CHEMICAL RISK EVALUATION: APPLICATION OF THE MOVARISH METHODOLOGY IN AN INDUSTRY OF THE TEXTILE SECTOR

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ABSTRACT
The present paper analyses the minimum requirements for workers' protection against health and safety chemical risks. The potential risks from exposure are divided into two categories which are often simultaneously present:
Health risks due to chronic exposure to toxicological or harmful substances;
•Safety hazards due to acute exposure: fire, chemical burns, eye injury, poisoning, suffocation.
A case study concerning chemical compounds used in a textile serigraphy department is proposed. A recently installed machine, with high level of automation, was analyzed. An operative spreadsheet tool combining "Workers' Safety Requirements" and "Risk Reduction Actions", has been defined. By evaluating the risk degree of each chemical product, if the assessed risk is acceptable, only safety requirements were considered.
Otherwise, if level and duration of exposure determine a harmful risk for workers, specific prevention and protection actions were suggested, such as appropriate work processes, technical planning, individual protections, Training and information.

Keywords: Chemical Risk, Health Risk, Risk reduction actions

1. INTRODUCTION

The concept of chemical risk and, more generally, of risks of dangerous substances, is considered in Title IX of the Italian Legislative Decree n. 81/2008 (Title IX of Legislative Decree 81/2008), which indicates the minimum requirements for the protection of workers against risks to health and safety arising from the effects of chemical agents present in the workplace or as a result of any work activity involving the presence of chemical agents (European agency for safety and health at work, 2002). The requirements identified in this Title can be applied to all hazardous chemical agents present in the workplace, with the exception of agents related to radiation protection (Bengtsson, 2010). A chemical agent is anything, substance or preparation, which constitutes a danger to workers; also lead and carcinogens, in general, and those substances can cause a hazard in certain conditions, though not dangerous by their very definition. In general, the production, handling and storage of chemicals involves a number of potential risks by chemical exposure (Kogg *et al*., 2010) In assessing workers' risks, we have to consider all the activities related to the production process (Di Bona *et al*., 2014), such as transport, handling or production of waste products that can cause a particular exposure to certain employees. In order to evaluate, in a first approximation, the chemical risk in the company, we can use different models of computation that refer to algorithms (Gnoni *et al*., 2010). In general, an algorithm (or model) is a procedure that assigns a numeric value to a number of factors or parameters involved in determining the risk weighting for each of them, and the absolute importance of mutual evaluation on the final result.
The model used for the Chemical Risk assessment was elaborated by Emilia Romagna, Lombardy and Tuscany Regions and within Legislative Decree n. 81/08 (Title IX - Chapter I "protection against chemical agents"). The model suggests a process of "facilitation" which enables the risk classification over or under the threshold "IRRELEVANT FOR HEALTH"; it is the first level of investigation and must be followed, if necessary, by additional investigations, also instrumental. The evaluation includes a comparison between the potential source of danger and exposed persons; specifically, we evaluate the probability of occurrence of an event (accident or illness) due to the use of a single chemical substance and compound (Weaver, 1993), identified through the air analysis in the various workplaces; the analysis of the company preventive systems in each process phase; the analysis of protective systems (PPE) provided to workers. According to the considered method, the risk depends on three factors

- Gravity (negative intrinsic quality of the chemical agent)
- Duration (duration of exposure to chemical agent)
- Level Of Exposure (qualitative and quantitative)

2. CASE STUDY

The studied company belongs to an industrial group leader in the wear production and global distribution of international brands. In particular, the analyzed department for the application of the methodology mentioned is the serigraphy department. Serigraphy or screen printing is an artistic printing technique of images and graphics on any material or surface, through the use of a fabric (printing fabric), by depositing the ink on a support through the free areas of the fabric.

2.1 Chemical Risk Onset in Movarish Methodology

The chemical risk happens when in the workplace both the following two risk factors are simultaneously present:

- presence of hazardous chemical agents (chemical risk factors);
- presence of conditions of exposure (risk factors exposition).

The chemical risk R of exposure to hazardous chemicals is the product of hazard and exposure:

$$R = H \times E \quad (1)$$

The danger H is the index of intrinsic hazard of a substance or preparation, identified through the risk phrases defined by European Directive 67/548/EEC. For each R phrase a score is assigned taking into account the criteria for the classification of substances and dangerous preparations, as indicated in Legislative Decree 28 July 2008, 145. The danger H represents the potential hazard of a substance regardless of the levels which people are exposed to (intrinsic hazard). The exposure E is the level of exposition of individuals in the specific work activity. In this model, the risk R can be separately calculated for inhalation exposure and dermal exposure:

$$R_{INAL} = H \times E_{INAL} \quad (2)$$

$$R_{DERM} = H \times E_{DERM} \quad (3)$$

In case there are both the above types of exposure, the cumulative risk R (R_{CUM}) is obtained thanks to the following equation:

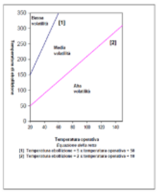
$$R_{CUM} = (R_{INAL}^2 + R_{DERM}^2)^{1/2} \quad (4)$$

The proposed methodology for identifying the H index (hazard of chemical risk to the health of workers) is based on the knowledge of the toxicological properties of chemical agents used or that are released into the workplace according to the exposure of workers, depending on the quantity, the method of use and the frequency of exposure. In order to evaluate the toxicological properties of chemical agents present in the productive activities, a score between 1 and 10 is assigned to each substance, single or combined, representing the danger H. Subsequently, a risk ranking is possible. In other words, the above index summarize in a single number the health hazards of a chemical agent. Another important aspect for a proper graduation of danger is the classification and labelling of substances and preparations which are dangerous according to Directive 67/548/EEC. The main principle is that the effects in the long-term (e.g. hazard category of toxic for reproduction) are more important than the acute effects. The numerical index that determines the hazard ranking must consider this general principle. Because of the low probability of occurrence, it was decided to give a quite low score, but not zero, according to the assessment of the intrinsic danger in the case of effects due to ingestion. If a chemical agent exerts its dangerousness exclusively in the case of ingestion, the risk can be eliminated using proper sanitation and behaviour. Then, to consider an inequality between dermal and inhalation, a "weight" was introduced.

The inhalation is the main way of entry into the body of dangerous substances at work. The risk of inhalation exposure to dangerous chemicals occurs when processes or operating procedures cause the dissemination in the air of chemical pollutants. The index of exposure via inhaled E_{INAL} is determined by the product of a Sub-index I (intensity of exposure) and a Sub-index d (distance of the worker from the source of intensity I)

$$E_{INAL} = I \times d \quad (5)$$

The calculation of the Sub-index I involves the use of the following five factors: Physical and Chemical Properties, Quantity in use, type of use, type of control, time of exposure. In particular, it is possible to use the criteria identified in S.C. Maidment, "Occupational Hygiene Considerations in the Development of a Structured Approach to Select Chemical Control Strategies."



Levels of dust availability
- Solid state/mist – broad spectrum granulometric
Low: pellets and similar non-friable solid, little evidence of dust observed during use. Medium: granular or crystalline solids. During use, the dust is visible, but the dust settles quickly. After use, the dust is visible on surfaces.
- Fine powders
High: fine dust and light. When using, you can see a cloud formation aerosuspended of dust that remains for several minutes.

Figure 1: Level of dust availability

Type of use

It identifies four levels, always in ascending order, regarding the possibility of leakage in the air, the type of use of the substance, which identifies the source of exposure.

- Use in closed system: the substance is used and/or stored in reactors or sealed containers and transferred from one container to another through pipes watertight.
- Use in inclusion in the matrix: the substance is incorporated in materials or products to which it is prevented or limited dispersal in the environment.
- Controlled and non-dispersive use: this category includes processes in which only limited selected groups of workers are involved, experts of the specific process and adequate control systems to monitor and control the exposure are available.
- Use with significant dispersion: this category includes processes and activities that may cause an uncontrolled exposure not only to people involved but also other workers and possibly the general population. Jobs with paints and other similar activities can be classified in this category of use.

Type of control

- Complete Containment: it corresponds to a situation in a closed cycle.
- Ventilation - Local exhaust of discharges and emissions (LEV): this system removes the contaminant at its release source, preventing dispersion in areas with human presence, where it could be inhaled.
- Separation: the worker is separated from the source of release of the contaminant by an appropriate security space, or there are adequate time intervals between the presence of the contaminant in the environment and the presence of staff in the same area.
- Dilution: natural or mechanical. This method allows minimising the exposure.
- Direct Manipulation (with individual protection systems): in this case the worker operates in direct contact with the hazardous material, adopting mask, gloves or other similar equipment.

2.2 Time of Exposure

Five ranges define the time of exposure to the substance or preparation:

- less than 15 min
- between 15 minutes and 2 hours
- between 2 and 4 hours
- between 4 and 6 hours
- more than 6 hours

Through the identification of physico-chemical properties of the substance or preparation and the amount in use, inserted into matrix 1, a first indicator D is defined on four levels increasing potential availability to aero-dispersion

- Once you have the D indicator and identified the type of use, as defined in paragraph 3, the following indicator U on three levels of increasing actual availability to aero-dispersion can be obtained through matrix 2;
- Once you have identified the indicator D and the "type of control", as defined in paragraph 4, through matrix 3, it is possible to obtain a subsequent C indicator that takes into account the compensation factors relating to the prevention measures and protection measures adopted in the work environment;
- Finally, using the indicator C, obtaining the time of actual exposure of the worker, the value of the sub-index I can be assigned through matrix 4, distributed on four different levels, which correspond to different "intensity of exposure," regardless of the distance from the source of exposed workers.

The sub-index d takes into account the distance between a source of intensity I and the exposed worker: if these are close to the source (<1 meter) the sub-index I is unchanged (d = 1); gradually, during which the employee is away from the source, the sub-index of the intensity of exposure must be reduced proportionately until arriving at a value of one tenth of I for distances greater than 10 metres. The values of d to be used are indicated in the following table:

Table 1: Values of d

Distance in meters	Value of d
less than 1	1
1 to less than 3	0,75
3 to less than 5	0,50
5 to less than 10	0,25
Greater than or equal to 10	0,1

Chemicals are absorbed by the skin more slowly than the gut or lungs. However, the chemicals (especially organic solvents) can enter the body either directly or via contaminated clothing. The risk of exposure for skin contact can occur during handling of dangerous substances. Values of E_{cute} index are a criterion for the assessment of risk from hazardous chemicals. In agreement with those reported in the previous paragraphs, it is possible to classify the use of preparations on the basis of the value of the risk index R.

Table 2: Classification risk

	RISK VALUES (R)	CLASSIFICATION
INSIGNIFICAT RISK TO HEALTH	0,1 ≤ R< 15	Insignificant risk to helth
	15 ≤ R < 21	Uncertainty interval: it is necessary, first of classification insignificant risk to the health, review with care the assignment of various scores, review the measures of prevention and protection measures adopted and consult a qualified doctor
HIGHER RISK THAN IRRILEVANT TO HEALTH	21 ≤ R ≤ 40	Risk outweighs the chemical risk irrelevant to health
	40 < R ≤ 80	Area of high risk
	R > 80	Area of serious risk to reconsider the path of the identification of the measures of prevention and protection with a view to their possible implementation. Intensify controls such as health monitoring, measurement of chemical agents and maintenance periods.

The model can also be applied to exposures to hazardous chemical agents arising from work activity. In this case the algorithm for the choice of the score and in the calculation of the exposure E must be used very cautiously. P is also necessary to take into account the model that may not always be specific for all the activities in which they can develop chemical agents. In particular, applying the model to choose the P score is extremely important to know if the amount of the development of the pollutants from the workforce is high or low and which classification can be attributed to chemical agents that are developed. After choosing the size of the emission, to assign a score P, it is necessary to identify chemical agents, assign relative rankings (very toxic, toxic, harmful, irritant inhalation) and to use for the calculation of R, the highest value of P. For the allocation of the value of E_{inal} value, it is necessary to use a modified matrix system:

- in the matrix 1 / bis using the amount in use, daily and overall, of the material from which they can develop hazardous chemical agents.
- in the matrix 2 / bis is used the index value obtained from the matrix 1 / a and the exposure time, according to the criteria previously defined, obtaining the value of the sub-index of intensity I

multiplied by the distance d which indicates the distance of the worker exposed to the source of emission. The risk R for inhalation of hazardous chemical agents developed from work must be considered against a conservative estimate and is calculated by:

$$R = P \times E_{inal} \quad (6)$$

Examples

Table 3: Matrix 1/bis

Type of Control				
Amount in use	Complete containment	Local exhaust	Segregation/separation	General ventilation
<10Kg	low	Low	Low	Medium
Tra 10 e 100Kg	low	Medium	Medium	High
> 100Kg	low	Medium	High	High

Table 4: Matrix 2/bis

Time of exposure					
	<15 min	Between 15 min and 2 h	Between 2 and 4 h	Between 4 and 6 h	>6 h
C1	low	low	Medium/low	Medium/low	Medium/high
C2	low	Medium/low	Medium/high	Medium/high	**High**
C3	Medium/low	Medium/high	**High**	High	**High**

2.3 Risk Evaluation For Safety

The evaluation of exposure to chemical risk is based on two methods of analysis, one that takes into account the health and the other which takes into account the safety. In assessing the safety risk due to the use of hazardous chemical agents a qualitative assessment is proposed.

2.4 Application Note for Case Study

In order to assess the risk of individual chemical products used in screen printing, we use an Excel spreadsheet where, through the use of safety data sheets, and can be determined as a function of exposure time, if the product constitutes a significant risk to the health of workers (Bureau of labor statistics, 2004; Bureau of labor statistics, 2005). Consider one of the most used products in screen printing: Printperfekt 226. This product is used in two distinct departments of screen printing: in dep. B, the department for the preparation and storage of paints, and in dep. C, the department in which printing occurs. Suppose that Printperfekt 226 is to be used in department B, specifying the employees in the department B, the date of the Safety Data Sheets, the total amount present in the department and the quantities used daily. Subsequently, through the material safety data sheet occurs if the product is made from hazardous substances. The considered product is made from a single dangerous substance namely ethane-1,2-diol. With regard to this substance, it is necessary to specify the concentration, the associated symbolism (if it is a corrosive substance, irritant, flammable, harmful, toxic, etc.) – Xn in this case (the substance is harmful) – the CAS number, which is an identifying number that unambiguously identifies a chemical substance, the code EC, or EINECS code that is a registration code, present in European inventory, of commercial chemicals and, finally, the risk phrases R. Through the risk phrase R22, which in our case is that the product is harmful if swallowed, it is possible to determine the hazard index P. It is important to take the risk phrase that has the highest score to evaluate the risk in a worse situation. After determining the hazard index P, the risk of inhalation exposure and the risk of dermal exposure are calculated. In order to determine the risk of inhalation exposure, the intensity of inhalation exposure is calculated and to do this it is necessary to:

- Determine the physical state of the product that we are using, which can be:

- Solid state/mists;
- Liquid of low volatility;
- Liquid medium and high volatility;
- Gaseous state.

If the product is a liquid, to determine the level of volatility, it is necessary to use a graph that shows the performance of the boiling temperature as a function of operating temperature. After defining the physical state of the product that we are using in the amount in use (expressed in kg / day) is calculated by multiplying the daily amount for the concentration;

- Determine the type of use that is supposed to be always controlled non-dispersive;
- Determine that the type of control is always local exhaust ventilation
- Specify the time of daily exposure of workers to the product, in this case 8 hours / day;
- Enter the table in which we have the amount in use and the physical-chemical properties so that, depending on the amount in use and the physical-chemical properties, fixed value Indicator of Availability (D) is estimated (in our case this is 3);
- Enter the table indicating the type of use and the value of Availability Indicator (D) so that, by entering the previously determined value of D and knowing that the type of use is always controlled use, the value Indicator of Use (U) is determined (in this case 3);
- Enter the table indicating the type of control and the value of (U) so that, by entering the value of (U) previously determined and knowing that the type of control is always localised aspiration, Compensation Indicator (C) can be determined (in this case 2);
- Entering in the table indicates that the exposure time and the value of Indicator Compensation (C) so that entering the value of (C) previously determined and knowing the exposure time, the

value of the Sub-Index Intensity (I) is estimated (in our case this is 10);

- Fix the index of distance (d) which happens to be always equal to 1 m;
- After fixing all these parameters, it is possible to calculate the index of inhalation exposure as E_{INAL}

$$E_{INAL} = I \times d \quad (7)$$

At this point it is possible to calculate the risk of inhalation exposure:

$$R_{INAL} = P x E_{INAL} \quad (8)$$

After determining the risk of inhalation exposure, this may determine the risk of dermal exposure progressing in a similar manner and then evaluating the intensity of dermal exposure:

- Determine the type of use that is supposed to be always controlled non-dispersive;
- Determine the level of skin contact, which happens to be always accidental contact;

Entering the table that shows the type of use, which we know is always controlled non-dispersive use, and the level of skin contact, which we know is always accidental contact, we have E_{CUTE} = 3. Once you know the risk of inhalation exposure and the risk of dermal exposure, the cumulative risk R can be calculated:

$$R_{CUM} = (R^2_{INAL} + R^2_{CUTE})^{1/2} \quad (9)$$

In this case RCUM = 18,27 and is shown in the table where the criterion for assessing the risk from hazardous chemicals shows that 15≤R <21. Then, we are in the range of uncertainty. Therefore, before classifying the risk as irrelevant to health, it is necessary to review with care the assignment of various scores, the measures of prevention and protection measures adopted and consult a doctor. The analysis carried out for Department B is repeated in a similar manner to Department C (pressroom). The only difference is in the time of exposure, which in B is eight hours, but 1.5 hours in C. Being less than the exposure time, the cumulative hazard is minor. In fact, in this case, RCUM = 7.42 and, therefore, the risk is irrelevant to the health and we must simply comply with the requirements of the safety data sheet. In the case of non-negligible risk, the employer must undertake specific measures of prevention and protection, such as:

- The design of appropriate work processes and engineering technicians (Falcone *et al.*, 2014).

2.5 Conclusion

In order to reduce the risk from exposure to chemicals in the workplace, important measures of prevention and protection can be taken, which help protect the health and safety of workers. As for preventive measures to be implemented to reduce the risk resulting from the presence of chemical agents, it is necessary to distinguish between:

- Preventive measures to be implemented to reduce the risk at source (elimination or substitution of dangerous products).
- Preventive measures relating to the workplace (local to local exhaust ventilation and separate in depression).
- Preventive measures to be implemented to reduce the organisational risk of work systems (reduction of exposure duration and intensity).
- Preventive measures to be implemented for the management of emergencies (first aid equipment and kits washing).
- Preventive measures to be implemented to reduce the residual risk (information, training, procedures).
- Preventive measures to be implemented to reduce the residual risk (use of PPE).
- Preventive measures to be implemented to reduce the residual risk (health monitoring).

Table 5: Scheme Excel sheet

N°	Denominazione preparato	Addetti	Scheda tecnica del/del	Quantità totale presente	Quantità preparato (prodotto utilizzato) (kg/gg)	Componenti preparato (punto 2 MSDS)	Conc. (%)	Simbologia associata	CAS	EC	Frasi di rischio ingredienti (punto 2 …)	Indice I*
1	*PRINT PERFEKT 225*	XXXX	Produttore/ver. 4 del 09/12/2005	600 Kg	10,000	Etan-1,2-diolo	2,50%	Xn	107-21-1	203-473-3	R22	1,75
2	*BIANCO ROTAPRINT NE*	XXXX	Produttore/ 20/05/2010	60 Kg	5,000	N.P.	—	—	—	—	—	—
3	*PRINT PERFEKT LAC 110 NEU*	XXXX	Produttore/ver.2 del 14/12/2005	30 Kg	1,000	Nafta (petrolio)	10,00%	Xn	64742-48-9	265-150-3	R 65; R66	3,50
						Dietilen glicole	2,50%	Xn	111-46-6	203-872-2	R 22	1,75
4	*PRINT PERFEKT DC 5*	XXXX	Produttore/ver.2 del 15/05/2009	30 Kg	1,000	N.P.	—	—	—	—	—	—
5	*PRINT PERFEKT DC5 WHITE*	XXXX	Produttore/ver.1 del 19/03/2012	30 Kg	1,000	Nafta (petrolio)	10,00%	Xn	64742-48-9	265-150-3	R65; R66	3,50
6	*GELATINA T DA 5 Kg*	XXXX	Produttore	10 Kg	1,000	Metilpropeno acrilato alcossilato	7,00%	Xi	—	—	R36;	2,50
						Estere acrilato	10,50%	Xi	—	—	R52/53;	2,75
7	*TUB VINYL 235 MC*	XXXX	Produttore/ver.1 del 30/01/2012	30 Kg	1,000	Acetato di 2-butossietile	3,00%	Xn	112-07-2	203-933-3	R20/21;	4,25
8	*DENMCOL SPEC-KRR (*)*	XXXX	Produttore/ver.4 del 7/10/2010	20 Kg	1,000	Acido citrico	2,50%	Xi	5949-29-1	201-069-1	R36;	2,50
						Tetraborato di disodio decaidrato	1,00%	T	1303-96-4	215-540-4	R60; R61	10,00

Intensità esposizione per via inalatoria									Indice distanza esposizione	Indice esposizione per via inalatoria (Einal)	Rischio esposizione inalatoria (Rinal)	Intensità esposizione per via cutanea		Indice esposizione per via cutanea (Ecute)	Rischio esposizione cutanea (Rcute)	Rischio cumulato R	RISCHIO
Proprietà chimico fisiche	Quantità (Kg/gg)	Tipologia uso	Tipologia controllo	Tempo esposizione	D	U	C	I				Tipologia uso	Livelli di contatto cutaneo				
Liquido media alta volatilità	0,2500	Uso controllato non dispersivo	Ventilazione-aspirazione loc	1,5 h/gg	3	3	2	3	1,00	3,000	5,250	Uso controllato non dispersivo	Contatto accidentale	3,000	5,250	7,42	RISCHIO IRRILEVANTE
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	RISCHIO IRRILEVANTE
Solido	0,1000	Uso controllato non dispersivo	Ventilazione-aspirazione loc	1 h/gg	1	1	1	1	1,00	1,000	3,500	Uso controllato non dispersivo	Contatto accidentale	3,000	10,500	11,07	RISCHIO IRRILEVANTE
Solido	0,1000	Uso controllato non dispersivo	Ventilazione-aspirazione loc	2 h/gg	1	1	1	1	1,00	1,000	1,750	Uso controllato non dispersivo	Contatto accidentale	3,000	5,250	5,53	RISCHIO IRRILEVANTE
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	RISCHIO IRRILEVANTE
Solido	0,1000	Uso controllato non dispersivo	Ventilazione-aspirazione loc	1 h/gg	1	1	1	1	1,00	1,000	3,500	Uso controllato non dispersivo	Contatto accidentale	3,000	10,500	11,07	RISCHIO IRRILEVANTE
Liquido media alta volatilità	0,0700	Uso controllato non dispersivo	Ventilazione-aspirazione loc	1,5h/gg	1	1	1	1	1,00	1,000	2,500	Uso controllato non dispersivo	Contatto accidentale	3,000	7,500	7,91	RISCHIO IRRILEVANTE
Liquido	0,0700	Uso	Ventilazione-	1,5h/gg	1	1	1	1	1,00	1,000	2,750	Uso	Contatto	3,000	6,250	6,70	RISCHIO
Solido	0,0300	Uso controllato non dispersivo	Ventilazione-aspirazione loc	1h/gg	1	1	1	1	1,00	1,000	4,250	Uso controllato non dispersivo	Contatto accidentale	3,000	13,050	13,76	RISCHIO IRRILEVANTE
Solido	0,0250	Uso controllato non dispersivo	Ventilazione-aspirazione loc	1h/gg	1	1	1	1	1,00	1,000	2,500	Uso controllato non dispersivo	Contatto accidentale	3,000	7,500	7,91	RISCHIO IRRILEVANTE
Solido	0,0100	Uso controllato non dispersivo	Ventilazione-aspirazione loc	1h/gg	1	1	1	1	1,00	1,000	10,000	Uso controllato non dispersivo	Contatto accidentale	3,000	30,000	31,62	RISCHIO NON IRRILEVANTE

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