Analysis and risk assessment of chemical exposure in a chemical laboratory

Abstract
In order to perform an analysis and risk assessment in a chemical laboratory it was established an integrated methodology, where a preliminary analysis based on hazard identification and characterization, followed by application of qualitative (cost-benefit analysis) and quantitative (EMKG-EXPO-TOOL, Stoffenmanager, additive model) methods were used to estimate the risk level of exposure to several chemicals. Three measures were applied in order to reduce exposure risk, namely the elaboration and use of one-page safety data sheets, personal protective equipment quick reference lists and storing and labelling procedures of aliquots. The use of a combination of assessment methods contributed to improve of the occupational safety and health conditions of the laboratory workers, thus contributing to improve the working conditions.

Keywords: risk assessment, EMKG-EXPO-TOOL, Stoffenmanager, additive model, cost-benefit analysis

1. INTRODUCTION
Occupational risks are inherent to the environment or to the operational process of the different activities. Generally the risks posed by hazardous chemicals refer to both safety and health of workers and are related to the manufacture, handling, and use of chemical substances, either in pure form or in mixture or preparation form. By law, employers in the EU must protect their workers from being harmed by dangerous substances in the workplace. The employers must carry out risk assessments, and act on them. EU legislation also identifies and label thousands of different substances that are registered in the EU market. By taking the appropriate actions, workers can be kept safe while using dangerous substances. Employers are also obliged to provide workers with information on the risks posed by hazardous substances, and training on how to use them safely.

2. MATERIALS AND METHOD
In order to reduce the risk of exposure to hazard chemical agents (ethanol, acetone, petroleum ether, benzene, cyclohexane, dimethyl phthalate, isoctane, n-dodecane, n-hexane, n-nonane, n-decane, n-tridecane, n-tetradecane, n-pentadecane, tetrachloroethylene, toluene and trichloroethylene) in the laboratory under study, it was established an integrated methodology, which is depicted in Figure 1. A preliminary analysis, based on hazard identification and characterization based on chemicals safety data sheet (SDS). The chemicals manipulated were grouped according to the characteristics of use: frequency, volatilization and volume. To perform the assessment of the identified risks the appropriate methodologies were selected, as well as the applicable legislation (DL n. 24/2012) and standards (NP 1796:2007).

The risk assessment of chemical agent’s exposure resulting from daily activities in the laboratory was performed using two simulation tools, properly validated for this purpose, the EMKG-EXPO-TOOL and the Stoffenmanager.

2.1. Risk assessment - EMKG-EXPO-TOOL
The EMKG-EXPO-TOOL is part of the “Easy-to-use workplace control scheme for hazardous substances”. This tool was developed within REACH context by BÄuA (BÄuA, 2008) and it is based on data from SDS. The data regarding the chemicals under evaluation were introduced in an Excel datasheet and five steps - definition of volatility bands, scale of use bands, short term exposure, applications on surfaces <1 m² and control strategies, were followed until the result - the risk assessment - is reached.

2.2. Risk assessment - Additive model
When two or more chemicals act simultaneously at the same level in the human body, must be considered their combined effect instead of their isolated effect. Thus, it was considered chemicals that produce effect at central nervous system, which were handled in the laboratory during a single period of work (acetone, petroleum ether, hexane, toluene, trichloroethylene and tetrachloroethylene). For this purpose it was applied the additive model using the more conservative values of concentration simulated by EMKG-EXPO-TOOL.

2.3. Risk assessment - Cost-benefit analysis
One of the first steps to be considered in risk management is the hazard substitution at the source. Therefore, in order to find a suitable substitute for n-nonane, a chemical often used in the laboratory, it were listed the desired characteristics such as cost, physic-chemical properties and safety features. It was assigned a numerical rating from 1 to 5, i.e. from not suitable to very adequate, and the total amount was analyzed for all candidate chemicals (n-dodecane, n-tridecane, n-tetradecane and n-pentadecane).

2.4. Risk assessment - Stoffenmanager
The Stoffenmanager® (version 5.0., www.stoffenmanager.nl) is a quantitative inhalation exposure tool for prioritizing worker health risks to dangerous substances. This tool has been recognized by the Dutch Labour Inspection and by the European REACH, as an instrument to assess hazardous substances in the workplace. Stoffenmanager classifies the risks of a product on the basis of H-phrases of a product in accordance with the scheme Essentials COSHH (Control of
substances hazardous to health). After the cost-benefit analysis, this tool was used to compare two scenarios - before and after replacement n-nonane for n-dodecane, according to the type of activity, duration, frequency, area, ventilation, PPE, etc..

Figure 1 – Study methodology.

2.5. One-page safety data sheet
The routine work may be considered as a risk for the workers. Sometimes the query of the SDS, before handling a chemical, is not performed efficiently given the extent of the presented information. In the other hand, the chemical manipulations are mainly performed solitarily. So, in case of accident, the potential rescuer will not know the characteristics of the products that were manipulated, which could make the difference between a fast and effective first aid and serious damage or even death of the worker. The one-page SDS will allow the operator to quickly consult the handling key points of the chemical. The short form of the SDS will also permit to post it in the work zone in a place identified as "Warning! Working with: …".

2.6. Quick reference lists of personal protective equipment
In order to increase the effectiveness of using the right type of gloves, regarding the chemical handled, it was posted on the laboratory wall a quick reference list with the types of gloves available and its characteristics.

2.7. Storing and labeling procedure for working aliquots
One of the increased risks of handling hazardous chemicals, results from the lack of unequivocal identification and labeling of the work aliquots as well as not suitable containers storage, resulting not only in the inadvertent spillage of the compound as in the modification of chemical properties. Thus, it was recognized the need to systematize the packaging and labeling of aliquots through the implementation of a procedure.

3. RESULTS AND DISCUSSION

3.1. Risk assessment - EMKG-EXPO-TOOL
Working scenarios at 20 °C, 25 °C and 30 °C were simulated in order to estimate the exposure interval to manipulated chemicals. It was also considered exposure times below and above 15 minutes, and manipulation with and without local exhaust ventilation. Based on the empirical and real data, from EMKG-EXPO-TOOL, it was possible to differentiate the conditions of dangerous handling, thus allowing to establish corrective measures in order to minimize the exposure risk, especially regarding the obligation of handling certain chemicals inside a hood. Thus, it was found that: the handling of petroleum ether, hexane, toluene, trichlorethylene, tetrachlorethylene should be made mandatory within the hood; the handling of dimethyl phthalate, even within the hood, is a situation of increased risk, with concentrations in the order of the OEL, and the is necessary to use respiratory mask with filter A and watertight goggles; and that the benzene is another compound of high risk and that their use should be made mandatory within the hood, with mandatory use of protective breathing apparatus (full face / semi-shade / room mask) with A2B2E2K2P3 filter.

3.2. Risk assessment - Additive model
The chemicals handling with mechanical air extraction did not exceed the Occupational Exposure Limits (OEL), however the action value (OEL/2) was exceeded thus requiring the application of measures. On the other hand the chemicals manipulation without mechanical air extraction carries out exposure values of about 6 times higher than the OEL. The individual exposure analysis showed however that the chemicals did not exceed the action values.
3.3. Risk assessment - Cost-benefit analysis
Despite not having been assigned a greater weight to the safety requirements than to the physical-chemical properties and to the cost, it was found that n-dodecane is an adequate substitute for n-nonane, having a score of 16 in 25.

3.4. Risk assessment - Stoffenmanager
With the introduction of two measures of exposure control: replacement of chemical to n-dodecane and the implementation of a system of air extraction, it was possible to lower the exposure class from 2 to 1, i.e., from medium to low. It was thus possible to confirm the result of the cost-benefit assessment.

3.5. One-page safety data sheet
The one-page SDS page included the following information: A. SUBSTANCE ID (CAS / INDEX / EC No.); B. HAZARDS (hazard pictograms, signal word, hazard statements, precautionary statements); C. FIRST AID (first aid measures; emergency phone numbers); D. FIRE FIGHTING (suitable extinguishing media, special hazards); E. HANDLING AND STORAGE (information for safe handling; guidance on protection against fire and explosion hygiene measures); F. PERSONAL PROTECTION; G. STABILITY AND REACTIVITY (reactivity, chemical stability, possibility of hazardous reactions, conditions to avoid, incompatible materials, hazardous decomposition products); H. OTHER INFORMATION (who and when it was made the SDS).

3.6. Quick reference list of personal protective equipment
The choice of glove type will lie in the material and thickness recommended for the type of contact: splash or full contact, according to chemical SDS.

3.7. Storing and labeling procedure for working aliquots
It was established that all aliquots must be stored in suitable containers, i.e. with the same type of packaging material of the original package and must also respect the head-space necessary to avoid problems due to expansion. It was also established that each aliquot should be labeled with adequate labels containing: compound ID; hazard pictograms, signal words, hazard statements and precautionary statements considered most relevant, operator ID and date.

4. CONCLUSIONS
Regarding the evaluation of chemicals exposure using methods based on the control banding approach (EMKG-EXPO-TOOL and Stoffenmanager) it was necessary to take into account its limitations, namely that this application requires a professional knowledge and experience that enables to verify that the control measures specified have been correctly installed, used and maintained.

The procedure for aliquots preparation, as well as the use and display of one-page SDS during the laboratory work with hazardous chemicals will significantly contribute to reduce the risk associated with these chemicals. Another contribution to the improvement of working conditions was related to the completion of the exposure risk assessment to chemical agents commonly using simulation tools via the inhalation exposure, due to the unavailability of instruments for the measurement of these concentrations in the air.

The results of the analysis of Stoffenmanager allowed corroborating the need to replace a commonly used chemical agent, in order to minimize the workers safety health risk.

The analysis of Stoffenmanager allowed corroborating the need to replace a commonly used chemical agent, in order to minimize the workers safety health risk. The results of the analysis and risk assessment performed in the chemical laboratory using a combination of assessment methods contributed to improve the occupational safety and health conditions of the laboratory regarding chemical contamination thus contributing to improve the working conditions.

5 REFERENCES
DL n. 24/2012, February 6 (2012). Estabelece a regulamentação sobre a proteção da segurança e saúde dos trabalhadores contra os riscos ligados à exposição a agentes químicos e estabelece valores limites de exposição profissional a agentes químicos.