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Risk assessment of chemicals in foundries: The International Chemical Toolkit pilot-project

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Abstract

In Brazil, problems regarding protection from hazardous substances in small-sized enterprises are similar to those observed in many other countries. Looking for a simple tool to assess and control such exposures, FUNDACENTRO has started in 2005 a pilot-project to implement the International Chemical Control Toolkit. During the series of visits to foundries, it was observed that although many changes have occurred in foundry technology, occupational exposures to silica dust and metal fumes continue to occur, due to a lack of perception of occupational exposure in the work environment. After introducing the Chemical Toolkit concept to the foundry work group, it was possible to show that the activities undertaken to improve the management of chemicals, according to its concept, will support companies in fulfilling government legislations related to chemical management, occupational health and safety, and environmental impact. In the following meetings, the foundry work group and FUNDACENTRO research team will identify "inadequate work situations". Based on the Chemical Toolkit, improvement measures will be proposed. Afterwards, a survey will verify the efficency of those measures in the control of hazards and consequently on the management of chemicals. This step is now in course.

Keywords: Foundry; Small enterprises; Risk assessment; Control banding approach

1. Chemical hazards in foundries

Founding is the simplest of all metallurgical processes and one of the oldest of all industries. Two main procedures are carried out in a foundry: sand molding and metal casting. The casting process consists basically of pouring liquid metal into a mold containing a socket in the geometry desired for the final part. The processes can be classified by the type of mold and model and by the force or pressure pair used to fill the mold with the liquid metal [1,2]. Fig. 1 presents a general foundry process fluxogram.

This industry is diverse in terms of materials and processes, resulting in occupational exposures to a wide range of hazard substances or workplace activities that could cause diseases, injury, ill health or death. Although many changes have occurred in foundry technology and materials [3], the basic processes and the associated hazards have remained much the same in many foundries [4]. Some of the most common causes of injury and illness in these industries are: (i) exposure to silica [5,6]; (ii) exposure to mineral wools and fibres [7]; (iii) contact with hot metal [8]; (iv) fire and explosion [9]; (v) extreme temperatures [8,10]; (vi) non-ionizing and ionizing radiation [8]; (vii) noise and vibration [8]; (viii) inhalable agents [11]; (ix) skin contact with chemicals [12–14].

This paper focuses on chemical hazards assessment in foundries. A chemical substance is a compound or mixture which may be present in the workplace in the form of a liquid, solid or gas. These substances may present a hazard as the result of contact with the body or absorption into the body, through the skin, by ingestion or inhalation.

The production in both ferrous and non-ferrous industry involves the consumption and generation of a variety of inhalable agents including gases, vapours [11], dusts [6], fumes [15], smokes and aerosols [1]. These agents comprise a variety of toxicological hazards as irritants, allergens [14], carcinogens [16] and systemic toxicants [12,13,15].

The pulmonary system can be affected by exposure to harmful agents and the most serious diseases are the development

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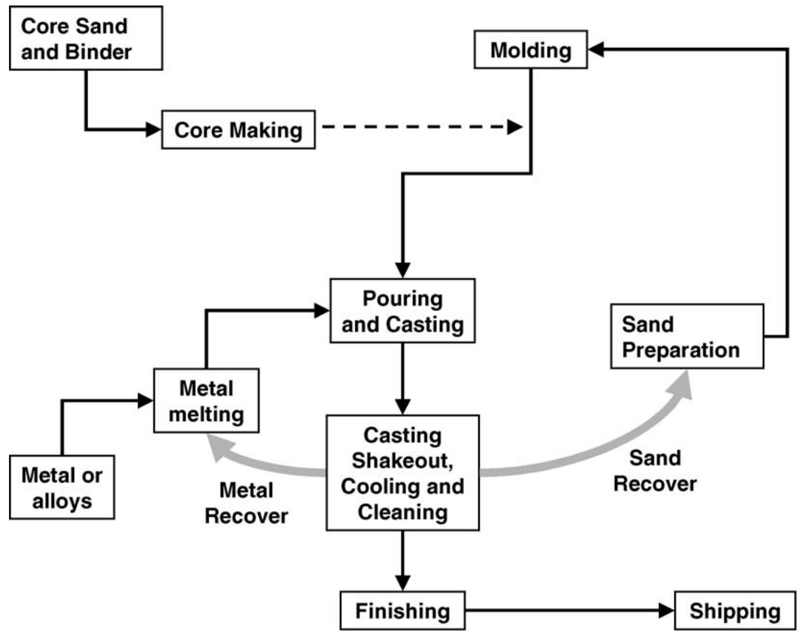

Fig. 1. Metal casting process.

of pneumoconiosis [17], pulmonary disfunction [18], chronic respiratory disease [19], occupational asthma [20,21] and the development of lung cancer [22].

Specific agents that may be found in this industry include: (i) primary metal fumes [22,23] and dust generated, for example, by melting aluminum, copper, lead, magnesium, manganese, nickel, or even metal alloys as bronze; (ii) aerosols of metal salts as copper sulphate; (iii) acid mists as hydrochloric and sulphuric acid; (iv) gases [24], including chemical asphyxiants, as carbon monoxide, chlorine, hydrogen fluoride and sulphur dioxide; (v) organic vapours [25]; (vi) silicate dusts from amorphous and crystalline silica, asbestos and talc [6,21].

Most of these hazardous agents are generated during the casting process when molten metal is poured into sand molds bound together with organic binders. Others are added to specific processes and/or are generated as waste by the action of heat on chemicals in various metals production processes [11].

During the general molding process, including shell molding, resin-bonded sand is coated with phenol–formaldehyde or urea–formaldehyde resin and heated until the mold has set. Gas catalysts as carbon dioxide and sulphur dioxide are sometimes used to facilitate curing. These phenol- or formaldehyde-based resins are a hazard if they are inhaled or come into contact with the skin [11]. In the hot-box molding, workers are also at risk from exposure to furfuryl alcohol–urea [26], formaldehyde [11], triethylamine [27], isocyanate [11], benzene and toluene [28].

Mold patterns are produced using wood, reinforced polyester, plastics and foam or wax. The wax material often contains a respiratory sensitizer, that is given off during the heated aspects of pattern making [20].

The refractory cores materials often consist of artificial mineral fibers, which are skin irritants. Exposure to crystalline silica dust is a recognized hazard of fettling and machining.

Despite the fact that occupational exposure to chemicals in foundries is very well-known, substantial occupational exposures to airborne polynuclear aromatic compounds, silica dust, metal fumes continue to occur in many foundries. A healthy work environment is still the privilege of a few, as too many workers continue to be exposed to occupational hazards.

2. Risk assessment

The occurrence of exposure to chemicals in foundries is due mainly to insufficient awareness, lack of human and financial resources and deficiencies in access to information [29]. The lack of training and education and poor work organization are also obstacles to be transposed [30].

The items pointed above interfere with the risk assessment quality, since in a simple way, risk assessment comprises a series of common sense judgments based on information about the type of the substance, its health effects and how it is being used in the workplace. In other words, risk assessment is a process used to determine the level of risk of injury or illness associated with each identified hazard, for the purpose of control. If the hazard is not identified, or the sense of what is hazard is not defined the risk assessment fails.

It is known that in the vast majority of small and medium-sized companies, those who process chemicals are not often able to protect themselves, assessing risks adequately and applying basic control strategies as engineering controls, procedural controls or housekeeping, even if they are motivated to do so. Sometimes prevention fails due to an inhability to apply existing knowledge [31].

Previous studies have demonstrated that the use of personal protective equipment features very highly, followed by the use of process controls. Little importance is given to eliminating the hazardous substance or using it in a safer form [32].

The observed lack of general knowledge required for protection from hazardous substances has lead Health and Safety Executive (HSE, UK) to develop a simple system of generic risk assessment to identify appropriate control strategies and a series of control guidance sheets providing good practice example for those strategies [33]. Published in 1998, the COSHH Essentials scheme [33–35] aimed to help small and medium-sized enterprises control health risks from chemicals, triggered intense and wide ranging discussion in the European occupational hygiene community. Most experts found this approach easy to use and understand and therefore well-suited to the special needs of small and medium-sized enterprises [31,36]. The COSHH acronym stands for Control of Substances Hazardous to Health, which is a set of general requirements for controlling exposure to hazardous substances, known as COSHH Regulations [37].

The HSE tool is a user-friendly, simple matrices that provide the user with guidance for controlling exposure to hazards. If adequately trained, people who have little or no occupational hygiene experience, like a small employer, can implement the hazard assessment process and understand the sound occupational hygiene advices in the form of guidance sheets.

This pragmatic approach provides guidance for the more routine occupational hygiene problems. Since they do not use on-site experts to conduct exposure monitoring, the focus for risk management shifts from measurement to exposure control. Yet, the method itself recommends that some situations be dealt with only experts on the subject.

2.1. COSHH Essentials concept: the control banding approach

The concept of control banding was developed in the late 1980s by occupational health experts in the pharmaceutical industry. The experts reasoned that a large number of compounds with few toxicity data could be classified into bands by their toxicity and by their need for restriction of exposure [38]. In the early 1990s, as the European system for classification and labeling developed, occupational health experts began to examine the alignment between the classification, the exposure limit, and data on exposure and control systems [39].

Control banding is a process in which a risk band is formed by combining a given hazard group (hazard band) to a chemical within a band of exposure. Each risk band is aligned with a control scheme needed to be applied in order to prevent hazardous substances from causing harm to people at work. The greater the potential to harm, the greater the degree of control needed to manage the situation. This approach focuses resources on exposure controls and describes how a risk needs to be managed.

The most developed model for control banding has been established by HSE, as COSHH Essentials, where hazards, risks and controls are grouped into bands, as predicted by the control banding process [33,34]. The method is briefly explained in the following paragraphs.

Hazards are grouped according to their classification and common hazardous properties (toxicological profile, usually found in safety data sheet from the chemical supplier, in the form of R-phrases) [40]. In the COSHH Essentials, common R-phrases have been used to categorize chemicals into hazard bands A–E (hazard bands). The most hazardous chemicals fall into hazard group E. The least hazardous are in hazard group A. In addition, there is a group S covering chemicals that can cause damage if they come into contact with the skin or eyes.

The exposure band is defined combining the substance's physical properties and the amount used. In the COSHH Essentials, *dustiness* is the key physical property and the user describes this subjectively. For liquids, *volatility* is the key and the user needs the boiling point, and the process temperature. The amount used of a substance was classified as small (grams or millilitres), medium (kilograms or litres) and large (tonnes or cubic metres). The volatility and dustiness were also classified as small, medium or large depending on the substance boiling point for liquids and particle size for solids. These data are important since the more a substance is used, or the more a substance is available in the air, the more likely it is to present an exposure problem.

Combining hazard band and exposure band, the risk band is assigned and can be associated with a particular control banding: control techniques ranked in order of stringency, with different levels of control. The four main control bands in COSHH Essentials, in order of stringency are: (i) general ventilation; (ii) engineering control; (iii) containment; (iv) special—in this case, an expert is required to select the right control measures.

The process, explained in a simple guideline, leads the user to select appropriate control guidance documents that present a number of key points that the user has to follow to reduce exposure to a certain level, displayed in items such as: access to the work area, design and equipment, examination and testing of equipment, cleaning and housekeeping, personal protective equipment and training and supervision.

2.2. International Chemical Control Toolkit

Due to the success of COSHH Essentials to control chemical exposures in small and medium-sized enterprises, there was consensus that the scheme had great potential for development and dissemination. For this reason, both International Labour Organizations (ILO) and World Health Organization (WHO) decided to promote this tool internationally as an "*International Chemical Control Toolkit*".

The key objective of the promotion of the Chemical Toolkit is to support countries to focus their efforts on both assessment and control of hazards. Chemical Toolkit offers opportunities to overcome the scarcity of technical expertise in developing nations. So, employers can save money on hazard and risk assessment and, therefore, have more to spend on risk management.

A meeting was organized in Utrecht in June 2004, by World Health Organization and International Program on Chemical Safety (IPCS) team, to promote and discuss models and strategies for Chemical Toolkit implementation [41]. The meeting was attended by representatives of University and Research Institutes from Belgium, Switzerland, The Netherlands, USA and UK, and also representatives of WHO collaborating centers on developing countries from Benin, South Africa, India and Brazil.

The most important objective of this meeting was to plan pilot-projects for the implementation of the Chemical Toolkit in developing countries. In this occasion, Brazil (represented by FUNDACENTRO—Fundação Jorge Duprat Figueiredo de Segurança e Medicina do Trabalho) decided to focus the effort on small and medium enterprises (SMEs) that use chemicals, more specifically in foundries.

3. The Brazilian pilot-project implementation in foundries

The whole foundry industry employs up to two million workers around the world. Brazil is the world's seventh largest melt producer. The Brazilian production of casting reached its peak in 1995 with 1610 tonnes [42].

Brazilian natural conditions show that the sector has potential to become one of the world's largest. The main factors that favor advantageous conditions to the Brazilian foundry industry are the costs with electric energy, raw materials and manpower. According to ABIFA [43], 75% of the castings are micro and small companies in Brazil, as shown in Fig. 2. Most of them are located in south and southeast regions of the country.

The sector of production of foundry parts in iron, steel and non-ferrous alloys is a segment of the economy that employs about 48,000 workers and generates revenues of US$ 2.9 billion a year. About 57% of the production is oriented to the automotive industry [43].

Despite the economic relevance of the foundry work in Brazil, there are difficulties in finding papers reporting the occupational profile of Brazilian foundries workers; exposure data are very scarce [44]. However, recent studies carried out in Loanda/PR have shown that foundries work environment present high levels of Cd and Pb [45]. Biological monitoring studies have also detected high levels of Pb and Cd in the workers' samples of blood and urine [46].

3.1. Pilot-project first step

The first step of this pilot-project comprised a series of visits to 11 small enterprises chosen randomly at the city of São Paulo. In such occasions, the concept of control banding was introduced to them and the foundry plants were visited in order to identify potential exposure situations.

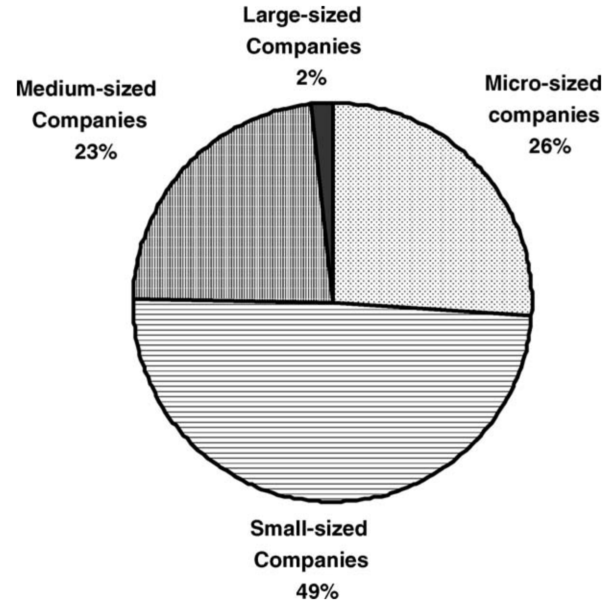

Fig. 2. Distribution of foundries according to the number of employees.

It was observed that there is a considerable lack of perception of occupational exposure in the work environment and that it can be attributed both to limited financial resources and limited skilled human resources. Difficulties to access specialized information were also observed. Consequently, the management of chemicals fails and exposure situations are usual, as described in the following paragraphs and presented in Fig. 3.

Exhaust ventilations systems are precarious: only 40% of those visited enterprises kept extractor hoods above the furnace. In this step, it was not verified the effectiveness of these systems.

Pouring and casting was not performed in designated area to avoid fume dispersion, thus indicating a poor foundry plant organization. In most cases, all workers were exposed to fumes from these operation steps. In 30% of cases, sand recovering is done in open area instead of an enclosed place. The spread of sand dust was not controlled.

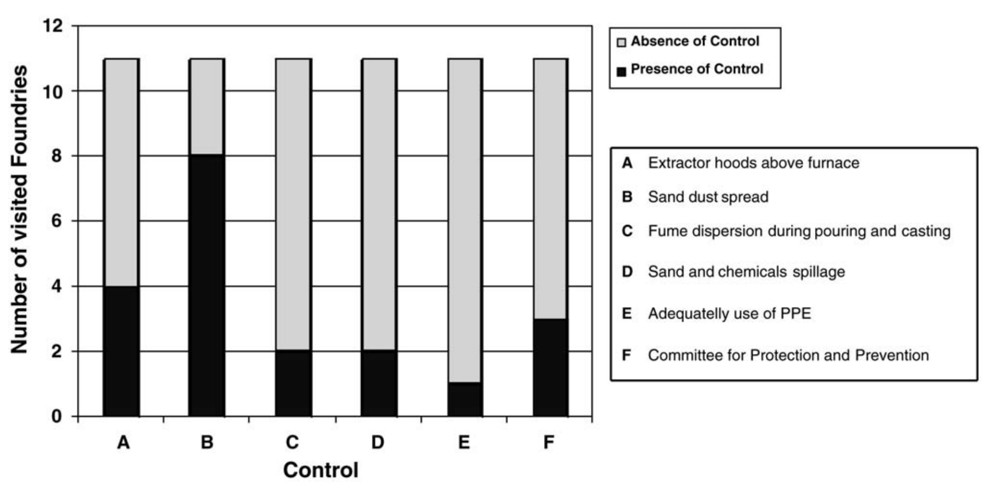

Fig. 3. Potential exposure situations.

Chemicals manipulation is unsatisfactory. It was observed, for example, spillage of sand and other chemicals on the entire foundry plant floor.

The absence of protective gloves during the core making resin–sand mixture preparation, for example, has shown that the use of personal protective equipment (PPE) and respiratory protective equipment (RPE) were often inappropriate. In some situations, non-existent.

Finally, only 30% of the companies had a committee for protection and prevention or a specialized professional on occupational safety working for them.

3.2. Pilot-project second step

Concomitantly to the first series of visits, both the control guidance sheets and the guideline were translated from English to Portuguese. The translated material was then formatted and revised. It must be kept in mind that, according to the COSSH Essentials, the set of control guidance sheets must be used by employers and employees, and before using it, they must understand it.

For this reason, the second step of this work comprised a meeting in three of the visited enterprises to discuss the usefulness of the guideline and the translated control guidance sheets. The foundry working groups were composed by an engineer (usually an OSH practitioner), the foundry manager and an operating supervisor. This step was important to ensure that all material presents an usual vocabulary, and approaches as many aspects of the work situation as possible. When necessary the material was adapted by modifying terms, eliminating irrelevant aspects, transforming others or adding new ones.

In this occasion, it was possible to show to them that (i) the impossibility to carry out quantitative exposure assessment should never be a blockage to the implementation of obviously required control measures, and that (ii) the activities undertaken to improve the management of chemicals, according to the Chemical Toolkit, will support companies in fulfilling government legislations related to chemical management, occupational health and safety and environmental impact.

As a result, an agreement between the companies and FUNDACENTRO was reached aiming to implement the Chemical Toolkit properly, and to verify whether by using this risk assessment tool, there is an improvement on the control of hazards and consequently on the management of chemicals.

In the following meetings, the foundry work group and FUNDACENTRO research team will identify “inadequate work situations” and the correspondent Chemical Toolkit control guidance sheets. Based on these sheets, improvement and adequate controls will be determined. Afterwards, actions will be implemented in a systematic way and the results will be monitored and evaluated.

4. Outlook

After the preliminary work presented above, it is clear that the Chemical Toolkit concept is a powerful tool to improve risk assessment in foundries. The control guidance sheets are very easy to read and understand, and moreover present concise and clear suggestions. It may be a simple way to reduce and control hazards.

It is important to highlight that the development of the Chemical Toolkit pilot-project is a first step on the long way towards effective implementation of strategies to risk assessment in Brazilian foundries.

New tools are very important, but not enough to improve the control of hazards in the small and medium-sized enterprises scenario. It must be kept in mind that the promotion and advancement of hazard and risk assessment systems must be a shared goal of the employers and employees. To reach this joint commitment between employers and employees, it is also needed to show the benefits of hazard prevention to both sides, planning and executing a broad range of activities. In doing so, the following items comprise the next steps of this research:

- *Quantitative evaluation*: measures to validate the Chemical Toolkit control strategies adopted by the enterprises involved in this research.
- *Training activities*: training small and medium-sized companies owners, employers and employees concerning the important reasons to use the Chemical Toolkit and how to use it.
- *Information*: awareness raising about hazards prevention and control through diffusion of information to authorities, employers, workers and their representatives. Providing access to information is fundamental to capacity building, besides training and education.
- *Development of new tools*: adaptation and/or creation of new strategies, methodologies and tools to assess and control hazards applied to other SMEs production sectors.

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