

Influence of workplace safety management on accident rates in opencast mining companies of Catalonia



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ABSTRACT

Aims: Mining incidence rates are sensibly higher than the ones registered by other economic sectors. One of the main reasons for these high-level indexes is the existence of an important number of dangerous workplaces. Therefore, workplace safety and prevention constitutes an important facet of mining activities. This work analyses the influence that occupational safety management has on workplace accident rates.

Methods: Primary data sources are: a) occupational accidents registered in the opencast mining industry of Catalonia throughout period 2003-2008; and b) results from a study of the occupational health and safety management practices of 60 mining companies, through a questionnaire of 41 items measured on a 1-5 Likert scale.

Results: The obtained results show that workplaces where safety management is more deficient (treatment plants, workshops and storages) are the ones that record higher injury incidence rates.

Keywords

Accident rates, occupational safety management, opencast mining

INTRODUCTION

In year 1997, a regulation of occupational health and security in the mining industry was published in Spain. We refer to Royal Decree 1389/1997 (BOE num. 240, 7th October 1997) concerning the minimum requirements for the safety and health protection of miners, which is the transposition of Directive 92/104/CEE of December 3rd into the national law. The decree provided in article 2 that employers must develop and maintain up-to-date a safety and health document (SHD) inter alia, taking stock of and evaluating risks, and also including a planning of health and security activities and a comprehensive occupational health management of all the activities developed in the mining company. Nevertheless, the decree did not detail point-by-point which the content of this safety and health document should be, thus every professional did its own lecture [1]. In January 30, 2006 the Order ITC/101/2006 was published, approving the minimum content and structure of the safety and health document for extractive industries (BOE num. 25, 30th January 2006). The application of this complementary technical instruction provides mining companies with a useful tool for the implementation of an occupational health and security management system therein.

Occupational health and security management is the process through which a company develops the planning of all the activities to be carried out, executes these activities and evaluates the results with respect to the expected ones, and finally, defines and implements corrective measures to channel the system into the requirements specified in the company's policy [2]. Different authors have studied the implementation of occupational health and safety management systems in different countries [3,4,5] and have suggested that the correct implementation of an occupational management program in a company is an essential tool for accident prevention [6,7].

In the total number of Spanish economic sectors, mining is one of those with the highest incidence in number of accidents per 100,000 workers. Thus, in 2006, Spanish mining had an incidence index that was 4.7 times higher than the total economic sectors. If the indexes of work accidents in Spanish mining are compared with those of other countries, we can see that the values are also much higher. In 2006 the incidence rate per 100,000 workers was 8.9 times higher than those of the United States and 20.4 times higher than those of the Australian state of Queensland. The high work related accident rate in the Spanish mining sector implies that research should be carried out in this field in order to show which aspects of the mining companies' prevention systems have to be improved.

Studies centered at European level seem to indicate the existence of a tendency to higher incidence rates in small than in bigger mines [8]. In year 2006, the incidence rate of accidents that lead to three or more lost workdays in companies with 1-9 workers increased to 1.26 times the mean. Different investigations also indicate that severe injuries are more frequent in small and medium companies [9]. Consequently, the Catalan mining industry, which is formed basically by small and medium companies, is in principle affected by the conclusions reached in the aforementioned studies.

The basic aim of this paper is to analyze the influence that occupational health and security management has on the incidence rates of the mining industry. The target sample consisted of 60 quarries of Catalonia, which were classified into 4 groups according to the size of the company expressed in number of employees.

MATERIAL AND METHODS

The study consisted of two parts: accident analysis, and evaluation of the quality of occupational safety management practices in the industrial and ornamental stone mining of Catalonia.

Accident analysis:

The study population was constituted by the accidents that took place in opencast mining exploitations of industrial and ornamental stone (limestone, marlstone, clay, gravel, sand, gypsum, marble, granite ...) of Catalonia (Spain) between 2003 and 2008. The accidents considered are those that were recorded in mining work centers, within regular work hours (the so-called "in itinere" accidents were not taken into account), and that caused the injured worker to miss at least one workday. Data was obtained from the annual digital database on accidents of the Spanish Ministry of Work and Immigration, using the software ArcGis 9.2.

Quality of occupational safety management practices:

The study population for the analysis consisted of 60 quarries of industrial and ornamental stone of Catalonia. Different visits were conducted during period 2007-2008 in order to collect information on the occupational health and safety management practices adopted.

To evaluate the quality of these practices, we conducted an analysis of 41 parameters in each one of the 60 quarries considered. We used the information included in the safety and health documents and the data obtained during the inspections. A questionnaire of 41 items grouped into 4 categories, specially designed to achieve this aim, was used (Table 1).

To rate the degree of implementation of each of the practices, a five-point Likert scale from level 1 (without evidence, strong deficiencies) to 5 (excellence) was used. These levels enabled us to evaluate the adequacy of different parameters concerning physical and documental aspects of the mines selected for the study. Each level had a punctuations associated:

- Level 1: Without evidence. Strong deficiencies. (punctuation = 0)
- Level 2: Some evidence. Some deficiencies. (punctuation = 1)
- Level 3: Evidence. It can be improved. (punctuation = 2)
- Level 4: Clear evidence. Adequate. (punctuation = 3)
- Level 5: Excellence. (punctuation = 4)

A weight-factor was also associated to each question (1 = not so important; 2 = very important). For those questions which were not applicable to a specific quarry, we gave them weight zero, so that they had no influence on the adjusted mean values. This was observed in electrical installations of the quarry, treatment plants,

From the analysis of the data obtained, we could draw conclusions about the state of the art of occupational safety and security management in Catalan the industrial and ornamental stone mining. To assure the statistical significance of these conclusions, it is necessary to select an adequate size of the study population. When we observe a sample ($n = \text{sample size}$) instead of the whole population ($N = \text{population size}$), we make a sampling error or estimation error, denoted here as " ε ". The larger the sample size, the smaller the sampling error tends to be. The formula for its calculation is expressed in equation 1 [10,11]:

$$\varepsilon = \sqrt{\frac{N-n}{n \cdot (N-1)}} \quad (1)$$

Table 1. Items of the questionnaire used to collect the information.

Occupational health and security management	Weight
Safety and health documentation to be kept up-to-date	1.00
Coordination of business activities	2.00
Occupational safety management	2.00
Occupational safety service – Mine project manager coordination	1.00
Employee hiring and training	2.00
Security clothes and personal protective equipment at the workplace	1.00
Hazard analysis	2.00
Hazard-based programs: occupational risk-management plan	2.00
Safety training and information	2.00
Worker consultation and participation	1.00
Internal safety regulations	2.00
Work procedures	2.00
Treatment plants, workshops and storages	
Protection from objects in movement	2.00
Footbridges: Cleanliness and order. Handrails	1.00
Electrical facilities: wires and protections	2.00
Environmental conditions: dust	1.00
Environmental conditions: noise	1.00
Maintenance works at height	2.00
Quarry	Peso
Slope mines	2.00
Platforms and berms	2.00
Tracks	2.00
Signs for entries and tracks	1.00
Signs and alerts for mobile machinery	1.00
Loading	2.00
Transport	2.00
Pouring	2.00
Use of vehicles and machinery	2.00
Maintenance of vehicles and machinery	1.00
Environmental conditions: dust	1.00
Environmental conditions: noise	1.00
Electrical facilities	2.00
Quarry machinery conditions	1.00
General questions	
Waste management	1.00
Changing rooms and lavatories	1.00
Toilets and showers	1.00
Oil installation	1.00
Pressure equipment	1.00
First aid. Evacuation and aid. Safety practices	1.00
Dust measurement	1.00
Noise measurement	1.00
Workplace signs	1.00

For a population of 500 quarries (which was the number of active quarries of industrial and ornamental stone in Catalonia in year 2008, according to data from the Directorate of Energy and Mining of the Economy Department of the Catalan Government), we find that the sample size should be at least 60 companies if we want a sampling error $\leq 12\%$.

RESULTS

Quality of occupational safety management practices:

Tables 2, 3, 4 and 5 show the average values of each one of the 41 parameters analyzed in the 60 mines. We consider that a value of 3 or higher denotes a correct management of the item evaluated.

Companies were classified into 4 groups according to the number of employees: type 1 (<10 workers), type 2 (≥ 10 and <20 workers), type 3 (≥ 20 y <50 workers), and type 4 (≥ 50 workers).

Table 2: Average values of occupational safety management items in the 60 quarries analyzed

Occupational safety management	Average value
1- Safety and health documentation to be kept up-to-date	3.33
2- Coordination of business activities	2.98
3- Occupational safety management	3.30
4- Occupational safety service – Mine project manager coordination	2.58
5- Employee hiring and training	2.77
6- Security clothes and personal protective equipment at the workplace	3.43
7- Hazard analysis	2.93
8- Hazard-based programs: occupational risk-management plan	3.20
9- Safety training and information	3.03
10- Worker consultation and participation	1.88
11- Internal safety regulations	3.48
12- Work procedures	3.20
Average value	3.05

Table 3: Average values of quarry items in the 60 quarries analyzed

Quarry	Average value
13- Protection from objects in movement	2.70
14- Footbridges: Cleanliness and order. Handrails	3.25
15- Tracks	3.18
16- Signs for entries and tracks	2.25
17- Signs and alerts for mobile machinery	2.78
18- Loading	3.37
19- Transport	3.60
20- Pouring	3.29
21- Use of vehicles and machinery	3.82
22- Maintenance of vehicles and machinery	3.68
23- Environmental conditions: dust	3.28
24- Environmental conditions: noise	3.57
25- Electrical facilities	2.83
26- Quarry machinery conditions	3.72
Average value	3.24

Table 4: Average values of treatment plant items in the 60 quarries analyzed

Treatment plants, workshops and storages	Average value
27- Protection from objects in movement	2.51
28- Footbridges: Cleanliness and order. Handrails	2.29
29- Electrical facilities: wires and protections	2.44
30- Environmental conditions: dust	2.29
31- Environmental conditions: noise	2.44
32- Maintenance works at height	2.68
Average value	2.48

Table 5: Average values of general questions in the 60 quarries analyzed

General questions	Average value
33- Waste management	3.70
34- Changing rooms and lavatories	2.25
35- Toilets and showers	2.27
36- Oil installation	3.17
37- Pressure equipment	2.86
38- First aid. Evacuation and aid. Safety practices	2.83
39- Dust measurement	3.33
40- Noise measurement	2.73
41- Workplace signs	1.78
Average value	2.77

A total of 25 quarries (41.7% of the total) received an average value of 3 or higher in the category "occupational management", whereas they had a score lower than 3 in some of the other categories. A percentage of 15% of the study population (9 quarries) received an average value lower than 3 in the four categories analyzed, and 11.7% of the total (7 quarries) received a score of 3 or higher in all categories.

The number of quarries and the average value of each of the 4 categories analyzed per group of size are indicated in table 6. Results show that as long as the size of the company increases, the average value obtained in the categories analyzed increases too. The lowest punctuations were mainly recorded in companies of type 1 and 2. The results drawn in table 6 indicate that the worst occupational management practices were observed in treatment plants and secondly in general questions.

The smallest mining companies, basically the ones with less than 10 workers, recorded worse occupational management practices in all aspects, and specially in general questions. Nevertheless, the average values obtained in the evaluation of treatment plants were practically equal negative in all groups of companies.

Table 6: Average values per type of company (according to the size expressed in number of workers)

Type of company	Num. of quarries	Occupational safety management	Quarry	Treatment plants, workshops and storages	General questions
1	14	2.8	3.0	2.4	2.0
2	18	2.9	3.3	2.0	2.7
3	5	3.0	3.3	2.7	2.7
4	23	3.4	3.4	2.6	3.2

Occupational accidents in the Catalan industrial and ornamental stone mining:

During period 2003-2008, the Catalan industrial and ornamental stone mining recorded 1,722 accidents that caused the injured worker to miss at least one workday. A total of 960 accidents (55.7% of the total) took place in treatment plants, workshops and storages of mines. Of the 1,722 accidents considered, 3 were fatal and 31 were severe, and 64.7% of those (21 severe accidents and 1 fatal accident) were registered in treatment plants, workshops and storages.

Half the severe and fatal accidents (11 accidents) were attributed to three types of occupational accidents: code #42 -being hit by a falling object or one that is detached (4 accidents), code #31 -blows or hitting something as the result of a fall (4 accidents), and code #63 -to be trapped or flattened (3 accidents). The 21 severe accidents caused 2,293 lost workdays, which corresponds to an average duration of 109.2 days away from work.

Table 7 lists the most common types of occupational accident, those which were recorded in at least 20 accidents, in the treatment plants, workshops and storages of the quarries analyzed during period 2003-2008. The most frequent type of accident was code #71 (physical over-exertion on the muscular-skeletal system), which accounted to 28.9% (277 accidents), and the second most frequent type of accident was code #42 (being hit by a falling object or one that is detached) with 10.1% of the total (97 accidents).

The 959 non-fatal accidents registered in treatment plants, workshops and storages involved 24,503 days away from work (average duration of 25.6 lost work days).

Table 7: Types of accidents recorded in treatment plants, workshops and storages

Accident code	Number of Accidents	%	Description
71	277	28.9	Physical over-exertion on the muscular-skeletal system
42	97	10.1	Being hit by a falling object or one that is detached
40	82	8.6	Being hit by an object in movement
31	60	6.3	Blows or hitting something as the result of a fall
32	46	4.8	Blows as the result of a fall, or crashing into an immovable object
50	46	4.8	Contact with a cutting, piercing, hard or rough material agent
41	36	3.8	Being hit by an object or projected fragments
44	23	2.4	Crash or blow against an object in movement, including vehicles
63	22	2.3	To be trapped or flattened.

DISCUSSION

The obtained results in the evaluation of treatment plants, workshops and storages (average score lower than 3) indicate that the occupational management practices involved therein should be improved. High accumulation of sand, stones and other material was observed in footbridges and tracks. Inadequate floor and handrails were also detected. These facts could be the basic causes of accident code #42 -being hit by a falling object or one that is detached (97 accidents registered) and #31 -blows or hitting something as the result of a fall (60 accidents registered). Protections of mobile elements received an average score of 2.51, which indicates that a considerable percentage of these elements were not properly protected in the treatment plants,

workshops and storages analyzed. This result could explain the 22 accidents code #63 registered (to be trapped or flattened, accident produced when a part of the worker's body contacts with an inadequately protected mobile element).

Questions about the quarry had the lowest average score in security signs for entries, tracks and machinery, as well as in slope mine items. Inadequate geotechnical aspects were observed in slopes, where different stretches had landslide danger due to inefficient geotechnical slope conditions.

As the size of the mines increased (expressed in number of workers), the average score for the 4 categories analyzed increased, and therefore the occupational management practices improved. However, treatment plants, workshops and storages had low values even in big-sized companies (group size 3 and 4).

Management of statutory documentation has shown a clear improvement (both in terms of quality and existence) since year 2004 (when an investigation team of Politechnical Engineering School of Manresa conducted a study about the analysis and degree of implementation of health and security documents in 13 opencast mines of ornamental stone of Catalonia) to 2007 and 2008. This amelioration has been experimented in part due to the publication of Order ITC/101/2006 of January 23th approving the minimum content and structure of the safety and health document for extractive industries.

Treatment plants, workshops and storages accounted for the highest incidence rate throughout period 2003-2008, and obtained the lowest average score in the analysis of occupational management practices among the study population in 2007 and 2008.

ACKNOWLEDGEMENTS

We would like to thank the Directorate of Statistics of the Spanish Ministry of Work and Immigration for giving us access to the annual databases on accidents in the mining sector from 1999-2008, and to the Directorate of Energy and Mining of Catalonia for the collaboration given during the visits to the 60 quarries of industrial and ornamental stone.

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