Risk Assessment for Occupational Exposure to Chemicals in an Electroplating Industry

Marco Silva and Miguel Corticeiro Neves

Instituto Superior de Línguas e Administração
ISLA Leiria
Leiria, 2414-014,Portugal

ABSTRACT

Risk assessment for occupational exposure to chemicals should be one concern of all electroplating industries. The quantities and characteristics of hazardous substances and mixtures used, requires a risk assessment to ensure the protection of workers, and the legal compliance to the requirements in this area. This paper aims to apply a general method (NTP 330) for this assessment and compare the results with the results obtained from the application of three qualitative methods of risk assessment of exposure to chemical agents: NTP 934, NTP 936 and NTP 937, all published by the Instituto Nacional de Seguridad e Higiene en el Trabajo Espanhol. After a description of the risk assessment methods applied, it will be performed a comparative analysis of risk level results and of the control measures to be implemented, with the aim of describing the advantages and disadvantages of each method and in what conditions it can be carried out. This will allow in certain situations the adoption of measures to control the risk without recourse to quantitative methodologies. Although in cases of high risk, assessment should be more detailed and use methodologies for measuring the concentration of chemicals in workplace atmosphere, for comparison with the threshold limit values.

Keywords: Chemical Agents, Chemical Substances, Electroplating Industries

INTRODUCTION

Electroplating activities are, by their own nature, activities that permanently require the consumption of hazardous substances and mixtures, therefore Occupational Safety and Health services, in what mainly concerns to the risk assessment of exposure to dangerous chemical agents, must be a constant and permanent concern to the employer and to these same services. The technical complexity of electrodeposition processes, allied to the dangerousness of used hazardous substances and mixtures, demand a deep approach from all Occupational Safety and Health technicians. (Rodrigues, et al., 1999). Portuguese legislative panorama regulated these questions through the Decree-Law n. º 24/2012, of 6th of February, which defines minimal prescriptions concerning workers protection against safety and health risks due to chemical agents occupational exposition, with obligation of being complemented by legislation concerning carcinogenic or mutagenic agents exposition during work, regulated in Portugal by Decree-Law n.º 301/2000, of 18th November. Both diplomas stipulate that the employer must evaluate the risk of safety and health on the workers, determining the nature, the degree and time of exposure. The legal diplomas above quoted do not define the applying methodology for the accomplishment of the risks assessment, for what we could assume that any generalist methodology of risks assessment could reach that objective. The organizations frequently use quantitative methodologies to determine the exposition risk to chemical agents, like for example measure methodologies of the amounts of chemical agents in labor atmosphere, in order to compare with legislated boundary-values of labor exposition. However, these methodologies imply processes of great technical complexity, with resource to laboratorial techniques that, by its very nature, cause great expenses in time and financial resources.

https://openaccess.cms-conferences.org/#/publications/book/978-1-4951-2100-5

(INSHT, 2013)

However, there are some qualitative (and semi-quantitative) methodologies published of risk assessment of the exposition to chemical agents, whom not intend to substitute quantitative methodologies, but to complement them, and to allow a first evaluation, as initial diagnosis on the risk, so that, in determined situations, they can allow the adoption of risk control measures without recurring to quantitative methodologies. On the other hand, these qualitative methodologies allow to demonstrate, by other means, when nature and dimension of risks exposition to chemical agents do not demand a more detailed evaluation, supporting, thus, the justification demanded on the Decree-Law n.º 24/2012, for these cases (INSHT, 2013).

The objective of this work is the application of the generalist method (NTP 330) and, especially, the application of three other methods on evaluation of chemical agents exposition (NTP 934, NTP 936 and NTP 937), all published by Instituto Nacional de Seguridad e Higiene en el Trabajo Espanhol (INSHT), to the chemical maintenance tasks, which are developed in a plant dedicated to the surface treatment of metals, namely by zinc or zinc-nickel electroplating. The plant has an installed capacity of 388,225 m3 in chemical treatment baths, it has at the moment 66 workers, and it is located in the center of Portugal, in the city of Marinha Grande.

It is intended, thus, to carry through a comparative analysis on the application of the methods above cited, to determine the advantages and disadvantages of each one of them, as well to find which applies better to the characteristics and necessities of the organization.

METHODS OF RISK EXPOSITION EVALUATION ON CHEMICAL AGENTS FOR INHALATION

According to the Portuguese legislative reality, the Decree-Law n. º 24/2012, of 6th February, in its 7th article, it is stated as an employer's obligation, when are consumed chemical agents in his plant, the risk assessment concerning to the safety and health of the workers in their workplace.

According to diploma in cause, risk assessment must be registered in a written document that, in situations where the risk nature and dimension don't justify a detailed evaluation, contains the organization's justification; to be reviewed whenever significant alterations occur; in situations where it has been exceeded an threshold limit value or a biological exposure index, and in situations where health monitoring results justify it; to include the specific activities carried through in companies or establishments, namely the maintenance activities, for which it is predictable the possibility of a significant exposition, or the ones that may cause negative effects in safety and health, exactly in situations where it has been taken all adequate measures techniques;

The quoted diplomas demands to accomplish the risk assessment, consider among other aspects:

• Information relative to safety and health that figures in safety data sheet, according to applicable legislation in classification, packaging and labeling of hazardous substances and mixtures, and other necessary information on risk assessment, provided by the producer, just like the specific risk assessement to users;

• When exposure to several hazard chemical agents occurs, must be considered on the risks resulting from the simultaneous presence of all agents, in other words the effect of potentiation or addition;

• The nature, degree and the duration of exposure;

• The work conditions that imply the presence of these agents, including its amount;

• The TLV and the biological exposure indexes contained in specific legislation, such as the relative to carcinogenic or mutagenic agents and asbestos;

• The TLV contained in Decree-Law n. º 24/2012, of 6th February;

• The available results of any health surveillance already undertaken.

Although the risk assessment could be performed by any of the general methods, such as the simplified method of

NTP 330 (INSHT), these do not fully respond to the requirements of the Decree-Law n. º 24/2012 of 6th February, immediately because they don't have in count the intrinsic characteristics of each hazardous substance or mixture.

Qualitative and simplified methodology for assessing accident risk by chemical agents (NTP 934)

INSHT published the NTP 934 as a review of NTP 749, due to changes introduced by REACH and CLP regulations, particularly with the introduction of new hazard phrases (H-phrases) (Simon & Ardanuy, sd). This document presents a methodology that provides to the companies and to the safety technicians, a tool that enables you to meet the legal requirement to carry out a risk assessment in health and safety of workers arising from exposure to hazardous chemicals.

The methodology in question seeks to answer, with the greatest possible objectivity, to these requirements, quantifying the potential of risk and, thus, ranking the prevention actions to be applied. Despite having the same characteristics of the general methods, considers the hazardous properties of each hazardous substance or mixture.

This methodology focuses on the maximum expected damage and estimates the probability levels, the exposure frequency and the expected consequences to, thereby, determinate the risk levels of accident and prioritize corrective actions.

For this, we start from the identification of deficiencies in facilities, equipment, processes and tasks with hazardous chemicals. These deficiencies are related to the R phrases or H phrases (they will coexist until 2015) contained in the safety data sheets and labels of the different chemical agents involved, in the determination of a objective dangerousness level (NPO) of the work situation, by applying a NPO checklist, proposed in the NTP.

In a second phase, it is estimated the risk factor, exposure frequency (NE) and the expected severity of its consequences (NC), being evaluated the risk level (NR) by the multiplication of these three variables. In other words, the evaluation can be illustrated by the following equation:

$$\mathbf{NR = NC \times NE \times NPO}$$

The NTP 934 defines NPO as the magnitude of the expected relation between the risk factors considered and its direct causal link with a possible accident, and must be quantified through existing deficiencies in facilities, equipment and tasks with hazardous chemicals, verified through a checklist that can be adapted to the specificities of each plant, whose proposal is presented in Table I.1 of NTP 934. The questionnaire is constructed to evaluate deficiencies in 5 levels:

- Identification of chemical agents;
- Storage and transportation of chemical products;
- Use or processing of chemical products
- Prevention actions in the use of chemical agents;
- Personal Protective Equipment (PPE) use and First-aid facilities.

Any negative response to the checklist implies a disability degree, independent of the chemical in question, and others whose result is obtained from the risk phrases R and hazard warnings H. When filling the checklist, as indicated in questions, should be consulted I.2 and I.3 of NTP 934 tables to determine the valuation criteria based in R phrases or H phrases.

In the case of applying the method on waste or byproducts from which is not known the R phrases, should be assigned one R phrase that characterizes closely as possible the product. One important note is that in the case of a substance or mixture having various R or H phrases, leading to different classifications, it should be chosen the one leading up to a rating of greater deficiency.

On the other side, NE is an indicator of the frequency of exposure to an determined risk. It can be determined as a function of time spent in areas or tasks where certain risk has been identified.

Relatively to NC, the expected consequences are considered in case of risk concretization. Four levels of consequences are defined, that classify expected damage in case of risk exposure. The NR, as already discussed, is defined as the product of three variables: Objective Dangerousness Level; Exposure Level and Level of Consequence. The result allows a risk prioritization, so that we can define a level of intervention that will be associated with the type of measures to be implemented.

Legislative Decree n. º 24/2012, of February 6th, refers in its 8th article which measures shall be implemented in accordance with the results of the risk assessment. Therefore, the following types of measures can be applied:

- General measures of prevention and protection (article 9th);
- Specific measures of prevention and protection (article 10th);
- Technical or organizational measures (article 11th);
- Measures in case of accident, incident or emergency situation (article 12th);
- Exposure to chemical agents measurement (article 13th);
- Workers health monitoring (article 14th).

The mentioned legal diploma states that, whenever the risk assessment reveals a risk to workers health and safety, all measures listed above should be applied, unless the level risk be considered low and it be considered that is sufficient the first item of the list measures above. Considering this issue, it can be considered, that a reduced level corresponds to NR I and NR II, and for those levels is only necessary to apply the general measures of prevention and protection contained in Article 9th, Decree-Law n.º 24 / 2012, 6th February. To the remaining NR, it should be applied all measures contained in Articles 9th to 15th from that diploma, or others resulting from specific legislation such as REACH and CLP regulations and others resulting from good practice codes.

Qualitative and simplified methodology of risk assessment in chemical agents inhalation (NTP 935 and NTP 936)

INSHT also published NTP 935 and 936 relating to qualitative methods and simplified risk assessment of exposure by inhalation to chemical agents. These models were not designed as an alternative to the quantitative assessment of exposure to chemical agents, but as an additional tool for the evaluation process, which sometimes, may be sufficient to reach conclusions without resorting to quantitative assessment.

They are models that can be used by safety at work technicians to accomplish a first approximation or diagnosis about exposure to chemicals in the workplace and decide prevention measures applicable to every situation. These methods can be applied in a project stage, where there is still no effective exposure, or else be applied to agents that do not have defined TLV (INSHT 2013).

These methods attend to the specificities of each chemical agent, but approach in a common way the following variables (INSHT 2013):

- The hazardous of each chemical agent;
- The frequency of the exposition;
- The used or stored amount;
- The chemical agent volatility or dustiness;
- The way of use;
- The prevention actions and the applied control measures.

The result of the assessment will be a prioritization into risk levels, which determines whether the risk is acceptable or not. For this purpose, it's important to differentiate two types of model: those who estimate the potential risk of

exposure without including, as variable, the preventive or control applied measures and, on the other side, those who estimate the expected risk taking into account the implemented measures. The first type, the NTP 935 highlights the method of the Health and Safety Executive (HSE) called Control of Substances Hazardous to Health-Essentials (COSHH), and the second, the method of the Institute National de Recherche et Sécurité (INRS) theme of the NTP 937, and that will not be approached in this work.

The methodology COSHH – Essentials, aims to determine the appropriate means of control (control levels), and not specifically to determine the level of existing risk, thereby providing practical solutions in the form of control sheets. This approach is discussed in NTP 936, and is based on control sheets that list safety work conditions and provide solutions for chemical agents exposure that do not have R or H phrases, for example, welding fumes and wood dust.

This method applies a risk classification into four groups, based on the consideration of three operation variables to assess. Variables related to volatility or dustiness and amount of chemical agents used indicates the level of potential exposure that may exist. This, combined with agent's hazard, leads to a classification of four levels of potential risk. The first variable refers to danger, according to the R and H phrases, and it is classified into five categories (A-B-C-D-E) in ascending order of hazard, depending on the R or H phrases, according to table that is in NTP 936.

In the case of a substance have phrases that correspond to more than one category, it should be assigned the upper level obtained.

These methods only take into account the risks of exposure by inhalation to chemical agents , and in the case of the substance presenting risks by contacting with skin or external mucous membranes, should be assigned the notation S (Skin) not going forward with the assessment (NTP 897).

The second variable is the tendency to contaminate the environment, which is ranked High, Medium and Low and it is measured, in the case of liquids by its volatility and use temperature, and in the case of solids, by their dustiness.

The third variable is related to the amount of substance used and can be characterized as Small, Medium or Large.

All variables described above are related to a table of three entries, which allows you to obtain four levels of potential risk and its preventive actions.

Preventive measures to be implemented are related to potential risk levels in a control banding logic.

When the total duration of risk exposure during a working day is less than 30 minutes you can go down one level to the calculated risk level, with exception of the level risk 4. This exception is based on the fact that the environmental concentration of the chemical agent obtained at below level control is compensated by the fact that the worker is exposed to that concentration less than 10 % of his working day.

Finally, it should be noted that the HSE, in COSHH- Essentials Internet site, offers an online tool, which after indicating the type of operating characteristics and characteristics of the substance or mixture used, returns the classification of the level of risk and respective control sheets per operation. Also INSHT offers in its website a tool that allows you to calculate the risk level and the control measures applicable, through the introduction of chemical variables; dustiness or volatility and amount of substance. They are very intuitive and allow, in a simple way, a first approach to the problem.

Qualitative and simplified methodology for risk assessment of inhalation of chemical agents (NTP 937)

The INSHT published a technical standard, NTP 937, that involves the application of a method, developed by the Institut National de Recherche et de Sécurité (INRS), which applied some changes in order to make it a risk assessment method of inhalation of chemical agents most complete.

The INRS method, which NTP 937 is about, differs from other methods, because it enters in account with existing control measures, allowing it to identify a level of expected risk exposure (final), as opposed to the COSHH method that only allows the identification of potential level.

Figure 1 intends to illustrate the input variables of the INRS method, until the obtaining of the risk level of inhaling dangerous chemicals.

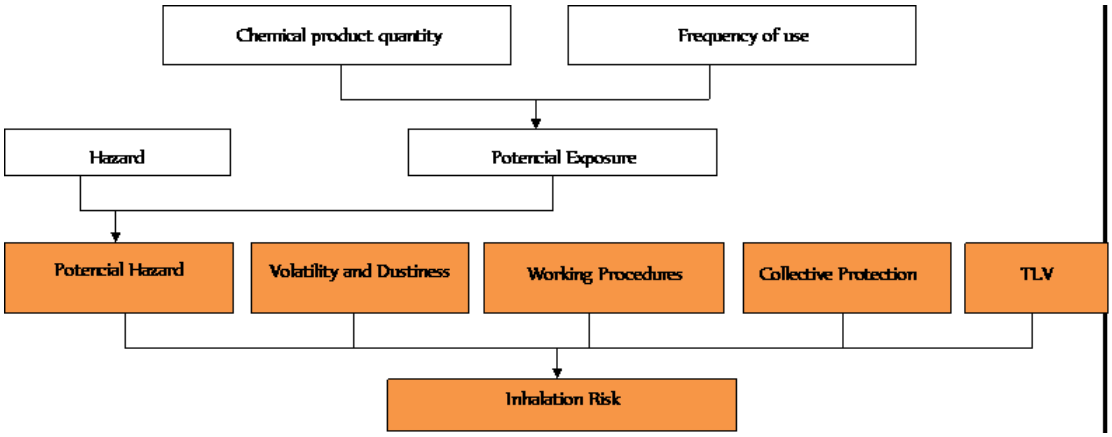

Figure 1 – Scheme to risk assessment by inhalation - NTP 937.

Adapted of (Rodriguez & Traspaderne, s.d.)

TLV variable has to do with a correction factor that applies to chemicals whose TLV is less than 0.1 mg/m3. For all variables are assigned classes and for each class are assigned values and the risk level score is obtained by the product of the four variables and the correction factor , if applicable . All classes are obtained by reading NTP 937 tables.

The hazard class is obtained by the agent dangerousness (R or H phrases), from existing TLV, and from the materials or processes in question. Relating this class with the amount and frequency class, we obtain the potential risk class.

Volatility or dustiness, just like in the other methods, is classified, in solids, for its ability to form dust in the air (3 classes of dustiness), or in the case of liquids, depending on their boiling temperature and work temperature.

Another parameter to consider is the working procedure in which the chemical agent is present and is graded according to its work in an open or closed system.

Another parameter that distinguishes this method from others is the existent collective protection related to the workspace ventilation. Possible scenarios range from spaces without ventilation through spaces with localized suction, ending in containment systems.

Lastly, and if the substance has a legislated TLV lower to 0.1 mg/m3, applies a correction factor depending on the classes provided at NTP 937 . This correction factor is applied to prevent underestimated risk when analyzing substances that have a very low TLV, because those can easily reach this value in the working atmosphere.

Once you have determined all variables, the risk value is determined by the product of the values obtained and compared with the intervals described in NTP 937

This method considers factors that decisively may influence the chemical concentration in the workplace atmosphere, such as the working procedure and collective protection measures. On the other hand, considering a semi quantitative method, scores can help in the decision- making process by allowing a prioritization of an action plan, and, moreover, it is very easy to see which variable has more influence in the result and try to act on it.

The disadvantage of this method , compared to others that group risk levels with similar control bands and propose appropriated control measures (such as the COSHH method) , appears the fact that the INRS method only categorize the risk , not establishing any control measures . (Rodriguez & Traspaderne, S.D.)

METHODS AND MATERIALS

The method used to develop work started initially by identifying chemical maintenance tasks that would configure activities with risk of exposure to hazardous chemicals. In a second phase the methods of risk assessment published by the Spanish agency INSHT were applied, among others:

- Norma Técnica de Prevención (NTP) 330: Sistema simplificado de evaluación de riesgos de accidente.
- Norma Técnica de Prevención (NTP) 934: Agentes químicos: metodología cualitativa y simplificada de evaluación del riesgo de accidente.
- Norma Técnica de Prevención (NTP) 936: Agentes químicos: evaluación cualitativa y simplificada del riesgo por inhalación (II). Modelo COSHH Essentials.
- Norma Técnica de Prevención (NTP) 937: Agentes químicos: evaluación cualitativa y simplificada del riesgo por inhalación (III). Método basado en el INRS.

From the first phase resulted the identification of the following tasks of chemical maintenance that will be subject to risk assessment: Addition / Dissolution of Sodium Hydroxide, Nickel Addition; Sulfuric Acid Addition; Zinc - Nickel Dissolution, Alkaline Zinc Dissolution and Degreaser Dissolution.

To collect the necessary data defining the level of disability of hazard and hazardous conditions, were used direct observation methodologies, interviews, checklists and to determine the hazard of chemicals used was analyzed the respective safety data sheets. To determine the use frequency, duration of use and volatility or dustiness characteristics was consulted and analyzed the written procedures existing in quality management system. Calculations of risk level and respective levels were performed on adapted spreadsheets for this purpose

The method NTP 330 starts with the identification of hazards and dangerous conditions through the application of checklists. This method categorizes the level of each hazard or hazardous situation and disability associated with the level of worker exposure, which determines the level of probability of the expected damage. Subsequently, is performed the risk valuation by the multiplication of the probability level and the magnitude effects, which, in turn, corresponds to a level of intervention. NTP 934 method is characterized by, in an early stage , estimate a level of objective danger featuring the shortcomings of the installation as a whole, taking into account the hazardous of the chemicals in question ,focusing on the expected maximum damage, in order to categorize and prioritize the risks identified and applicable control measures (Simon & Ardanuy , sd) . On the other way, NTP 936 method aims to determine which control measures are applicable to reduce the risk into acceptable levels, rather than properly assess the risk in detail (Oller, sd) .Finally, NTP 937 differs from the others by considering the existing control measures and because it determines the final risk and not a potential risk (Rodriguez & Traspaderne , sd).

OBTAINED RESULTS

The NTP 330 implementation method, because of its general characteristics, led to a not accurately identification of all the tasks of manually added chemicals, which did not allow the identification of hazards and risk assessment in exposure to dangerous substances and mixtures, unlike what happens when we use specific methods for assessing chemical agents exposure.

After application of all above mentioned methods for the evaluation of the chemical maintenance tasks, it was found that the results were somewhat different with regard to the risk levels, but were consistent in classifying the task of adding nickel as the one with higher NR, and needing urgent action, as it can be analyzed in table 1

Table 1 - NR and NI results

Chemical Maintenance Tasks	NTP 934		NTP 936		NTP 937	
	NR	NI	NR	NI	NR	NI
Addition / Dissolution of Sodium Hydroxide	4	I - Urgent Correction	3	III - Confinement	3	3 - No intervention
Nickel Addition	4	I - Urgent Correction	4	IV - Specific Measures	1	1 - Urgent Correction
Sulphuric Acid addiction	3	II - Fix	2	II - Located Extraction	3	3 - No intervention
Dissolution of Zinc Nickel	3	II - Fix	2	II - Located Extraction	3	3 - No intervention
Dissolution of Alkaline Zinc	2	III - Improve	1	I - General Ventilation	3	3 - No intervention
Degreaser Dissolution	4	I - Urgent Correction	4	IV - Specific Measures	3	3 - No intervention

The methods are also concordant regarding control measures to be applied, so, for the mixing of nickel, all methods classifies it as an urgent intervention, and not being possible the substitution for a less dangerous agent or even substituting its solid form for its solution form, it's important to adopt engineering measures on localized aspiration, or dosing closed systems. In NTP 934 and NTP 936 methods also were evaluated tasks considering addition and dissolution of sodium hydroxide and degreasing dissolution with high NR, and therefore urgent intervention levels. The same is not true in NTP 937, because it includes the existing control measures in these tasks, such as the fact that the treatment vats have localized aspiration systems bilaterally disposed, thereby calculating the final risk, not the potential risk.

CONCLUSIONS

After application of the above methods, it was possible conclude that general methods do not permit the complete fulfillment of the requirement for risk assessment in Decree-Law n. º 24/ 2012 of 6th February, because they do not consider the intrinsic properties of each chemical agent and the type of exposure, and for such, should be applied specific methods of risk assessment of exposure by inhalation to chemical agents.

NTP are valuable tools in a stage of the initial diagnosis of risk assessment of exposure to chemical agents, NTP 934 and 936 are methods that allow, in addition to risk assessment, the determination of the applicable control measures, while NTP 937 valorize the existing control measures, and as such, sets the value of ultimate risk, which can be used to monitor the effectiveness of control measures implemented.

It should be emphasized that these methods allow only to make an estimation (diagnosis) of the initial risk, in cases where the risk is too high, and so, there is a need for urgent intervention, whether NR is greater or smaller, or, where NR is too low, being the risk considered acceptable and which is controlled with no need for intervention. In the other cases, should always be carried out a quantitative analysis on the risk of exposure to chemical agents so that can be possible a detailed analysis risk and comparison of the chemicals concentration present on workplace atmosphere with the TLV set out in legislation. These methods of risk assessment of chemical exposure also permit systematic application, which allows that different technicians apply the method reaching the same conclusions, ensuring objectivity in the evaluation results.

The results obtained by applying methods of assessing the risk of exposure by inhalation to chemical agents allowed the accurate identification of chemical maintenance tasks that have a higher level of risk, and as such, require more urgent action, as it is the case the mixture of nickel, which consists in a manual addition of nickel sulphate. This evaluation provided a plan of control actions which suggests that the application of this chemical agent in its dissolved form, or, failing that, the implementation of localized air extraction, or a confined automatic dosing system.

These methods are a valuable tool so that ocupational safety services can anticipate the inherent risks in their activities that have risk to exposure to hazardous chemicals, in conjunction with the implementation of REACH and CLP Regulations, which require the exposure scenarios annexation to the Safety Data Sheets of chemical substances and mixtures (for substances or mixtures sold in excess quantities of 10 t / year). That implies estimate an expected exposure in each one of the possible uses of the substance and compare to levels derived of no-effect exposure (DNEL), in other words, the level of exposure that is considered not to offer any risk to human health. This exposure estimation must be performed using models that consider such variables as the amount used, time of use, volatility, and the existing counter measures. These exposure scenarios, therefore, describe the conditions under which the chemical should be used and which ensure the effective exposure reduction, reaching, consequently, the objective of protecting workers against the risks of exposure to chemical agents in the occupational context.

REFERENCES

INSHT. (2013). Guía técnica para la evaluación y prevención de los riesgos relacionados con los agentes químicos presentes en los lugares de trabajo. Madrid: INSHT.

Oller, N. C. (s.d.). NTP 935 - Agentes quimicos: evaluación cualitativa y simplificada del riesgo por inhalación (I). Aspectos generales. Barcelona: INSHT.

Rodrigues, F., Sousa, J. P., Telo, E., Gonçalves, G., Aleixo, I., Vicente, F., et al. (1999). Riscos dos processos de electrodeposição: Manual de prevenção (1.ª Edição ed.). Lisboa: IDICT.

Rodriguez, M. E., & Traspaderne, J. N. (s.d.). NTP 937 - Agentes químicos: evaluación cualitativa y simplificada del riesgo por inhalación (III). Método baseado en el INRS. Barcelona: INSHT.

Simón, N. J., & Ardanuy, T. P. (s.d.). NTP:934 - Agentes químicos: metodología cualitativa y simplificada de evaluación del riesgo de accidente. Barcelona: INSHT.