sciendo CzOTO 2022, volume 4, issue 1, pp. 257-268

CHEMICAL RISK ASSESSMENT IN A SELECTED ROMANIAN STAINLESS STEEL PROCESSING COMPANY

doi: 10.2478/czoto-2022-0027
Date of submission of the article to the Editor: 13/12/2021
Date of acceptance of the article by the Editor: 21/06/2022

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Abstract: The production and use of chemicals are continuously increasing worldwide. For example, the global output of chemicals increased approximately 12 times between 1970 and 2020. The burden of disease attributable to exposure to chemicals is significant. World Health Organization estimates that globally, about 5 million deaths and 90 million disability - adjusted life years are attributable to occupational, environmental exposure and management. Public authorities and employers need access to reliable information on chemicals and practical, widely-accepted risk assessment methods in order to effectively control and minimize this threat. To support the management of chemical substances in small and medium-sized enterprises, the UK Health and Safety Executive developed the Control of Substances Hazardous to Health Essentials (COSHH Essentials), a control banding technique that determines the management method by assigning the qualitative work environment characteristics of the enterprises to a hazard and exposure prediction band. Qualitative tools were used for assessing the risk of these chemicals, creating solutions, and implementing control measures in various industrial fields. The present paper synthesizes the results of an extensive research study, dedicated to the evaluation of chemical risks within a Romanian company which has as object of activity the mechanical processing of steel laminates and their treatment by methods of electrochemical deposition of hard chromium / electrochemical nickel plating. The application of the simplified health, safety and environmental risk assessment methodology developed by the French National Security Research Institute (INRS) was considered to be the most appropriate in the preliminary phase of identifying and prioritizing the risks associated with chemicals used in technological processes in selected company. Based on the obtained results, the prevention and protection plan regarding the chemical risks was elaborated, the implementation of which led to the reduction of the workers' exposure and to the minimization of the probability and severity of the potential consequences.
Keywords: risk assessment, chemical hazard, worker exposure, health, environment

1. INTRODUCTION

Statistics show that most accidents occur in small and medium-sized enterprises, and their number is almost double that of large enterprises (Cioca et al, 2010). These could be prevented if employers, workers, employers organizations and trade unions became aware of the importance of complying with the minimum occupational safety and health requirements imposed by Romanian legislation transposing European Union directives (Băbuţ et al., 2011). Risk assessment involves identifying all risk factors in the analyzed system and quantifying their size based on the combination of two parameters: the severity and frequency of the maximum possible consequence on the human body.

Thus, partial risk levels are obtained for each risk factor, respectively global risk levels for the entire analyzed system (Aven et al, 2006).

Law no. 319/2006 on occupational safety and health contains the following provisions regarding the obligation of risk assessment (Romanian Parliament, 2006):

- the employer has the obligation "to assess the risks to the safety and health of workers, including the choice of work equipment, chemicals or preparations used and the arrangement of jobs" (art. 7, paragraph 4, letter a);
- the employer has the obligation “to carry out and be in possession of a risk assessment for occupational safety and health, including for those groups sensitive to specific risks” (art. 12, paragraph 1, letter a).

Employee protection is based, first and foremost, on risk assessment and the implementation of an appropriate prevention policy (Romanian Government, 2006; 2010). In terms of chemical risk, the assessment process is often difficult due to the multitude of products and preparations used (Sillière, 2014).

In order to support businesses facing this problem, the National Security Research Institute (INRS) in France, in cooperation with the National Center for Protection and Prevention (CNPP), has developed a simplified methodology for health, safety and environmental risk assessment (INRS, 1998).

The method has been applied in many companies in different sectors (but not yet in Romania), and the results are in line with the assessments of the experts. (Berrubé et al., 2013).

Regarding the chemical risk, the assessment procedure is often difficult due to the multitude of chemical agents and preparations used, as well as the ignorance of the hazards they present (Triolet, 2009). The perception of chemical risk is even more difficult in small businesses whose activity requires the use of chemicals, without them being registered as having activity in the field of chemistry. Then, the chemical risk is not only limited to the company's premises, but also extends to its vicinity, near or far, due to the impact that the company's activities may have on the environment: fire, explosion, air and groundwater pollution (Carter et al., 2003).

Because of this dual constraint on risk prevention, for employees and the environment, the business leader will need to implement a prevention policy that favors the replacement of hazardous products with less hazardous products (Moraru and Băbuţ, 2009). It will have to consider, in particular, the reduction of chemical risks for employees, taking care not to harm the environment and, conversely, not to increase the risks for employees in an attempt to reduce the impact on the environment. Indeed, an evaluation approach logically leads to the proposal of a preventive action plan that includes all aspects related to the chemical risk. (ISO, 2018).

2. RESEARCH METHODOLOGY

2.1. Brief description of the applied research method

INRS 'simplified method of chemical risk assessment in the fields of health, safety and environment is progressive, using simple and easily accessible criteria. Evaluations performed with a certain frequency allow to optimize the collection of information and to facilitate the workload. Indeed, this tool makes it possible to limit the amount of information collected at each stage and to avoid an excessive initial request for information, which is sometimes difficult to obtain, which could suddenly discourage those in charge of the evaluation. The method comprises the following main steps:

a. Inventory of products and materials used in the enterprise, in a workshop or at a workplace: it is the most important stage, because it conditions the quality of the risk assessment approach. The inventory of chemicals and raw materials - including intermediates - must be as comprehensive as possible. The data collected during this stage are as follows:

- product information or product name;
- quantity used (per year / month or up to that time ...);
- frequency of use;
- the work area where the product is used;
- information on the hazards, provided by labels (pictograms, risk phrases ...);
- information provided by the safety data sheet (hazards, physico-chemical properties ...).

In the inventory phase, the 16-point safety data sheet (SDS), mandatory for the company (according to the legislation in force), is an essential aid in this endeavor.

b. Hierarchy of potential risks:

The ranking of the products identified during the inventory is carried out by taking into account the hazards, the potential exposure (for health), the ignition potential (fire-explosion) and the potential for transfer (environmental impact). The combination of the values of the classes of each parameter allows the calculation of a potential risk score. It sets the risk assessment priorities for a section / workshop, job, etc., providing objective decision elements for determining the situations that require, as a matter of priority, a risk assessment.

The assessment priorities are classified by ***Homogeneous Exposure Group*** (GEO), in order to organize the next stage "risk assessment". A GEO corresponds to a set of people, jobs, or work tasks for which the exposure is estimated to be of the same nature and intensity. The establishment of a GEO can be done according to three approaches to:

- the chemical agent;
- the workstation;
- the technological process (production line).

c. Risk assessment

This stage consists in the assessment in a simplified manner of the real risks taking into account the effects on health, safety and the environment, based on the analysis of the real work and the operating conditions and taking into account:

- specific hazards associated with the chemical agents used;
- physico-chemical properties (physical state, volatility…);
- conditions of use (type of process, temperature…);
- existing means of prevention (e.g. ventilation).

In order to achieve the assessment of health risks (fig. 1), by inhalation and skin contact (fig. 2), of the risk of fire-explosion (fig. 3) and of the impact on the environment (water, soil and air), were used the tools for rating the parameters specific to the INRS method (labeling hazard classes, occupational exposure limit values and the nature of chemical agents emitted during the various activities, frequency of use and potential exposure classes, potential risk score grid, powder hazard classes, volatility classes of liquid products, classes of collective protection, flammability, ignition sources, transfer coefficients according to physical and environmental condition, rating scales of potential impacts on the environment, etc) (Vincent et al, 2005).

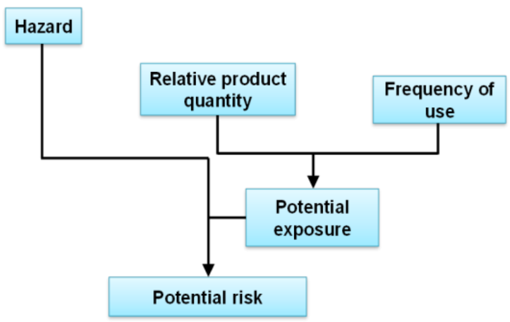

Fig. 1. Simplificată chemical risk assessment for human health

Fig. 2. Skin contact risk assessment principle

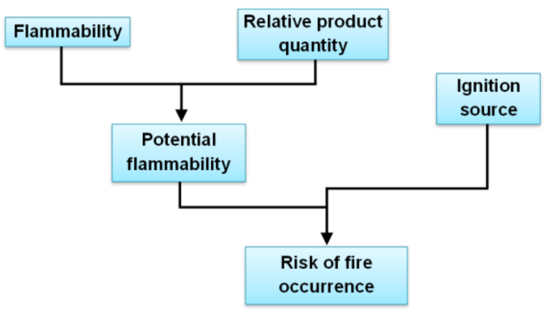

Fig. 3. Fire-explosion risk

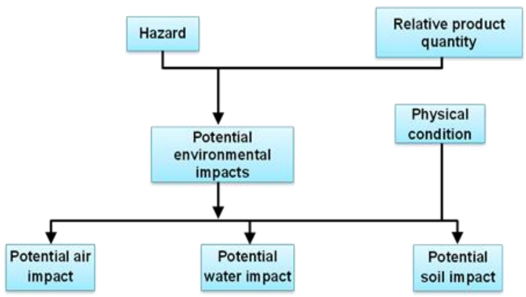

Fig. 4. Environmental impact risk asseessment principle

A score was then calculated for each pair (chemical agent – work task). This score then allowed the characterization of the risk inherent in the work task and, further, by summing the scores, the characterization of the risk of a GEO. At the end of this evaluation stage, there are elements that will allow the classification of risk situations and the establishment of priority remedial measures to be put into practice..

2.2. The company investigated in the case study

The company that was the subject of the research is specialized in the industrial processing of quality carbon steels as well as stainless steels, in order to transform them into industrial products used as semi-finished products in other industries. It has 450 employees: 80 „white-collar” staff and 370 directly productive workers. The main technological processes are performed with production equipment equipped with computerized numerical controls and include:

A. Technological processes for preparing the surface of steels for galvanic coatings (*chromium plating and nickel plating****)***

B. The technological process of galvanic coatings:

B.1. The chrome plating process: consists in the deposition of a layer of hard chromium on the surface of the steel by the process of electrochemical deposition. The process is closed, the electrolytic liquid is in closed cells equipped with a vapor capture system. The electrolytic liquid consists of water-soluble hexavalent chromium, sulfuric acid and chemical catalysts, and the electrodes are made of lead. Hard chrome plating is performed in traditional chrome plating installations and chrome plating installations with continuous operation.

B.2. The nickel plating process consists in the electrochemical deposition of a layer of soft nickel on the surface of the steel, the piece being immersed in a horizontal bath with electrolytic liquid and equipped with nickel anodes. Vapor filtration systems have the role of aspirating vapors due to the heating of the electrolyte in the technological process of chromium plating. They consist of fans with a capacity of 20,000 m^3 / h, connected to filtration systems - chromic water retention type of washing column with filling (Zinni filter with Rashing rings). The operation of the systems is automated, the vapors are exhausted from within each cell and above the electrolyte storage tanks, its efficiency being 95%. The systems are provided with a water washing circuit, in countercurrent with the aspirated vapors, the water containing chromium being recirculated in the electrolyte storage tanks. The operation of the systems is automated, the vapors are sucked from within each cell and above the electrolyte storage tanks.

C. Technological processes of preparation for delivery

3. RESULTS AND DISCUSSION

a) Potential risk ranking

Following the inventory of chemical agents, Homogeneous Exposure Groups (GEOs) were established and analyzed (we mention the fact that in this paper, for reasons related to the extension of the volume of data and information, we are restricted to present only a summary of the results obtained during the research carried out):

- GEO 1 – traditional chrome plating;
- GEO 2- continuous chrome plating;
- GEO 3- nickel plating;
- GEO 4 – demineralization plant;
- GEO 5 – chemical storage facility.

In order to prioritize the risks, the following information was established with the help of safety data sheets: a) hazard class; b) quantity class; c) frequency of use; d)

potential exposure class. The determination of the **hazard class** is based on the labeling (hazard pictogram), occupational exposure limit values and the nature of the chemical agents emitted during the various activities (Table 1)..
To establish the **quantity class**, the reference consumption per unit of time was established (daily, weekly, monthly, annually). The determination of the quantity classes was performed on the basis of the reference consumption for one year, reporting the quantity consumed (Q_i) of the analyzed chemical agent to the quantity of the most used agent (Q_{Max}).

Table 1.
Hazard class

Crt. no.	Product name	Hazard class
1	Chromium trioxide	4
2	Catalyst	2
3	Sulfuric acid	4
4	Sodium metabisulphite	3
5	Nickel chloride	4
6	Nickel sulphate	4
7	Boric acid	4
8	Enprep OC	2
9	Elpelyt	4
10	Hydrochloric acid	1
11	Sodium hydroxide solution	1

The quantity class was calculated by department (GEO). For GEO 1 and GEO 2, QMax is the amount of chromium, for GEO 3 the amount of nickel sulphate and for GEO 4 the amount of hydrochloric acid (Table 2).

Table 2.
Quantity class

Crt. no.	GEO	Product name	Used quantity (t/year)	Quantity class
1.	Chromium plating	Chromium trioxide	190	5
2.		Sulfuric acid	0.18	1
3.		Sodium metabisulphite	0.1	1
4.		Catalyst	2	2
5.	Nickel plating	Nickel chloride	0.3	3
6.		Boric acid	0.4	4
7.		Elpelyt	0.65	4
8.		Sulfuric acid	1.5	5
9.		Nickel sulphate	2.5	5
10.		Enprep OC	2.1	5

11.	Demineralization plant	Hydrochloric acid	1	5
12.		Sodium hydroxide	2.2	5
13.		Hydrochloric acid	4	5

In order to determine the **frequency classes** of use, the reference consumption per unit time must be identical to that established for the determination of the quantity classes: daily, weekly, monthly, annually. Frequency class and potential exposure class were determined at the GEO level - the duration of exposure to the resulting mixture, the electrolyte used, the frequency of use and the amount class were taken into account (Table 3).

Table 3.
Frequency class and potential exposure class

GEO	Product name	Quantity class	Frquency class	Exposure class
Chromium plating	Chromium trioxide	5	2	5
	Sulfuric acid	1	2	1
	Sodium metabisulphite	1	0	0
	Catalyst	2	2	2
Nickel plating	Nickel chloride	3	2	3
	Boric acid	4	2	4
	Elpelyt	4	2	4
	Sulfuric acid	5	2	5
	Nickel sulphate	5	2	5
	Enprep OC	5	2	5
	Hydrochloric acid	5	2	5
Demineralization plant	Sodium hydroxide	5	1	4
	Hydrochloric acid	5	1	4

The potential risk arises from the combination of hazard classes and potential exposure classes. This is the probability of identifying a hazard, taking into account the general conditions of use (quantity, frequency) of a hazardous chemical. The hierarchy of potential risks (IRP) for the whole unit can be found in Table 4.

Table 4.
Potential risk ranking

Product name	Hazard class	Qua-ntity class	Fre-quency class	Expo-sure class	Potential risk score	Prio-rity	Potential risk [%]	Cumulative potential risk [%]
Chromium trioxide	4	5	2	5	100,000	high	26.86	26.86
Sulfuric acid	4	5	2	5	100,000	high	26.86	53.72
Nickel sulphate	4	5	2	5	100,000	high	26.86	80.58

Boric acid	4	4	2	4	30,000	high	8.07	88.65
Elpelyt	4	4	2	4	30,000	high	8.07	97.72
Nickel chloride	4	3	2	3	10,000	me an	2.69	99.41
Sulfuric acid	4	1	2	1	1,000	me an	0.27	99.68
Enprep OC	2	5	2	5	1,000	me an	0.27	99.95
Hydrochlo ric acid	1	5	2	5	100	me an	0.03	99.98
Catalyst	2	2	2	2	30	low	0.008	99.99
Sodium hydroxide	1	5	1	4	30	low	0.008	100
Hydrochlo ric acid	1	5	1	4	30	low	0.008	100
Sodium metabisulp hite	3	1	0	0	1	low	0.0002	100

The column "potential risk" indicates, for a product, the percentage of potential risk expressed as a function of the total potential risk of all products. Table 5 shows the potential risk distribution by GEO.

Table 5.
Potential risk distribution by GEO

GEO	Nr. of products used	Potential risk score per workshop	Potential risk for GEO
Chromium plating	4	101,031	27.15%
Nickel plating	7	271,100	72.83%
Demineralization plant	2	60	0.02%
Total	13	372,191	100%

b) Risk assessment by skin contact: the results of the skin contact risk assessment are shown in Table 6.

Table 6.
Risk assessment by skin contact

GEO	Product name	Hazard class	Risk score	Exposed surfaces score	Exposure frequency score	Skin risk score	Priority for action
Traditional chrome plating	Chromium trioxide	4	1,000	2	5	10,000	1
	Sulfuric acid	4	1,000	2	5	10,000	1
	Catalyst	2	10	2	5	100	2

Continuous chrome plating	Chromium trioxide	4	1,000	2	1	2,000	1
	Sulfuric acid	4	1,000	2	1	2,000	1
	Catalyst	2	10	2	1	20	3
Nickel plating	Sulfuric acid	4	1,000	2	2	4,000	1
	Nickel sulphate	4	1,000	2	2	4,000	1
	Boric acid	4	1,000	2	2	4,000	1
	Elpelyt	4	1,000	2	2	4,000	1
	Nickel chloride	4	1,000	2	2	4,000	1
	Enprep OC	2	10	2	2	40	3

Risk characterization
1- Very high risk;
2- Moderate risk that probably requires corrective action;
3- A priori low risk.

c) Simplified fire - explosion risk assessment:

For the analysis of the fire risk, the GEO 5- chemical deposit was evaluated, the results obtained being synthesized selectively in table 7.

Table 7.
Fire - explosion risk assessment

Product	Flammability class	Quantity class	Source class	Potential flammability class	Fire risc score	Fire potential risk
Chromium trioxide	5	5	2	5	5.000	important
Sodium hydroxide	1	1	2	1	1	low
Sulfuric acid	3	1	2	2	10	low
Sodium metabisulphite	1	2	2	1	1	low
Catalyst	1	1	2	1	1	low
Nickel chloride	1	1	2	1	1	low
Acid boric	1	1	2	1	1	low
Elpelyt	1	1	2	1	1	low
Sulfuric acid	3	2	2	2	10	low
Nickel sulphate	1	2	2	1	1	low
Enprep OC	1	2	2	1	1	low

Sodium hydroxide	1	2	2	1	1	low
Hydrochloric acid	1	1	2	1	1	low

d) Interpretation of results

For the safety component, the risks associated with the chemicals present in the following work places were assessed:

- ***GEO 1-2 – chrome plating***: the substances are used in the form of a solution (water mixture, chromium trioxide, sulfuric acid and catalyst), the working temperature is between 55-60 ° C. The baths in which the mixture is located are equipped with a steam washing / filtration system. The mixture is made in an automatic plant and is transferred to the plant by the head of the working shift under the direct guidance of the chemist;
- ***GEO 3- nickel plating***: the solution consists of nickel chloride, nickel sulfate and nickel metal. The installation is provided with baths for washing and pickling (sulfuric acid, enprep oc, elpelyt, boric acid). The baths in which the mixture is located are provided with a steam washing / filtration system due to the heating of the solution. Substance supplementation is performed by the chemist;
- ***GEO 4 –Demineralization plant***: plant closed, the substances are used only to complete the level, it is operated by the staff of a collaborator.
- Access to the analyzed jobs is allowed only to properly trained and equipped workers (antacid overalls, antacid gloves, goggles, mask). Following evaluation, the following substances received a high risk score:
- Chromium trioxide;
- Sulfuric acid;
- Nickel sulphate;
- Boric acid;
- Elpelyt.

High skin risk presents the same chemical agents mentioned above, whereas the risk of inhalation is low for all substances analyzed. For the fire component, the substances at the storage site were analyzed. The evaluation showed that chromium trioxide has a significant risk of fire. For the environment component, the impact of both the substances and the resulting waste on the components of the environment was evaluated: air, water, soil.

In the case of substances in the environment, the risk is as follows:

- *air component*: 6 substances with moderate risk and 6 with low risk;
- *water component*: 9 substances with moderate risk and 3 with low risk;
- soil component: 4 substances present moderate risk and 8 low risk.

In the case of waste, the risk is as follows:

- chromium-plated waste poses a very significant risk to air and water and a moderate risk to soil;
- waste from the nickel-plating bath poses a significant risk to water and air and a moderate risk to soil;

- waste from pickling baths present moderate risk to water and air and low risk to soil.

4. CONCLUSION

Hazardous chemical substances/products, paint, phytosanitary product, wood dust, oil, gasoline… are present in all sectors of activity. Even though they are part of everyday life, many of them can have serious effects on health and the environment. As with any occupational risk, chemical risk assessment is an essential step prior to the implementation of a prevention approach. Identifying hazardous chemical products, mixtures or processes and knowing their effects is a first step before implementing appropriate means of prevention. Chemical risks are the 3rd cause of occupational disease in Romania, responsible in particular for many cancers each year. In a chemical risk assessment, it is also important to take into account simultaneous exposures to several chemical substances, because the effects of the substances can be additive, inhibit, synergize or potentiate each other.

The research summarized in the paper was developed based on the data provided by the company investigated in the case study through job descriptions, lists of technical equipment, their technical books, regulations for the provision of personal protective equipment, information on technological processes, safety data sheets and the development of the work process for each job, received from the management and the technical staff of the company, as well as the own observations made during the documentation visits and follow-up of the activity for each working place. The following steps have been taken as materialized research objectives and can be recommended as a basic succession in carrying out a similar approach::

I. analysis of the activities carried out within the company;
II. determination of workstations in which chemicals are used (defined as GEO);
III. identifying risk factors for each job;
IV. chemical inventory;
V. potential risk preliminary ranking;
VI. health risk assessment, fire-explosion and environmental risk assessment;
VII. drawing up the plan of prevention and protection measures;
VIII. plan implamentation, monitoring and review.

Whatever the limits of the method used in this research, its use makes it possible, in an industrial environment and in the presence of a large number of products, to help the safety specialist to carry out an initial sorting, by identifying a certain number of products which must be checked with priority concern. Simple tools that can be used by companies with no expertise in the field lead to incomplete results that sometimes do not meet all the requirements of prevention specialists... while complex tools, giving results closer to those expected by prevention specialists, require a high level of expertise to be usable by the company. The determining criterion is probably not the size of the company but rather its level of internal technicality in the field of chemistry and chemical risks. In Romania, the more frequent use of such tools, even simplified, chemical risk assessment could be a big step forward, especially in terms of awareness of workers, line and top managers, as well as other categories of stakeholders.

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