International Journal of Industrial Ergonomics 40 (2010) 321–329

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Assessment of occupational risks in an aluminium processing industry

O.N. Aneziris [a,*], I.A. Papazoglou [a], O. Doudakmani [b]

[a] National Center for Scientific Research "DEMOKRITOS", Terma Patriarchou Gregoriou, Aghia Paraskevi 15310, Greece
[b] Center for Prevention of Occupational Risk, Hellenic Ministry of Employment and Social Affairs, Thessaloniki, Greece

ARTICLE INFO

Article history:
Received 23 February 2009
Received in revised form
10 December 2009
Accepted 14 January 2010
Available online 6 February 2010

Keywords:
Occupational risk
Aluminum processing industry
Risk assessment

ABSTRACT

This paper presents the quantification of occupational risk in an aluminum plant producing profiles, located in Northern Greece. Risk assessment is based on the Workgroup Occupational Risk Model (WORM) project, developed in the Netherlands. This model can assess occupational risk at hazard level, activity level, job level and overall company risk. Twenty six job positions have been identified for this plant, such as operators of press extruders, forklift operators, crane operators, painters, and various other workers across the process units. All risk profiles of workers have been quantified and jobs have been ranked according to their risk. Operators at the entrance of the painting unit have the highest fatality risk (3.25×10^{-5}/year), followed by the workers at the storage area (2.18×10^{-5}/year) and the workers performing sandblasting of dies (1.91×10^{-5}/year). Occupational risk has also been assessed for all plant units and the overall company. Storage area has the higher expected number of fatalities (2.8×10^{-4}/year) followed by the surface treatment area (2.54×10^{-4}/year) and the extrusion unit (1.7×10^{-3}/year).

1. Introduction

Occupational safety and health is a major concern to many countries. Traditional way to deal with it is legislation, regulation, standards, safety guidelines, accident investigations and safety inspections which provide information on causes of accidents amongst particular groups of employees. Such studies have been performed by the National Institute of Occupational Safety and Health, NIOSH (2000), by OSHA (1979, 1991), McCann (2003), Hakkinen (1978), Suruda et al. (1997), Fabiano et al. (2008), Hämäläinen et al. (2006), Lind (2008), Chi et al. (2004, 2009), Yoon and Lockhart (2006), Mital et al. (1999a,b,c), Ale et al. (2008a), and Jeong (1997). Various studies describing the distribution of injuries, in terms of person, place and workplace characteristics have been performed by Armell et al. (2002), Biddle and Marsh (2002), Salminn (2005), Sorock et al. (2001), and Trontin and Bejean (2004). Accident data have been analysed using descriptive statistics by Kines (2003), factorial analysis by Dedobbeleer and Beland (1991), variance analysis by Janicak (1998) and multiple regression by Gillen et al. (2002). A Bayesian network analysis of workplace accidents caused by falls from height has been proposed by Martin et al. (2009), for identifying causes of accidents such as experience, task duration, training, knowledge of regulations, hazard perception, safety harness and incorrect posture. Two semi-quantitative risk assessment methods for occupational risk assessment appear in the literature by Papadakis and Chalkidou (2008) and Marhavilas and Koulouriotis (2008) and have the following characteristics. The first is based on risk matrices with two dimensions, which are the frequency of occurrence of an accident and the severity of its consequences. The second is the proportional risk assessment technique the so called "RSPE" method based on the function R = SPE, where R is the risk, S is the severity of the accident consequences, P the frequency of the accident and E the frequency of employee exposure factor.

Recently a number of attempts for quantitative risk assessment appear in the literature. A model has been developed to predict the frequency of occupational accidents in offshore oil and gas industry, based on direct, corporate and external factors by Attwood et al. (2006). Risk for various occupational groups in Sweden, based on the number of accidents and relevant exposure has been presented by Larsson and Forsblom (2005). Fuzzy methods have been used for risk assessment of occupational accidents in a steel company by Mure and Demichela (2009), at construction sites by Gürcanli and Müngen (2009) and in workplaces by Grassi et al. (2009). Artificial neural networks and a fuzzy inference system have been proposed to assess occupational injury risk indexes and predict number of injuries by Ciarapica and Giacchetta (2009). Finally Papadakis and

Abbreviations: NIOSH, National Institute of Occupational Safety and Health; FACE, Fatal Accident Circumstances and Epidemiology; GISAI, Gemeenschappelijk Informatie Systeem Arbeidsinspectie (Occupational Accident Database); ORM, Occupational Risk Model; OSHA, Occupational Safety and Health Administration; WORM, Workgroup Occupational Risk Model; RIVM, Dutch National Institute for Public Health and the Environment.

* Corresponding author. Tel.: +302106503703; fax: +302106545496.
E-mail address: olga@ipta.demokritos.gr (O.N. Aneziris).

0169-8141/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.ergon.2010.01.005

Chalkidou (2008) propose an exposure – damage approach for occupational risk quantification in workplaces involving dangerous substances.

The Ministry of Social Affairs and Employment in the Netherlands developed Workgroup Occupational Risk Model (WORM) project, a large scale project during 2003–2008 to improve the level of safety at workplace, by introducing quantitative occupational risk. This project had four major parts: assembly and analysis of accident and exposure data, generalization of these data into a logical risk model, deriving improvement measures and their costs and developing an optimizer that supports cost effective risk reduction strategies, as described by Ale et al. (2008b), Papazoglou et al. (2008) and Oh and Sol (2008). The results of the WORM project are presented in RIVM (2008) and its main achievement is the development of the probabilistic occupational risk model, which is built on the detailed analysis of 9000 accident reports in the Netherlands, extracted from the Occupational Accident Database GISAI (*Gemeenschappelijk Informatie Systeem Arbeidsinspectie*), and data concerning the exposure of the Dutch population to various hazards, as reported by Kuiper et al. (2008). Probabilistic occupational risk provides risk assessment for each particular worker, each process unit and a whole plant and also provides a rational way to prioritize risk reducing measures.

The objective of this paper is to demonstrate the features and capabilities of the WORM occupational risk model through the application on a specific Greek site. Occupational risk is performed for an aluminium processing plant, located in Northern Greece. The qualitative characteristics of the specific plant have been considered in the risk assessment, regarding workers' jobs, activities and hazards, but the quantification is performed on the quantitative characteristics of the WORM model, based on the average working conditions in the Netherlands.

2. Methodology for occupational risk assessment

In the framework of the WORM project a model for the quantification of occupational risk has been developed. According to this model, occupational risk in a company is calculated by assessing the hazards the workers in this company are exposed to, the duration of the exposure and the integration of the risk to all hazards and all workers.

A tree-like structure is used to develop the composite model of the Occupational Risk Methodology (ORM) as depicted in Fig. 1. The Top Level of the tree corresponds to the entity under analysis. The second level provides the type of "Company-position" corresponding to a specific type of job along with the number of people in each position-type. There are $i = 1,2, \ldots, n$ company positions each occupied by $T_1, \ldots, T_n$ employees, respectively.

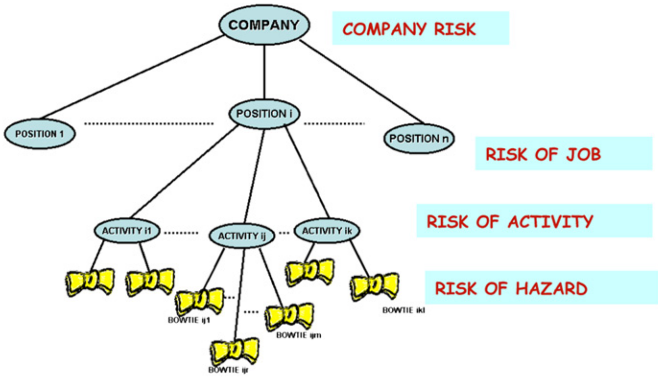

Fig. 1. Composite ORM model structure.

The third level of the tree describes for each position-type the activities required to perform the corresponding job along with the respective frequencies. This means that a particular job is described in terms of a number of activities each one of which is performed a specific number of times over a given period. Thus the ith job position is characterized by M_i activities $A(i,1),\ldots, A(i,j),..,A(i,M_i)$ each performed with annual frequency $f(i,j)$, (see Fig. 1).

Finally, performance of a specific activity is associated with a number of single hazards, such as fall from ladders, scaffolds, roofs, contact with falling object, contact with electricity e.t.c., which are presented in Table 1 and discussed in more detail RIVM (2008) and also a corresponding duration of exposure to each and every hazard. Thus activity $A(i,j)$ is associated with hazards $h(i,j,1)$, $h(i,j,2),\ldots,h(i,j,m)$, where m is the total number of hazards of activity $A(i,j)$, as depicted in Fig. 1. Risk is calculated as a combination of the contributions of jobs, activities and hazards.

Risk is calculated as probability of unwanted consequence (recoverable injury, permanent injury or fatality) at any time during a base period of time (e.g. 1 year), from the combination of the contributions of jobs, activities and hazards. Risk is calculated in a bottom up method, from hazard to company level, while considering Fig. 1. Therefore first risk of each hazard is calculated by considering the duration of exposure of a worker to the specific hazard. Then risk for each activity is calculated by considering risks of all relevant hazards and finally risk for each job, by considering risks from all relevant activities. Company risk is estimated by integrating risk of all job positions. All the details on the Occupational Risk model are provided in the WORM report (RIVM, 2008) and by Papazoglou et al. (submitted for publication), while the basic assumptions of the risk model are the following:

A worker in a given period of time undertakes a number of activities, where each activity consists of a number of hazards. Activities are sequential but may be repeated several times during the base period (e.g. a year) risk is calculated. The duration of the activity and the exposure to each hazard is estimated by the analyst. When performing a specific activity the worker is exposed to a number of hazards, which can occur simultaneously, specified by the risk analyst, out of the 63 hazards presented in Fig. 1. All sixty three hazards have been quantified in the WORM project on the basis of the characteristics of the average Dutch worker, as presented by Papazoglou et al. (2008) and Ale et al. (2008b). While the worker is exposed to a particular hazard an accident may occur according to a poisson random process and therefore the accident rate is constant. If an accident occurs at any instant of time during the performance of an activity, then the exposure to the same hazard and to subsequent hazards stops. Thus the probability of an accident during an activity is equal to the probability of an accident due to any of the hazards of this activity. In addition, if an accident results in a recoverable injury during the performance of an activity, then it is assumed that the worker will continue to work in other subsequent activities during the year and the exposure to the hazards of the remaining activities continues. But, if during an activity an accident occurs resulting to permanent injury or fatality, then it is assumed that the exposure to the subsequent activities stops.

At a company level the expected number of consequences of a particular type is calculated by multiplying the probability of a particular consequence (e.g. fatality) for a particular job by the number of workers in that job position.

3. Aluminium processing plant description

The aluminum plant produces profiles for various applications in the industry and building construction. The heart of the industry is the extrusion press section, where raw material arriving in the