REGULATORY ISSUES AND FLAME RETARDANT USAGE IN UPHOLSTERED FURNITURE IN EUROPE

E. Guillaume, C. Chivas, A. Sainrat
LNE –CEMATE – Fire Behaviour Division
Research, Studies Fire Safety Engineering Activities
78197 Trappes Cedex (France)

ABSTRACT

Accidental fires in dwellings are responsible for over ten thousand injuries and more than 460 deaths every year in France. Many of these fires involve upholstered furniture. Within Europe, the regulations for such furniture vary considerably between countries and applications. The European Commission addresses this issue in the EU General Products Safety Directive. In some cases, the introduction of such regulations implies usage of flame-retardants in the fabric or foam of the furniture. The incorporation of flame retardants has the benefits of improving reaction to fire properties and reducing the fire hazard due to fire spread and heat release, but might also increase the toxicity of the fire emissions or introduce other risks due to the chemicals themselves.

The study presented was carried out to evaluate the risks and the benefits of introducing flame-retardants into upholstered furniture within the life-cycle risk assessment. The paper examines the currently available literature on the different risks due to the presence of flame-retardants in upholstered furniture, that is:

1. The risk of exposure to flame-retardants during manufacture of the products (worker acute and chronic toxicity);
2. The risk of exposure to flame-retardants under normal living conditions. This risk mainly results from accumulation of release flame-retardants in indoor air (inhalation) and/or skin contact and migration of substances (chronic toxicity);
3. The environmental risk during recycling or incineration of the products (mainly ecotoxicity);
4. The risk of increasing emissions of toxic gases from accidental fires due to cigarettes or matches on upholstered furniture (acute toxicity).

Several studies show that estimation of exposure to people by using consumer products containing flame-retardants is not very easy. A methodology was proposed to estimate the risks and the benefits of flame-retardants within the life-cycle risk assessment, considering REACH and GHS directives, and also flammability standards. Data sheets for some common flame-retardants used in upholstered furniture were devised in order to evaluate the complete risk-balance equation for long-term health from exposure to consumer products containing flame-retardants and from exposure to their fire effluents.

ACTUAL REGULATION ON UPHOLSTERED FURNITURE AND NEW QUESTIONS

Accidental ignition due to cigarettes in dwelling fires is responsible of 11 000 fires every years in the 14 Member States of European Union and Norway, with 520 deaths, 1 600 injuries and 14 € million of material damage, for a population of about 160 million [i]. Fire statistics from 1999 to 2002 are given by NFPA report [ii] on fire deaths in home in U.S. due to smoking materials, and represent about 23 % for all ages. The incorporation of flame retardants gives advantages: by reducing the fire hazard due to the propagation and heat released, and by improving fire reaction properties. However, it may increase the toxicity of fire emissions.

Regulations in UK and in Ireland since 1988 [iii],[iv] induced the use of flame retardants and smoke alarms in residential dwellings. All upholstered funiture, sold in UK and intended to the general public, need to be fire retardant to ignition by a cigarette, a small flame like match and by BS:Crib 5 (17 ± 1 g of wood). In UK for textiles, foams and fabrics, specifications are fixed by standards such as BS 5852 and EN 1021-1 and 1021-2. There requirements can reduce the fire risks, but toxicity risks due to flame retardant systems are not really demonstraded. Only few of them are examined during life-cycle and incineration, as chemical substances would be, i.e. not during accidental fire. Life-cycles studies [v] tend to assess pollutant emissions during incineration of furniture containing flame-retardant or not. Other studies demonstrated that the use of flame retardants does not increase the total polycyclic aromatic hydrocarbon emission. But, these studies excluded the impact of accidental fires, which are different from incineration. Safety risks in accidental fire in dwellings, due to flame retarded ulpholstered furniture, is not taken into account. One should notice that in the rail or maritime transport [vi], firstly, the reaction to fire requirements induce the use of flame retardants, and secondly, the fire safety requirements are very important and take into account detection, extinction aspects, opacity of smoke and toxicity of effluents.

Contrary to other european countries, UK and Ireland take into account cigarette and match but also other higher ignition sources with different levelsdepending on the hazard. Even if fire safety requirements must be increased in Europe for upholstered furniture, according to study of LNE [vii], more than 35 % of upholstered furniture products without flame retardant systems pass cigarette and match tests.

Many countries use EN standards like EN 1021 and 597 to evaluate the ignitability of furniture by cigarette or match. Some countries have higher ignition sources described in national standards. National regulations and standards in Europe towards the ignitability of upholstered furniture are presented in the following Table 1 (Sainrat, 2006 completed [viii],[ix]).

Country	Type of Building	Reference regulations	Type of furniture	Requirement	Test methods	Classifi-cation
France	Domestic	N°200-164	Bedding	No ignition by cigarette	EN ISO 12952-1 and 2	Pass/ Fail
	Public	U 23 (Health)	Bedding	No ignition by cigarette	EN ISO 12952-1 and 2	Pass/ Fail
			Mattress	No ignition by cigarette	EN 597-1	
		AM 18 (Spectacle)	Seat	No ignition by 20g paper cushion equivalent burner	NF D 60013	Pass/ Fail
				No ignition of the frame	NF P92501 and NF P92507	M3
		GPEMD1 – 90 (Prisons)	Mattress	No ignition by cigarette	EN 597-1	E
				No ignition by match	EN 597-2	D
				No ignition by higher ignition sources	GPEM D1-90 procedure	C,B,A (A the best)
UK/ Ireland	Domestic	Furniture and furnishing Regulations n°1324	Seat/Mattress Covering Filling	No ignition by cigarette No ignition by match No ignition by crib five	EN 1021-1 EN 1021-2 BS 5852	Pass/ Fail
	Public	BS 7176	Seat	No ignition by cigarette No ignition by match No ignition by higher ignition sources in function of the level of hazard	EN 1021-1 EN 1021-2 BS 5852	Pass/ Fail

Country	Type of Building	Reference regulations	Type of furniture	Requirement	Test methods	Classifi-cation
		BS 7177	Mattress	No ignition by cigarette No ignition by match No ignition by higher ignition sources in function of the level of hazard	EN 1021-1 EN 1021-2 EN 6807	Pass/ Fail
Italy	Public	DM26/06/1984	Seat/Mattress Filling	No ignition by a 40 mm high flame during (s) 20, 80, 140	CSE RF 4/83	3IM 2IM 1IM
Finland	Domestic	N°743/1990 N°479/96	Seat	No ignition by cigarette	EN 1021-1	SL2
	Public	Finnish fire safety guidelines for furnishings published by Ministery of Interior, rescue Department Guideline A:56,1988	Seat	No ignition by cigarette and match	EN 1021-1 EN 1021-2	SL1
Sweden	All	No regulations, only recommendation from consumer agency	Seat	No ignition by cigarette	EN 1021-1	Pass/ Fail
			Mattress	No ignition by cigarette	EN 597-1	Pass/ Fail
Norway	All	Crown Prince Regent's Decree 07/09/1990	Seat	No ignition by cigarette	EN 1021-1	Pass/ Fail
			Mattress	No ignition by cigarette	EN 597-1	Pass/ Fail
Spain	Public	Same as French Regulations				
Portugal	Public	Same as French Regulations				
US	Domestic	Federal Mattress Flammability Standard	Upholstered funriture Mattress	No ignition by cigarette	16 CFR Code of Federal Regulations – Part 1632 (FF4-72, as amended)	Pass/ Fail
Other countries	-	No Regulations				

Table 1: National regulations and standards in Europe and USA towards the ignitability of upholstered furniture [viii], [ix]

Harmonization seems to be necessary and the European Commission examines the possibility of adopting Europe-wide legislation concerning furniture fire safety by cigarette and match tests (two EN standard regulations EN 597-1 & 2:1994 and EN 1021-1 & 2:1996). To ensure the possibility to use Flame-retardants in upholstered furniture, some questions need answers. The first is to assess the impact of the flame retarded upholstered furniture in term of global risk on the human health [vii], [x]. There are risks induced by flame retardants during process, those induced by the exposure of people through skin contact with flame retardants that has migrated from upholstered furniture, risks by inhalation of substances emitted in the atmosphere during it's the life of the product, risks by emission of toxic gases during incineration and by emanation of gaseous effluents during combustion in the event of fire. These risks of toxicity, induced by the introduction of flame retardants in upholstered furniture that are found in dwellings, should be studied according to the recommendation of General Safety Products Directive (2001/95/CE) [xi] in order to achieve the required high level of protection for health and safety of people.

FLAME RETARDANTS USED IN UPHOLSTERED FURNITURE

The upholstered furniture structure is made of three parts (cover fabrics, upholstery and interliner), as described in the Table 2 [xii],[xiii],[xiv].

Covering (fabric)	Upholstery (foam)	Interliner
- Cellulosic fibre (cotton, linen) - Protein fibre (wool, leather)	- Polyurethane foam - Polyester foam - Latex	- Aramid fibre (Note : an interliner should behave as a fire barrier) - Glass fiber
- Synthetic fibre (acrylic, polyester)		
- Chloride synthetic fibre (polyvinyl chloride)		

Table 2: Main different textile fibres found in upholstered furniture

Some of these products smoulder and lead to fire propagation. Synthetic fibres may burn strongly and may drip, carrying flames to other surfaces. Foam without fire retardant treatment burns and is easy to ignite if the material is in contact with a flame. Less dangerous textile fibres, such as Aramid, don't burn because of their intrinsic fire reaction properties. Flame-retardants ensure an appropriate fire safety level for several natural and synthetic fibres, depending on requirements. Flame-retardants act as a barrier between flame and foam, or by limiting oxygen supply to fire. Treatment can be carried out at manufacture time by impregnation, on end products by pulverization or coating. These treatments are often not durable in time. Flame retardant can also be introduced during the process in the cover fabrics, upholstery or/and interliner, and in this case linked to the matrix [xv],[iii]. Then, this couple forms a new chemical product.

PROCESSING BY INCORPORATION OF FLAME RETARDANT IN THE MATRIX

Fabrics

- *Fireproofing of cotton*

The principal agents used for cellulose fibres such as cotton are phosphorate compounds coupled in synergy with nitrogen derivatives. Most of the time, these flame retardants agent are not durable in time.

- *Fireproofing of wool*

According to the scope of application, wool is used in binary mixture, such as wool /polyamide, wool /polyester, or wool /polyacrylic. It should be noted that the major compound is the wool associated with another fibre in proportions varying from 15 to 20 % by weight. Several levels of fireproofing are found for the associations stated above:

- treatment of fabrics by zirconium or titanium salts presents a light improvement. Their use depends on the further applications.
- treatment with zirconium or a titanium salt combination with acid tetrabromophtalic.

The purpose of fireproofing treatments is to reduce the flammability of material. However, it does not necessarily reduce the emission of smoke. To get a lower smoke emission, the wool fabrics are treated with a combination of zirconium potassium fluorozirconate and acetate.

- *Fireproofing of synthetic fibres*

Halogen compounds can be used in most cases such as, for example, polyethylene terephthalate and acrylic resins. It should be noticed that chlorinated synthetic fibres, made up starting from halogenated monomers, have an intrinsic fireproof characteristic and thus do not require chemical modifications.

Foams for upholstery

Foams used as stuffing require a good fire performance. Stuffing is mainly containing polyurethane or latex, or polyether. It can be fireproofed with for an example, Tris (1-Chloro-2-Propyl) Phosphate (TDCPP) or melamine salts. The components for polyurethane foams can be modified to improve fire retardant properties, such as PU (CMHR): polyurethane with combustion modified melamine high resilience or flame retarded latex. These can also be modified to improve mechanical behaviour, such as, PU (HR): polyurethane high resilience, or other fillings mixed with graphite.

As mentioned above, flame retardants applied to finished textiles often do not afford such durability, and are only suitable for temporary applications. Flame retardants for textiles can react with matrix fibres to become a part of the textile (added by reaction and therefore called reactive flame-retardant), or the flame-retardant and the matrix can be incorporated at the same step during the process (added by mixing, and called additive flame retardant).

The main advantage of reactive systems is their chemical bond between the flame-retardant and the matrix. Thus, the flame retardant can not migrate. Reactive flame retardants are usually more expensive than additive components. They are used mainly in processing matrices such as, polyurethane, polyester. In contrast, additive flame retardants are added during the manufacture of the upholstered furniture but form no chemical bond and therefore can be released through time (by evaporation).

METHODOLOGY TO ESTIMATE THE LIFE CYCLE IMPACT OF FLAME RETARDANT USED IN UPHOLSTERED FURNITURE IN RELATION WITH THE DIRECTIVE 2001/95/EC

According to the Directive 2001/95/EC of the European Parliament and of the Council, december 3rd, 2001 on General Product Safety, all producers shall place only safe products on the market [xi]. A product is defined as safe if the health and safety requirements of the product (upholstered furniture) are fulfilled. In this paper, a methodology was proposed to estimate risks and benefits of flame-retardants within the life-cycle risk assessment (Figure 1).

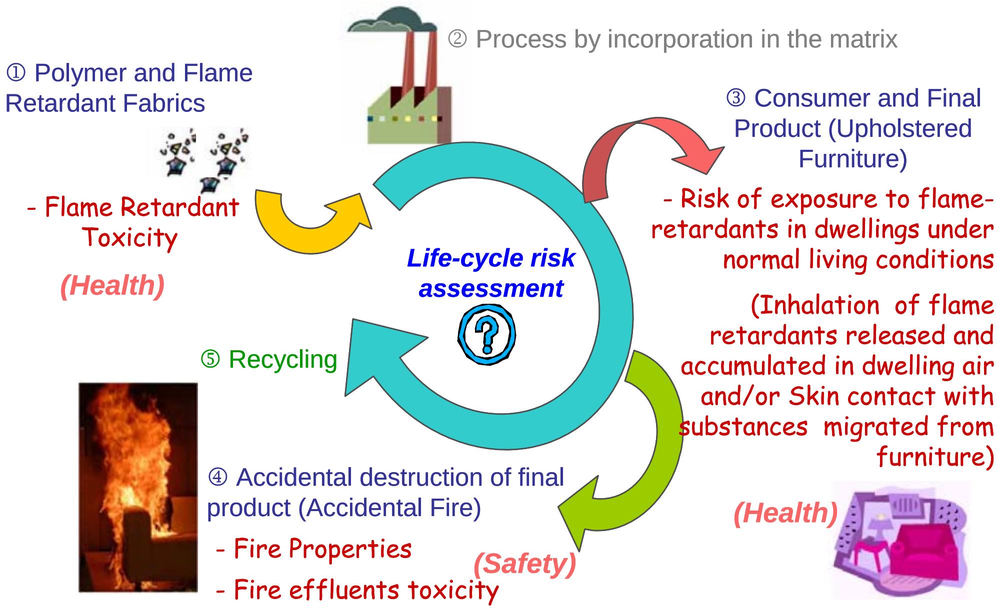

Figure 1: Impact of flame retardant used in upholstered furniture during Life-Cycle

Available literature on the different risks due to the presence of flame-retardants in upholstered furniture has been examined, and we focuses on three points of the Figure 1:

- The risk of intrinsic toxicity of the flame-retardants ①. Tools available to evaluate the potential risk on health are principally data sheets for some common flame-retardants used in upholstered furniture. In this case, health risks assessment concerns acute chemical toxicity. Long term toxicity describes the adverse health effects from repeated exposures to a substance over a longer time period (such as, chemical exposure during process for workers or environnement).

- The risk of exposure to flame-retardants in dwellings under normal living conditions ③. This risk mainly results from accumulation of released flame-retardants in interior air (inhalation) and/or from migration of substances and subsequent skin contamination. Several studies [xvi],[xvii],[xviii] show that estimating the exposure of people when using consumer products containing flame retardant is not very easy. Chronic toxicity is a property of a substance that has toxic effects on a living organism, when that organism is exposed to the substance continuously or repeatedly.
- The risk of worsening emissions of toxic gases from accidental fires due to cigarettes or matches on upholstered furniture, whether they are flame retarded or not ④. Acute toxicity describes the adverse effects of a substance, which result either from a single exposure or from multiple exposures in a short period of time (such as, exposure to smoke effluents during combustion).

Scenarios of emission of pollutants during life-cycle of the substance and the final product are given by OECD [xix] (Organisation for Economic Co-operation and Development). For each category of product or activity, a guidance document describes the emission scenario used in risk assessment of chemicals. This establishes the conditions of use and release of the chemicals, and assists in the estimation of releases of chemicals to the environment. This document gives keys to estimate the yield of chemicals released during life-cycle of the product, including recycling, waste and incineration. Nevertheless, accidental fires are not considered.

TOOLS FOR THE EVALUATION OF THE GLOBAL RISK ON HEALTH AND SAFETY ACCORDING TO THE 2001/95/EC DIRECTIVE

This part focuses on the tools available to evaluate the risk on health and safety in relation with the 2001/95/EC Directive on General Product Safety. The first approach takes into account the risk of a global safety through ignitability of the final product (the upholstered furniture) [xx], [xxi] and the impact of flame retardants on smoke toxicity [xxii]. The second approach deals with the risk on global health (chemical substances as flame retardants, their processing, the life cycle of the product and finally recycling) [xxiii].

SAFETY RISKS IN UPHOLSTERED FURNITURE

Safety risks due to ignition

A large number of tests on upholstered furniture has been made during CBUF program in 1994 by several laboratories within Europe [xxi] [xxiv] [xxv], with cigarette and match ignition sources. The tests were made according to EN 1021-1 and 2 on 360 combinations of 20 cover fabrics and 18 fillings foams (polyurethane, latex, polyester), sometimes combined with different types of interliners. In this case, 61% of combinations contained a flame retardant, either in the cover fabrics or in the filling foams. The results of this tests are summarised to express the percentages of upholstered furniture that pass both cigarette and match, only cigarette, only match or that do not pass neither cigarette nor match (Figure 2).

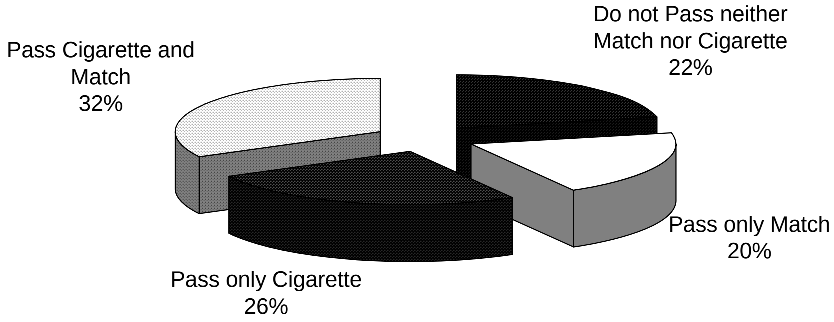

Figure 2: Percentages of upholstered furniture combinations, which pass both cigarette and match, pass cigarette or match only and do not pass neither cigarette nor match

Combinations passing the cigarette and match test depend on the association of fabric (flame retarded or not), filling foam (flame retarded or not) and on the effectiveness of the flame-retardants additives. For fabrics that pass the match test only, the allocation of where the flame retardant is located in the upholstered furniture is shown on Figure 3. The same is shown on Figure 3 for fabrics that pass both cigarette and match tests.. These results are extracted from an European study led in 1994 [xxi] and from CBUF project [11] representative of some possible combinations (but not all): it is a sample of the market. The tested products were representative of the technical possibilities (assemblies) but not of the whole market.

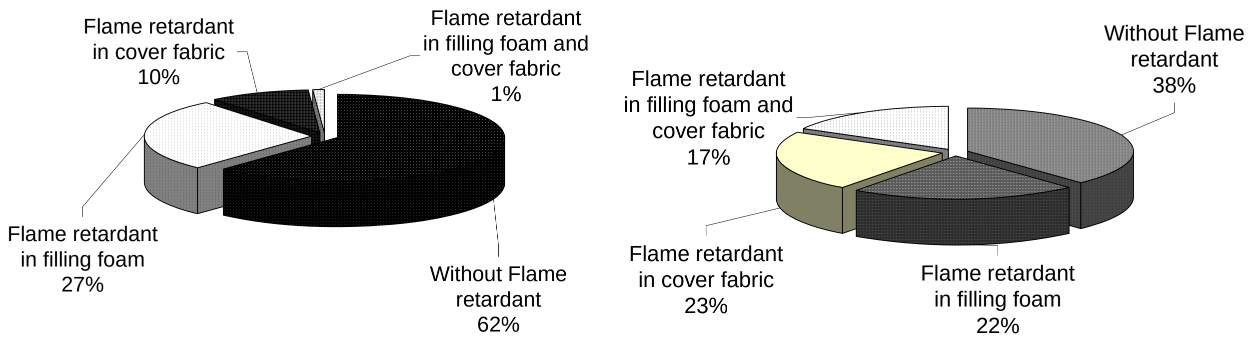

Figure 3: Fabrics that pass cigarette test only and fabrics that pass match and cigarette tests

Fig. 3a shows that among the 26 % of furniture that pass the match test (Figure 2), 38% were flame-retarded, when 62% were not. Fig. 3b shows that among the 32 % of furniture that pass both cigarette and match tests (Figure 2), 62% were flame-retarded when 38% were not. Some fabrics, which are not flame retarded, such as leather, nevertheless have good fire performances due to their intrinsic properties. Fire risk should be evaluated according to ignitability tests on upholstered furniture, such as EN 1021-1 and 2 (upholstered furniture), EN 597-1 et 2 (mattresses and upholstered bed), depending on the performance level required.

<u>Safety risk due to toxicity of fire effluent during combustion</u>

Smoke toxicity is not evaluated through quantification of fire effluents during combustion, but can be evaluated considering the performance of the products against match or cigarette tests. The evaluation of the safety risk has nevertheless to take into account the representativeness of the fire scenarios that led to the creation of these tests (size of the room, ventilation, domestic situation). Two cases should be considered:

- The upholstered furniture does not ignite when it is submitted to a reasonable ignition source, but is subject to smouldering;
- The upholstered furniture ignites when it is submitted to that ignition source.

In both cases, it is necessary to have an assessment method to predict the toxic effects, which is realistic and reliable. The method should not take into account the sole toxic potential of the effluents, but must integrate the amount of product really burnt.

A previous study from LNE [xxvi] show the possibility to predict the time to incapacitation and lethality through the measurement of mass loss, whether if upholstered furniture is flame retarded or not. To assess the toxicity risk by the direct relationship between the mass loss of the product during combustion and the toxic effects, it is necessary to check if the mass loss of the final product has reached a critical threshold in a representative volume of dwelling. In this study, it was verified that, during match or cigarette tests, according to EN 1021-1 and 2 or EN 597-1 and 2, the mass loss of upholstered furniture, whether it is flame retarded or not, , is never sufficient to release enough toxic gases to present a risk on health. This conclusion relies on the assumptions that there is a homogeneous diffusion of gases, and that the fire is of small size. Attention is drawn to the fact that the way the toxic risk due to fire effluents is evaluated, is through the fire scenario (match, cigarette or both) and not through quantification of gaseous products.

For example, the combustion of upholstered furniture made with a polyurethane foam (PU foam) and a covering based on cotton coated with polyvinyl chloride (PVC), should mainly lead to the formation of the following toxic effluents: CO, CO2, HCN and HCl. The experimental part of the study from LNE, gave the mass loss for various types of upholstered furniture (including the one cited in the example), to reach the incapacitation and the death of mice (Table 3).

Mice effects	Mass Loss (g/m^3)
Incapacitation	17 - 27
Lethality	21 - 37

Table 3: Mass loss to reach the incapacitation and the lethality of mice

The mass loss was expressed in gram of burnt material per volume (of the room, m3) in which gaseous effluents are accumulated. Results from LNE are confirmed by Neviaser and al. [10] studies on the lethality, giving lethal concentrations between 12 and 40 g/m3.

Lethal concentration LC50 (g/m3) at 30 min for various types of polyurethanes, flame retarded or not, are presented in Table 4.

Polyurethane (PU)	Lethal concentration LC50 (g/m^3) at 30 min
PU without flame retardant	40
PU with a flame retardant unknown	26
PU with melamine	12.5

Table 4: Lethal concentration for various polyurethane foam

To illustrate this example, the calculation of the maximal mass loss to reach the incapacitation or the lethality in specific scenario representative of a dwelling fire was made: In a room of 20 m3, the maximum mass loss to reach the incapacitation and the lethality of mice are respectively in our case, 540 g (incapacitation) and 740 g (lethality). The maximum mass loss required to pass the cigarette test was evaluated to 123 g (on the basis of a flexible polyurethane foam with an average density of 35 kg/m3 representative of a furniture of dwelling, with an extended carbonisation on 50 mm on both sides from the cigarette, which is the maximal criteria of material burn to fulfil EN 1021). This value is far lower than the 540 g mentioned above. It should be noted that this calculation supposes an homogeneous dilution of smoke in the considered volume, and correspond only to small fires. Additionally, the sedimentation of gases is neglected.

Several studies [xxii] show that the safety risk due to ignition is reached before the safety risk due to toxicity. Thus, the fulfilment of the ignition criterion link to the absence of risk from fire effluents on the toxicity side. Fire safe cigarette are already sold in Canada, in Australia and in some American States [xxvii],[xxviii]. Bands of cellulose or alginate are put into the cigarette paper so that the burning tobacco goes out if not puffed on. These "self-extinguishing" cigarettes do not generate sufficient heat to self maintain combustion and cause ignition of adjacent furniture. By introducing self-extinguishing cigarettes, the cigarette fire scenario could thus become inappropriate to assess the risk of toxicity from fire effluents.

HEALTH RISK IN UPHOLSTERED FURNITURE

This paragraph gives keys (tools and information sources) available for assessing the global health risk linked to intrinsic toxicity of flame retardant introduced in matrix (fabrics, foam, interliner). Assessment of possible risks to consumers (through normal furniture use: skin contact, inhalation, other routes), to the environment (through final disposal of furniture at the end of life), and risks of emission of toxic gases during recycling were examined.

The REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulations [xx] is based on Globally Harmonised System of Classification and Labelling of Chemicals (GHS) and Organisation for Economic Co-operation and Development (OECD)protocols. GHS [xxiii] provides a harmonised basis for globally uniform physical, environmental and health and safety information on hazardous chemical substances (Directives 67/548/CEE and 1999/45/CE abrogated). The toxic risk of the substance is evaluated by mean of protocols recognized for the evaluation of substances during life cycle (OECD) [xix]. Within the framework of the evaluation of the toxic risk of the substance during life cycle, the OECD recommends well known and established methods for the evaluation of the toxic risks of the substances during the life cycle of the product. The scenarios of toxic emission are defined on OECD Internet site (http://www.oecd.org/ehs/). Documents of OECD defining scenarios of emission are designed to provide information on models employed and evaluations of release of chemicals in environment. REACH is the regulatory tool to assess the global health risk using GHS and Scenario from OECD, which give guidance on the conducting of toxicological tests .

Note : REACH does not consider flame retardants only: the association [matrix-flame retardant] has to comply to its requirements too.

CONCLUSIONS AND PERSPECTIVES

The main conclusions of this study are that there is no risk of health and safety with flame retardant agent introduced in upholstered furniture if:

1 The flame retardant agent itself, and the flame retardant agent introduced in the matrix (final product) are both compliant with REACH requirements (health). This includes considerations about the absence of risk due to the substances, about the process (fixation mode of the agent), about the ways of contamination (skin contact, exposition by inhalation) and environmental impact with incineration (as a normal step in the life-cycle of the products).

2 The upholstered furniture is compliant with fire reaction scenarios of EN1021-1 and EN 1021-2 (safety requirements). In this case, the maximum destructed zone compatible with the requirements leads to a maximum mass loss that produces an amount of toxic gases not sufficient to induce a toxic risk, whether the product is flame-retarded or not.

However, introduction of the forthcoming "self extinguishing" cigarettes discussed in last European Mandate M/425 relative to the safety requirement for cigarettes, could entail the cigarette fire scenario to become inappropriate to assess the risk of toxicity. Our study was limited to upholstered furniture, and so to flame retardant agents used in this field.

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