants is the 29,6% of 13286 accidents. The second most frequent accidents in mines and processing plants is “collision or hit against a falling object” (code = 42), meanwhile in quarries is “falling of an employee” (code = 31). The falling of an employee appears in the fifth position in mines, 5,1% of the accidents, as well as in the fourth position in the case of processing plants, 6,9%. The type of accidents with the code 42 appears in the fourth position in the case of quarries as well, 7,9% of the accidents. The code 50, contact with sharp objects, and the code 32 stumbling due to a moving object are quite usual in all the mining centres. The code 50 is the third most frequent in mines and processing plants, meanwhile in quarries is the code 32. The types of accident 71, 42, 31, 32 and 50 are the 62,2% (n= 6334) of all the accidents in quarries, 68,7% (n=23592) in mines and 59,5% (n=7904) in processing plants.

Quarries		Mines		Processing Plants	
Code	Nº accidents	Code	Nº accidents	Code	Nº accidents
71	3132 (30.8%)	71	8303 (24.2%)	71	3934 (29.6%)
31	1268 (12.5%)	42	7616 (22.2%)	42	1359 (10.2%)
32	836 (8.2%)	50	3857 (11.2%)	50	964 (7.3%)
42	808 (7.9%)	32	2064 (6.0%)	31	913 (6.9%)
41	543 (5.3%)	31	1752 (5.1%)	32	734 (5.5%)
50	290 (2.8%)	41	1394 (4.1%)	41	539 (4.1%)
44	259 (2.5%)	40	1305 (3.8%)	40	496 (3.7%)
63	255 (2.5%)	43	833 (3.4%)	51	388 (2.9%)

Table 6: The eight most frequent accidents if the mining sector in Spain from 2003 to 2012 for each mining centre.

Code	Description
30	Collision by a moving employee against a immobile object – no specification
31	Hit of an employee due to falling down
32	Stumbling due to a moving object
40	Collision against a moving object – no specification
41	Collision against objects or thrown fragments
42	Collision against a falling object
43	Collision against a twisting object
44	Collision against a vehicle or object while the employee is immobile
50	contact with sharp objects – no specification
51	contact with sharpen objects – such as knifes
63	Trapped or crushed between two objects, one of them moving
71	Physic overexertion

Table 7: Codes and accident type description.

The first most frequent immediate cause in quarries is “no coordinate unusual or inappropriate movements” (code = 64), in mines is “material sliding or falling over an employee” (code = 33) and in processing plants is “raising and carrying objects” (code = 71). Observing the figures it can be concluded that the main direct cause is due to physic overexertion in quarries and processing plants. Meanwhile in mines the relation cause-effect is not so clear. Other remarkable point is that the three most frequent immediate causes are the same, with different order, in quarries and processing plants, while in the mines are different.

The second most frequent immediate cause is “falling down of an employee” (code = 52) in quarries, “losing control of an object (carried, manipulated, etc.)” (code = 44) in mines and in processing plants is the cause codified as 64.

Quarries		Mines		Processing Plants	
Immediate cause	Nº accidents	Immediate cause	Nº accidents	Immediate cause	Nº accidents
64	1213 (11,9%)	33	5071 (14,8%)	71	1477 (11,1%)
52	1061 (10,4%)	44	3386 (9,9%)	64	1293 (9,7%)
71	922 (9,1%)	30	2932 (8,5%)	52	835 (6,3%)
44	614 (6,0%)	52	2859 (8,3%)	44	815 (6,1%)
43	548 (5,4%)	71	2421 (7,0%)	70	724 (5,4%)
51	547 (5,4%)	70	2207 (6,4%)	43	631 (4,7%)
75	391 (3,8%)	40	1669 (4,9%)	33	589 (4,4%)
32	379 (3,7%)	32	1486 (4,3%)	32	583 (4,4%)

Table 8: The 8 most frequent immediate cause of accident in the Spanish mining sector from 2003 to 2012 for each mining centre.

Code	Description
30	Material or object breaking, sliding, falling or collapsing – no specification
32	Materials breaking to pieces (wood, glass, metal, stone, etc.)
33	Material sliding or falling over an employee
40	Losing control (partial or total) of working equipment o materials – so specification
43	Losing control (partial or total) of any tool, with or without engine and the elements working with
44	Losing control (partial or total) of an object (carried, manipulated, etc.)
51	Falling off of an employee
52	Falling down of an employee
64	No coordinate, unusual or inappropriate movements
70	Body movement due to physic exertion – no specification
71	Raising and carrying objects
72	Pushing or pulling
75	Stumbling or sliding without falling

Table 9: Code description of the immediate causes of accident.

Preventive organization

The table 10 indicates the accident distribution based on the preventive organization of the company where the injured employee belongs, depending on the three types of mining centres.

Preventive organization method	Quarries	Mines	Processing Plants
Owner or manager of the company	102 (1%)	274 (0,8%)	186 (1,4%)
Designed employee	285 (2,8%)	4603 (13,4%)	664 (5%)
Prevention department	916 (9%)	16419 (47,8%)	2352 (17,7%)
Joint prevention service	743 (7,3%)	4156 (12,1%)	1023 (7,7%)
External prevention service	6302 (61,9%)	6148 (17,9%)	6869 (51,7%)
No preventive organization	1832 (18%)	2748 (8%)	2192 (16,5%)

Table 10: Accidents distribution depending on the preventive organization method and the mining centre.

The quarries and processing plants have suffered more accidents with the external prevention service because of the size of the mining companies, which are mainly small or medium ones, while the mines usually are bigger. It has been taken into account the national survey of the Statistic National Institute and the statistic mining data in 2011.

Lost days due to the accidents

The table 11 shows the accident distribution modelling results based on the number of lost days in the three types of mining centre from 2003 to 2012. The results display that the null hypothesis with a significance level of 0,05 in the three modelling. It means the adjustment of each accumulative distribution of the accident based on the number of lost days with an exponential accumulative distribution is poor because the K-S D-statistic value is higher than the critic value with a significance level of 0,05. The best adjustment is in the processing plants and then the quarries.

	Quarries	Mines	Processing Plants
Average	28.7	23.1	23.5
Number of accidents	10180	34348	13286
K-S D-statistic	0,060	0,080	0,050
Critical value for p=0,05	0,014	0,007	0,012

Table 11: Adjustment parameters of the accidents distribution exponential functions based on lost days in the mining working centres (2003-2012).

The table 12 shows is pointed out the probability of suffer an accident of 10, 20, 30 and 60 lost days in the three different centres depending on the adjusted distribution functions. It can be concluded from the tables that the quarries have suffered more severe accidents. On the other hand, the processing plants have suffered accidents with less severe consequences, with a similar result compared to the mines.

	Quarries	Mines	Processing Plants
>= 10 lost days	70.6%	65.5%	65.4%
>= 20 lost days	49.8%	43.0%	42.7%
>= 30 lost days	35.1%	28.1%	27.9%
>= 60 lost days	12.3%	7.9%	7.8%

Table 12: Probability of suffering an accident of more than 10, 20, 30 and 60lost days in underground and surface mining in Spain (2003-2012).

The table 13 shows the results of comparing the three adjusted distribution functions through the Kolmogorov-Smirnov test.

	Mines	Quarries
Number of fatalities	36	50
Number of injuries	34348	10180
Number of injuries with Lost workdays>=180	469	209
Number of injuries with Lost workdays>=60	20742	1136
Lost workdays for nonfatal injuries	847342	306440
Percentage of total losses for two periods	73.4	26.6
Goodness-of-fit (K-S D-statistic)	0.070	
Critical value for p=0.05	0.009	
	Mines	Processing plants
Number of fatalities	36	14
Number of injuries	34348	13286
Number of injuries with Lost workdays>=180	469	1051
Number of injuries with Lost workdays>=60	20742	163
Lost workdays for nonfatal injuries	847342	329840
Percentage of total losses for two periods	72.0	28.0
Goodness-of-fit (K-S D-statistic)	0.002	
Critical value for p=0.05	0.009	

	Quarries	Processing plants
Number of fatalities	50	14
Number of injuries	10180	13286
Number of injuries with Lost workdays>=180	209	1051
Number of injuries with Lost workdays>=60	1136	163
Lost workdays for nonfatal injuries	306440	329840
Percentage of total losses for two periods	48,2	51,8
Goodness-of-fit (K-S D-statistic)	0,072	
Critical value for p=0,05	0,013	

Table 13: Comparison of the adjusted distribution functions from the lost days as a consequence of the accidents produced in each mining centre analysed.

The comparison between the mines and the processing plants, without being able to refuse the null hypothesis, implies that there is not enough significance statistic difference in the accidents distribution of the number of lost days with a significance level of 0,05. The table also show the number of fatalities, the accidents with more than 60 and 180 lost days, etc.

Results discussion

The evolution of the statistic indexes, which point out the incidence of the accidents (incidence and frequency indexes) and the consequence of the accidents depending on the number of lost days for the injured employee (severity and average duration indexes), is decreasing during the analysed period (2005-2011). This trend coincides with what is happening in USA during many years according to several reviews [4], [20], [21]. An article about energetic mining in Spain during the period 1999-2006 [22] pointed out that the severity index had considerably decreased from 1999 to 2006. The risk index calculated for every statistic index allows distinguishing among sub-populations (in this article mines, quarries and processing plants) clearly. The main statistic values of the risk index from 2005 to 2011 have been calculated with the MINITAB 16 software. Obtaining for the incidence index that: the mines have an average risk index and confidence interval of 95% of 3,24 (2,92-3,57), the quarries of 0,34 (0,28-0,39) and the processing plants 1,03 (0,6-1,47). The values of the frequency index are similar: 3,36 (3,06-3,65) in mines, 0,35 (0,28-0,41) in quarries and 0,95 (0,54-1,36) in processing plants. Taking into account an average value of 1 for the risk index, the mines have an accident incidence 3,4 times higher than the average, the quarries 3,3 times and the processing plants are near the average value.

The severity ratios (average duration and severity indexes) display very different results. The average duration risk index with a confidence interval of 95% is 0,95 (0,93-0,98) in mines, 1,17 (1,13-1,22) in quarries and 0,99 (0,95-1,02) in processing plants. In this case, there is significant coincidence among the three types of mining centres in the accident severity based on the duration of the accident leaves. It must to be considered the fact that the mines have accident leave duration inferior than quarries and processing plants. However, the results of severity index are completely different. The average risk index and the confidence interval of 95% in all the period are 3,15 (2,94-3,36), 0,41 (0,33-0,49) and 0,93 (0,55-1,32) in mines, quarries and processing plants, respectively. In addition, the risk indexes of the accident incidence indicators have similar values, so that the mines have had a ratio of 3,36 times the average value of lost hours every 1000 working hours, an inferior value of 2,5 times in quarries and a value close to the average in the case of processing plants.

The percentage of accidents with an immediate environmental cause (workplace conditions in the moment of the accident) has been of 47,8% in mines, 38,8% in quarries and 38,6% in processing plants. These figures does not coincide with the review [9] where it was found out that the first cause of accident in unground and surface mining was environmental in a 68& and 51% respectively. A possible explanation could be the distinction of the accident severity, between light, serious and fatalities injuries in the current review and serious and fatalities injuries in the review [9]. In this case, doing the same distinction in both reviews, the serious and fatal accidents in mines, quarries and processing plants during the period of 2003-2012 were 203, 295 and 161 respectively. Considering only this type of accident, the percentages of the accidents with an immediate environmental cause was 66% in mines, 67,8% in quarries and 50,9% in processing plants.

The accidents produced in the processing plants have had less serious consequences than in the mines and quarries. Thus, the probability of having an accident of 10 or more lost days, from 2003 to 2012, have been 65,4% in processing plants, 65,5% in mines and 70,6% in quarries. These values are much higher than in the underground mining metal/non-metal and coal sectors in the USA during the period from 2000 to 2004. Therefore, the probability of suffering an accident with 10 or more lost days is 52% and 35%, respectively, according to the adjusted beta distribution in the underground mining metal/non-metal and coal sectors in USA [19].

It is important to indicate the limitations of the annual accidents database from the Ministry of Labour and Social Security in Spain. According to several reviews [23] some limitations come from too complicated designs of the accident report and its processing, as well as from the classification a definition of some variables, such as the number of lost days in serious accidents and fatalities.

Conclusions

The evolution of the occupational accidents index in the period analysed (2005-2011) in the three types of mining centres in Spain (mines, quarries and processing plants) have been positive either from the view of accidents severity or the accident incidence taking the number of employees or the hours worked. It has been confirmed that the occupation incidence in the Spanish mining sector is quite higher than in the other economic sectors. The incidence and frequency indexes were 13 times higher in mines, 1,5 in quarries and 2 times in processing plants during 2011. Despite the quarries and processing plants have an incidence index rather inferior compared to the mines, their values are still higher than in other countries like USA. The accident incidence was 2 and 3 times higher in the quarries and processing plants, respectively, than taking into account the overall mining sector in USA (mines, quarries and processing plants). Analysing the severity of the accidents, the evolution has also been positive. However, the severity and average duration indexes were also greater than in the rest of the economic sectors. The severity index was 14 times greater in the mines and 2 times in quarries and processing plants.

The most frequent accident in the three types of mining centres is the physical overexertion. This type of accident is closely related to a lack of knowledge of manipulating burdens as well as a lack of proper equipment usually. Hence, the responsible of the preventive organization should analyse these questions and if it is detected any weakness, the adequate measures should be carried out. Some of the possible measures could be: improving the frequency and quality of the formation programs and the information towards the employees, mechanising as activities related to manipulate burdens as possible, changing the current equipment for other that imply less overexertion, choosing the most suitable employees to make the chores that imply moving heavy objects.

The second most frequent accident in mines and processing plants has been related to collide against a falling or sliding object. In the case of the mines, this type of accidents could be reduced improving the roof of the galleries (specially the zones where there are more employees working), taking the proper preventive measures if any part of the roof is considered as dangerous. Other option would be using reinforced equipment in order to protect the employees from falling rocks from the roof. In the processing plants the possible measures are: arranging and cleaning the working places and walkways, a proper program of planning and maintenance of the equipment, paying special attention in the places where the material could gather and fall.

The accidents suffered during the period analysed have created more lost days than in the mines and processing plants. In fact, the percentage of serious accidents and fatalities in quarries was 3%, 0,6% in mines and 1,2% in processing plants from 2003 to 2012.

Hence, after seeing all the information and the hazard characteristics in the mining sector, especially in the mines [1], [2], [3], it is obvious that the governmental administration in charge and the management of the mining companies must pay special attention in the health and safety activities.

Acknowledgements

We would like to thank the Directorate of Statistics of the Spanish Ministry of Employment and Social Security for giving us access to the annual database of accidents in the mining sector from 2003-2012. Also we would like to thank the congress organization for the opportunity to present our work on it.

References

1. Mitchell, R.J., Driscoll, T.R. & Harrison, J.E. (1998).*Traumatic work-related fatalities involving mining in Australia*. Safety Science, 29(2), 107-123.
2. Hull, B.P., Leigh, J., Driscoll, T.R., Mandryk, J. (2006). *Factors associated with occupational injury severity in the New South Wales underground coal mining industry*. Safety Science, 21 (3), 191-204.
3. Gyekye, S.A. (2003). *Causal attributions of Ghanaian industrial workers for accident occurrence: Miners and non-miners perspective*. Journal of Safety Research, 34(5), 533-538.
4. Leigh, J., Waehrer, G., Miller, T., Keenan, C. (2004). *Cost of occupational injury and illness across industries*. Scandinavian Journal of Work Environment and Health 30 (3), 199–205.
5. Piqué, T. (1991). *NTP 274: Accidents investigation: Causes Tree Analysis*. Madrid: Instituto Nacional de Seguridad e Higiene en el Trabajo.
6. Grayson, R. L.; Layne, L.A.; Althouse, R.C. & Klishis, M. J. (1992). *Risk indices for roof bolter injuries using microanalysis*. Mining Engineering, 2, 164−166.
7. Ames, R. G., & Trent, R. B. (1985). *Respiratory predictors of disability days: a five year prospective study of U.S. coal miners*. American Journal of Industrial Medicine, 7, 337−342.
8. Hunting, K. L.,&Weeks, J. L. (1993). *Transport injuries in small coal mines: an exploratory analysis*. American Journal of Industrial Medicine, 23, 391−406.
9. Sanmiquel L, Freijo M, Edo J, Rossell JM. (2010). *Analysis of work related accidents in the Spanish mining sector from 1982–2006*. Journal of Safety Research, 41(1), 1–7.
10. Williamsom, A., & Feyer, A. -M. (1998). *The Causes of Electrical Fatalities at Work.* Journal of Safety Research, 29(3), 187−196.
11. García-Herrero, S., Mariscal, M.A., García-Rodríguez, J., Ritzel, D.O. (2012). *Working conditions, psychological/physical symptoms and occupational accidents. Bayesian network models*. Safety Science 50, 1760-1774.
12. Guzman, A. (2004). *Gestión de la prevención. Tendencias actuales. Congreso de seguridad, salud y medioambiente*. Bogotá: Fundación MAFRE.
13. Luna-Mejias, G. (2013). *Process safety management - A practical view*. AICHE Annual Meeting, Conference Proceedings. San Antonio (USA).
14. Yoon, S.J., Lin, H.K., Chen, G., (...), Choi, J., Rui. (2013). *Effect of occupational health and safety management system on work-related accident rate and differences of occupational health and safety management system awareness between managers in South Korea's construction industry*. Safety and Health at Work, 4(4), 201-209.
15. Kartam NA, Flood I, Koushki P. (2000). *Construction safety in Kuwait: issues, procedures, problems and recommendations*. Safety Science, 36(3), 163–84.
16. Grau R, Martínez IM, Agut S, Salanova M. (2002). *Safety attitudes and their relationship to safety training and generalised self- efficacy*. International Journal of Occupational Safety and Ergonomics (JOSE), 8(1):23–35.
17. Martín, J.E., Rivas, T., Matías, J.M., Taboada, J., Argüelles, A. (2009). *A Bayesian network analysis of workplace accidents caused by falls from a height*. Safety Science, 47 (2), 206-214.
18. Butani S.J. (1988*). Relative risk analysis of injuries in coal mining by age and experience at present company*. Journal of Occupational Accidents, 10(3), 209–216.
19. Coleman, P.J. & Kerkering, J.C. (2007). *Measuring mining safety with injury statistics: Lost workdays as indicators of risk*, Journal of Safety Research, 38(10), 523-533.
20. Ramani, R., Mutmansky, J. (1999). *Mine health and safety at the turn of the Millennium*. Mining Engineering, 51(9), 25–30.
21. Kecojevic V., Komljenovic D., Groves W., Radomsky M. (2007). *An analysis of equipment-related fatal accidents in U.S. mining operations: 1995–2005*. Safety Science, 45, 864-874.

22. Sanmiquel L., Freijo M., Rossell J.M. (2012). *Exploratory Analysis of Spanish Energetic Mining Accidents*. International Journal of Occupational Safety and Ergonomics (JOSE), 18(2), 209–219.
23. Benavides F.G., Serra C. (2003). *Evaluación de la calidad de el sistema de información sobre lesiones por accidentes de trabajo en España*. Archivo Prevevención de Riesgos Laborales, 6, 26-30.