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Chemical risk ranking and evaluation: case study in a paint manufacturing company

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Abstract. As economies grow and the use of chemicals becomes more and more widespread, the adoption of effective control measures allows for safer use of chemicals on an industrial scale. Chemical hazards can have severe negative consequences for both the health of employees, the safety of personnel and facilities (fire and explosion risk) and the environment. To characterize them, it is necessary to combine the inherent hazards associated to chemicals with their conditions of use that may generate emissions and exposures. Various methods, both qualitative and quantitative are available worldwide for chemical risk assessment, but unfortunately in Romania this important aspect is treated in a minimalist manner, which can often be considered as insufficiently rigorous. In this perspective, the present paper aims to validate through a practical case study conducted in a Romanian paint manufacturing company, the application of a simplified method of chemical risks prioritization and assessment. The obtained results allowed the substantiation of the control measures of these risks, being also able to constitute an instrument of raising awareness for all the interested parties (occupational safety and health inspectors, managers, safety officers, supervisors, workers), in the effective management of the chemical risks.

1 Introduction

The identification of hazards, the assessment of their risks and the implementation of control measures to ensure the health and safety of employees is a major element for the management of health and safety, under Law 319/2006 on safety and health at work [1-3]. Ubiquitous in the workplace, chemicals sometimes go unnoticed in many workplaces. However, many chemicals can have severe side effects on human health and the environment [4]. Identifying hazardous products, mixtures or chemical processes and knowing their effects is a first step before implementing the appropriate means of prevention which is based in particular on the identification of hazardous products in the company, regardless of its activity, and a thorough and rigorous risk assessment [5]. In addition, regulations include specific provisions for hazardous chemicals and carcinogens, mutagens, or toxic to reproduction [6-8]. Hazardousous chemical agent is any substance which, due to its physico-chemical, chemical or toxicological properties, and its use or

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presence in the workplace, poses a risk to the safety and health of workers [9]. At work, employees may be exposed to hazardous chemicals, either accidentally (explosions, fires, damage to pipes or tanks, etc.) or during use, handling, or transportation. Risk assessment is the key to proper safety and health at work and effective prevention can generally be achieved through the following five steps [10]:

- identification of hazards and those exposed at risk,
- risk assessment and prioritization,
- establishing prevention and protection measures,
- implementation of prevention and protection measures,
- monitoring and verifying compliance and effectiveness of measures.

In practice, the following trends continue to emerge from this perspective: i) the creation of simplified evaluation methods; ii) developing methods for prioritizing hazardous chemicals to be evaluated; iii) development and use of online tools [11].

The chemical risk assessment must also include occasional activities within the enterprise / unit, such as *maintenance* (overhauls, repairs, cleaning), be carried out *before* the start of the work process and take into account:

a. their hazardous properties (label);
b. information provided by the manufacturer/supplier regarding OSH, such as safety data sheets;
c. level (concentration), type of exposure (inhalation, dermal, ingestion) and duration of exposure (frequency);
d. the conditions under which the work is carried out in the presence of such agents, including their quantities (powder / paste / pellets, gun / brush, roller / immersion, temperature, pressure);
e. occupational exposure limit values or national biological limit values;
f. the effect of preventive measures taken or to be taken (open / closed system, ventilation, etc.);
g. the conclusions resulting from the surveillance of the health status already performed, when available;
h. the necessary additional information that the employer must obtain from the supplier of the hazardous chemicals or from other available sources. Where applicable, this information shall contain the specific risk assessment for users, established on the basis of the provisions of the applicable national law.

The risk is assessed separately for: i) *Health* (toxic, caustic, harmful, irritating, sensitizing, carcinogenic, reprotoxic) due to inhalation exposure, skin contact and ingestion (accidental poisoning); ii) *Safety* (flammable, explosive, oxidizing).

Variables used by chemical risk assessment methods include the intrinsic hazard of the chemical: frequency / time of exposure; the quantity used; liquid volatility or solid pulverulence; process type (immersion, spraying, etc.); the type of prevention and protection measures applied and their effectiveness (closed system, local or general ventilation). The chemical risk assessment must be accompanied by documents submitted in an appropriate form, in accordance with national law and practice, and may include a justification by the employer that the nature and extent of the risks posed by the chemical agents do not require further detailed risk assessment. The risk assessment will need to be *updated*, in particular, if significant technological changes have taken place, activities, working procedures or safeguards have changed, new knowledge of the properties of the substances has emerged (label, safety data sheet, limit values exposure), the effectiveness of protective measures has changed or the results of medical research have highlighted additional risks. In Romania, chemical risk assessment is at the beginning, sporadically applying the Simplified Health, Safety and Environmental Risk Assessment Methodology

developed by INRS France [12], and this paper illustrates a case study developed in the research conducted in a Romanian paint manufacturing company.

2 Material and method

2.1 The investigated company and the homogeneous exposure groups

The company that was targeted in the research is a Romanian company specialized in the paint production and sale of the entire spectrum of road marking systems, as well as anti-corrosion protection systems, being an important player on the Romanian and Eastern European market. It is located in a small town in southern Romania, and dates back to 1951, when the company was established as an independent unit called "Chemical Enterprise" with production activities in paints, plastics, rubber and candles. In 2002, the company changed its name and continued to produce various paint systems (alkyd resin, alkyd paint, epoxy paint, PU paints, thinners and washable water-based paints) for both industrial and retail use. In 2006, the company joined a major German group and began producing road marking paints according to German standards and know-how. The company's road technology group, based in Innsbruck / Austria, has an international network of production facilities, offices and partners on all continents and offers one of the most comprehensive portfolios of solutions for road marking, signaling and urban traffic management. for parking, administration of motorways and tunnels and public transport.

Fig. 1. General view of the Company building.

Two homogeneous exposure groups (GEOs) located in the same workspace were assessed for chemical risk:

GEO 1: work stations for the manufacture of one-component road marking paints. Operational features:

- the mixtures (road marking paints) are made at a temperature of 25 - 30 ° C, in 3 sinusoids dissolvers, capacity 2600 l, provided with agitators with variable speed (290-1250 rpm, Ex construction, equipped with emergency stop, equipped with sensor mounting arms, which do not allow the stirrer to start if the vessel is not properly anchored. The vessels are of the semi-open type, provided with lids with a hatch (manhole) open for dosing the raw materials or for taking samples;
- each sinus is provided with local ventilation for powdery materials;

- the work room, where the sinusoid dissolvers are located, is equipped with two general ventilation systems (one for liquids and one for powders), both in construction EX.
- tasks performed by operators include:
  - *weighing of the solvent mixture and loading in the sinus dissolver*: the solvents are transferred from the tanks, through individual pipes for each type of solvent, into a stainless steel scale, equipped with tensiometric doses, display and control panel. Weighing of solvents is done in a closed system. From the scale, with the help of a pump, the weighed solvent is introduced through pipes into the sinus dissolver. When loading the solvent vessel the system is half open (manhole open), general ventilation is on, the stirring system is on.
  - *loading solid acrylic resin packed in bags*. The bags are loaded manually, bag by bag, through the inspection mouth of the vessel. Semi-open system, local sinus ventilation and general ventilation are on, agitation system on. The bags are lifted with the pallet truck to the mouth of the sinus. Each bag is taken by two operators, is supported by the sinus and overturned in the vessel, through the manhole, in small portions (loading a bag takes about 1 minute).
  - *dissolving solid acrylic resin*. Semi-open system, local sinus ventilation and general ventilation are on, agitation system on.
  - *loading liquid acrylic resin*: it is loaded directly from the barrels into the preparation vessel (sinus dissolver). Lift the barrel with the forklift and load the resin in a continuous flow through the manhole. Semi-open system, local sinus ventilation and general ventilation are on, agitation system on.
  - *loading powdery materials*: titanium dioxide, pigments, calcium carbonate, packed in bags. The bags are loaded manually, bag by bag, through the inspection mouth of the vessel.
  - *weighing, loading additives*: they are weighed on a semi-automatic scale in metal vessels. They are loaded manually into the preparation vessel through the manhole. Semi-open system, local sinus ventilation and general ventilation are on, agitation system on.
  - *homogenization of the mixture* is done with the manhole closed, the local ventilation related to the sinus and the general ventilation are turned on, the stirring system is on.
  - *sampling* is done in a semi-open system, local ventilation related to the sinus and general ventilation are turned on, stirring system off.
  - after manufacture and compliance with the acceptance criteria, the product is transferred through the pipe, using the pump, to the storage vessel, from which the packaging will be made. Closed system (manhole closed), general ventilation on.

GEO 2 - work points intended for the packaging of single-component road marking paints. Operational characteristics:

- from the storage vessel, the product is filtered, by free fall through pipes, in the filter (closed system).
- packaging is done in metal cans, placed directly on the scale, under the spigot at the bottom of the filter. Open system, general ventilation on.

2.2. Methodology applied for chemical risk assessment

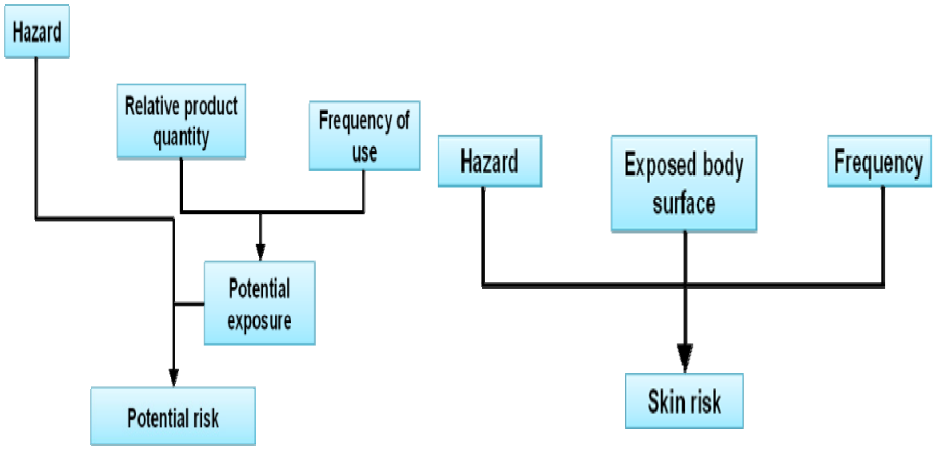
The simplified INRS (*Institut Nationale de Recherche pour la Securite-Fr*ance) method of chemical risk assessment in the fields of health, safety and the environment is based on simple and easily accessible criteria, allowing the limitation of the volume of data and information collected. The method comprises the following main steps [13]:

a. Inventory of products and materials used in the enterprise, in a workshop or workplace;

b. Hierarchy of potential risks (IRP);

c. Risk assessment.

For the simplified assessment of the health risks (fig. 2a), by inhalation and skin contact (fig. 2b), the instruments for rating the parameters specific to the INRS method were used. (hazard classes according to labeling, occupational exposure limit values and nature of chemical agents emitted during the various activities, frequency of use and potential exposure classes, grid for determining the potential risk score, etc).



a b

Fig. 2. a. Simplified chemical risk assessment for health: b. Risk assessment by skin contact.

A score was then calculated for each couple (chemical agent - operation), a score that allowed the calculation of the risk associated with the task and, then, by summing the scores, the risk characterization of each GEO. The inhalation and skin contact risk characterization grid according to the method is shown in Table 1.

Table 1. Risk characterization grid.

Risk score	Priority for action	Risk characterization grid
≥ 1000	1	Probably very high risk (immediate corrective action)
100 - 1000	2	Moderate risk that probably requires the implementation of operational control measures
<100	3	Apriori low risk (no changes)

3 Results and discussion

a) The result of the product inventory: the classification of substances / mixtures has been carried out in accordance with Regulation (EC) No 1234/2007. 1272/2008 with subsequent amendments, the results being shown in Table 2, where LA = permissible occupational exposure limits; Fp = very dangerous; C = carcinogenic; P = penetrates the skin; NA = Not applicable;Y=yes.

Table 2. Inventory of chemical agents used.

Chemical agents	LA [mg/m^3]		Measured value [mg/m^3]		Fp	C	P
	8 h	15 min	8 h	15 min			
Solid acrylic resin: Not classified as hazardous	-	-	-	-	-	-	-
Liquid acrylic resin: H226 - Flammable liquid and vapor. H336 - May cause drowsiness or dizziness. Pf = 126°C	-	-	-	-	-	-	-
Methyl Ethyl Ketone MEK: CAS 78-93-3; EC 201-159-0; H225 - highly flammable liquid and vapor; H319 - Causes serious eye irritation; H336 - may cause drowsiness or dizziness; EUH066 - repeated exposure may cause skin dryness or cracking;Pf = 80°C	600	900	24.5	39	NA	NA	Y
Methyl Isobutyl Ketone MIBK: CAS 108-10-1; EC 203-550-1; H225 - highly flammable liquid and vapor; H319 - Causes serious eye irritation; H332 - harmful by inhalation; H335 - may cause respiratory tract irritation; EUH066 - Repeated exposure may cause skin dryness or cracking; Pf = 80°C	83	208	51.4	82	NA	NA	Y
N-butyl acetate: CAS 123-86-4; EC 204-658-1; H226 - flammable liquid and vapor; H336 - may cause drowsiness or dizziness; EUH066 - Repeated exposure may cause skin dryness or cracking; Pf = 126°C	241	723	77.4	123	NA	NA	Y
Ethyl acetate: CAS 141-78-6; EC 205-500-4; H225 - highly flammable liquid and vapor; H319 - Causes serious eye irritation; H336 - may cause drowsiness or dizziness; EUH066 - repeated exposure may; causes dryness or cracking of the skin; Pf = 77°C	734	1468	112	181	NA	NA	Y
ToluenE: CAS 108-88-3; EC 203-625-9; H225 - highly flammable liquid and vapor; H304 - may be fatal if swallowed and enters airways; H315 - causes skin irritation; H336 - may cause drowsiness or dizziness; H361 d - likely to cause harm to the fetus, toxicity to reproduction; H373 - may cause damage to organs through prolonged or repeated exposure; Pf = 111°C	192	384	70.2	112	NA	NA	Y
Dowanol PM 1metoxi-2 propanol: CAS 107-98-2; EC 203-539-1; H226 - flammable liquid and vapor; H336 - may cause drowsiness or dizziness; Pf = 120°C	375	568	79.6	116	NA	NA	Y
Dispersion additive: H315 - causes skin irritation; H317- may cause an allergic skin reaction; H336 - may cause drowsiness or dizziness; H373 - may cause damage to organs through prolonged or repeated exposure; Pf = 116°C	-	-	-	-	NA	NA	Y
Anti-depot agent: Not classified as dangerous	-	-	-	-	-	-	-
Breathable fractionable materials: **Powders without specific effect**: fillers (calcium carbonate, titanium dioxide)	10	-	1.623	-	NA	NA	Y

b) Hierarchy of potential risks: (Tables 3 and 4) was performed according to hazard class and potential exposure class (determined by quantity class and frequency class). Quantity classes for ***manufacturing*** have been established in relation to Q_{max} = 1,021,000 kg / year (Calcium carbonate), and for ***packaging*** have been established in relation to Q_{max} = 650,000 kg / year (VM3). 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.

c) Chemical risk assessment: by inhalation and skin contact was based on the analysis of the actual work and the conditions of execution / operation, taking into account the chemical agents to which the operators are exposed. Exposure, after labor analysis, was estimated according to:

- physicochemical properties (volatility);
- conditions of use (process, temperature, area of exposure, frequency of use, quantity classes, etc);

- means of collective protection (ventilation);

The use of personal protective equipment was not taken into account in this assessment.

For inhalation: Risk score (V_{inh}) = hazard score × volatility score × procedure score × collective protection score.

Table 3. Hierarchy of potential risks in GEO 1: manufacture of one-component marking paints.

Product	Quantity [kg/year]	Frequency of use	Hazard class	Quantity class	Frequency class	Potential exposure class	Potential risk score	Potential risk	Cumulative potential risk
Solid acrylic resin (non-hazardous)	110,000	Frequent-daily between 2 - 6 hours	1	3 (10.77%)	3	3	10	0.20%	0.20%
Liquid acrylic resin	94,000		2	3 (9.21%)	3	3	100	2.04%	2.24%
Anti-depot agent	7,500		1	1 (0.73%)	3	1	1	0.02%	2.26%
Dispersion additive	4,200		3	1 (0.41%)	3	1	100	2.04%	4.3%
Titanium dioxide	149,000		2	4 (14.59%)	3	4	300	6.12%	10.42%
Calcium carbonate	**1,021,000**		**2**	**5 (100.00%)**	**3**	**5**	**1,000**	**20.40%**	**30.82%**
Pigments	5,600		2	1 (0.54%)	3	1	10	0.20%	31.02%
Dowanol PM 1metoxi-2 propanol	5,300		2	1 (0.52%)	3	1	10	0.20%	31.22%
Toluene	302,000		3	4 (29.57%)	3	4	3,000	61.22%	92.44%
MEK	37,000		2	2 (3.62%)	3	2	30	0.62%	93.06%
MIBK	40,000		3	2 (3.92%)	3	2	300	6.12%	99.18%
Butyl acetate	30,500		2	2 (2.99%)	3	2	30	0.62%	99.80%
Ethyl acetate	3,800		2	1 (0.37%)	3	1	10	0.20%	100%
TOTAL							4,901		

Table 4. Hierarchy of potential risks in GEO 2: packaging one-component marking paints.

Product	Quantity [kg/year]	Frequency of use	Hazard class	Quantity class	Frequency class	Potential exposure class	Potential risk score	Potential risk	Cumulative potential risk
VM 1	510,000	Frequent-daily between 2 - 6 hours	2	5 (78.46%)	3	5	1000	4.76%	4.76%
VM 2	580,000		3	5 (89.23%)	3	5	10,000	47.62%	52.38%
VM 3	650,000		3	5 (100%)	3	5	10,000	47.62%	100%
TOTAL							21,000		

For skin contact: Risk score (V_{skin}) = hazard score × surface area score × exposure frequency score.

The results obtained are centralized in Tables 5, 6 (for GEO 1), 7 and 8 (for GEO 2). GEO 1 chemical risk assessment: a. by inhalation: 389; b. by skin contact: 340. GEO 2 chemical risk assessment: a. by inhalation: 73.5; b. by skin contact: 440.

Table 5. Inhalation chemical risk assessment –GEO 1.

Task	Chemical agent	Hazard class	Hazard score	Volatility class	Volatility score	Procedure score	Procedure score	Collective protection class	Collective protection score	Risk score (V_{inh})	Total risk score
Solvent loading	Toluene	3	100	2 Pf= 110 °	10	2 (semi-open)	0,05	3 general ventilation	0.7	35	80.5
	MIBK	3	100	2 Pf= 117 °	10	2 (semi-open)	0,05	3 general ventilation	0.7	35	
	MEK	2	10	1 Pf= 80 °C	100	2 (semi-open)	0,05	3 general ventilation	0.7	3.5	
	Butyl acetate	2	10	2 Pf= 126 °	10	2 (semi-open)	0,05	3 ventilație generală	0.7	3.5	
	Ethyl acetate	2	10	1 Pf= 77 °C	100	2 (semi-open)	0,05	3 general ventilation	0.7	3.5	
Loading + dissolving solid acrylic resin	Solid acrylic resin	1	1	2	10	4 (disperse)	1	2 suction slot	0.1	1	81.5
Loading liquid acrylic resin	Liquid acrylic resin	2	10	2 Pf= 126 °	10	2 (semi-open)	0,05	2 suction slot	0.1	0.5	82
Loading + homogenization dispersion additive; dowanol PM; antidepressant agent	Dispersion additive	3	100	2 Pf= 116 °	10	2 (semi-open)	0,05	2 suction slot	0.1	5	87.51
	Dowanol PM	2	10	2 Pf= 120 °	10	2 (semi-open)	0,05	2 suction slot	0.1	0.5	
	Anti-depot agent	1	1	3	1	2 (semi-open)	0,05	2 suction slot	0.1	0.005	
Loading +powder material	Titanium dioxide	2	10	1	100	4 (disperse)	1	2 suction slot	0.1	100	387.51
	Pigments	2	10	1	100	4 (disperse)	1	2 suction slot	0.1	100	
	Calcium carbonate	2	10	1	100	4 (disperse)	1	2 suction slot	0.1	100	
Mixing homogenization+ sampling	Marking paint	3	100	3 gummy	1	2 (semi-open)	0,05	2 suction slot	0.1	0.5	388
Empty vessel, transfer to storage vessel	Marking paint	3	100	3 gummy	1	2 (semi-open)	0,05	2 suction slot	0.1	0.5	388.5
TOTAL											388.50

Table 6. Chemical risk assessment by skin contact –GEO 1.

Task	Chemical agent	Hazard class	Hazard score	Exposed surface	Exposed surface score	Exposure frequency	Exposure frequency score	Risk score × potential risk	Total risk score
Dosing of liquid raw materials (not solvent)	liquid acrylic resin; dowanol PM; dispersing agent	2	10	two hands	2	intermittent 30 min - 2 hours / day	2	40	40
Dosing of powdery raw materials	titanium dioxide, pigments, calcium carbonate	2	10	two hands	2	frecvent 2 – 6 hours /day	5	100	140
Sampling	Marking paint	3	100	one hand	1	intermittent 30 min - 2 hours / day	2	200	340
TOTAL									340

Table 7. Inhalation chemical risk assessment –GEO 2.

Task	Chemical agent	Hazard class	Hazard score	Volatility class	Volatility score	Procedure score	Procedure score	Collective protection class	Collective protection score	Risk score (V_{inh})	Total risk score
Packaging	VM1	2	10	3 gummy	1	3 (open)	0.5	3 General ventilation	0.7	3,5	73.5
	VM 2	3	100	3 gummy	1	3 (open)	0.5	3 General ventilation	0.7	35	
	VM 3	3	100	3 gummy	1	3 (open)	0.5	3 General ventilation	0.7	35	

Table 8. Chemical risk assessment by skin contact –GEO 2.

Task	Chemical agent	Hazard class	Hazard score	Exposed surface	Exposed surface score	Exposure frequency	Exposure frequency score	Risk score × potential risk	Total risk score
Packaging	VM	2	10	One hand	1	intermittent 30 min – 2 hours/day	2	20	20
	VM2	3	100	One hand	1	intermittent 30 min – 2 hours/day	2	200	220
	VM 3	3	100	One hand	1	intermittent 30 min – 2 hours/day	2	200	440
TOTAL									440

4 Conclusions

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 granting 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 job. 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 jobs in which chemicals are used (defined as GEO);
iii. identification of risk factors for each job;
iv. chemicals inventory;
v. risk ranking;
vi. health risk assessment by inhalation and skin contact;
vii. drawing up the plan of prevention and protection measures.

The results obtained in the hierarchy phase *for GEO 1, manufacture of one-component marking paints* indicate the following: no chemical agent presents a high potential risk (value of potential risk score IRP >10.000); 6 chemical agents present an average potential

risk (value of potential risk score 100 ≤ IRP ≤ 10,000); 7 chemical agents present a low potential risk (value of potential risk score IRP < 100).

For GEO 2, packaging of one-component marking paints: no chemicals present a high potential risk (value of potential risk score IRP >10.000); 3 chemical agents present a medium potential risk (value of potential risk score 100 ≤ IRP ≤ 10,000).

The chemical risk assessment shows that: the level of risk of inhalation for GEO 2 (packaging of road marking products) is a low risk. The process does not require changes. The risk score has a higher value for VM 2 and VM3, due to the assigned hazard and quantity classes. The level of risk of inhalation for GEO 1 (manufacture of one-component road marking products) and the level of risk of skin contact for GEO1 and GEO 2 is a moderate risk.

In Romania, the more frequent use of such tools, even simplified, aimed at 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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