FIRE SAFE EUROPE

Position Paper

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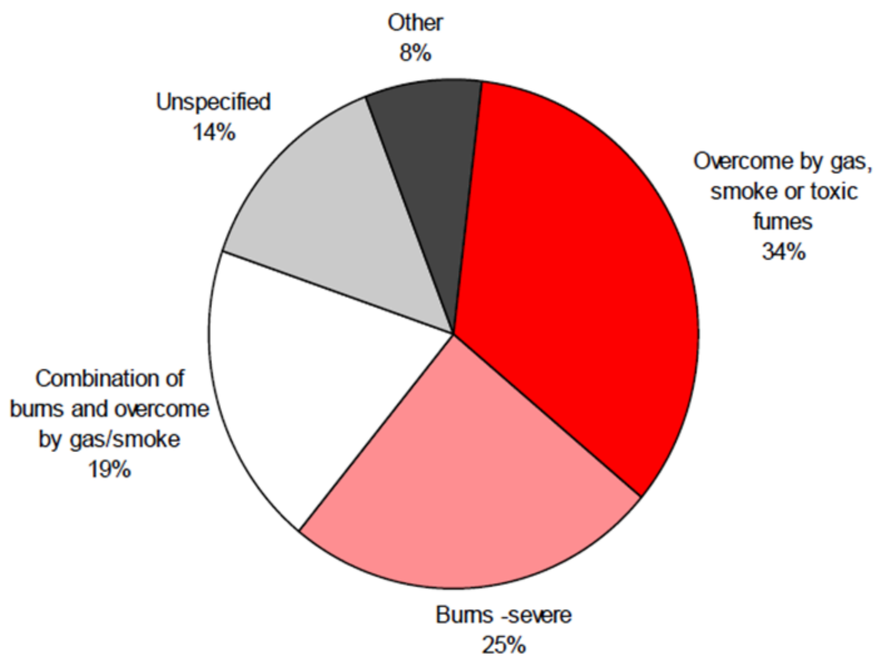
Smoke Toxicity

Inhalation of toxic smoke is the leading cause of death in case of fire and also a major contributor to fire related injuries. Yet fire smoke toxicity is not considered in the European regulatory framework for buildings. ISO has developed both test and calculation methods for smoke toxicity so the methodology is now available to tackle this issue. There are no longer any excuses for ignoring smoke toxicity in fires in EU regulations.

Smoke is the issue in fire safety

According to the fire statistics for Great Britain 2011-2012[1]: being overcome by gas, smoke or toxic fumes was partly or wholly the cause of death in over half (53%) of all fire fatalities.

Figure 1: Fatalities by cause, Great Britain, 2011/12p



'Other' includes head/chest or other physical injuries, fractures, shock or other medical conditions

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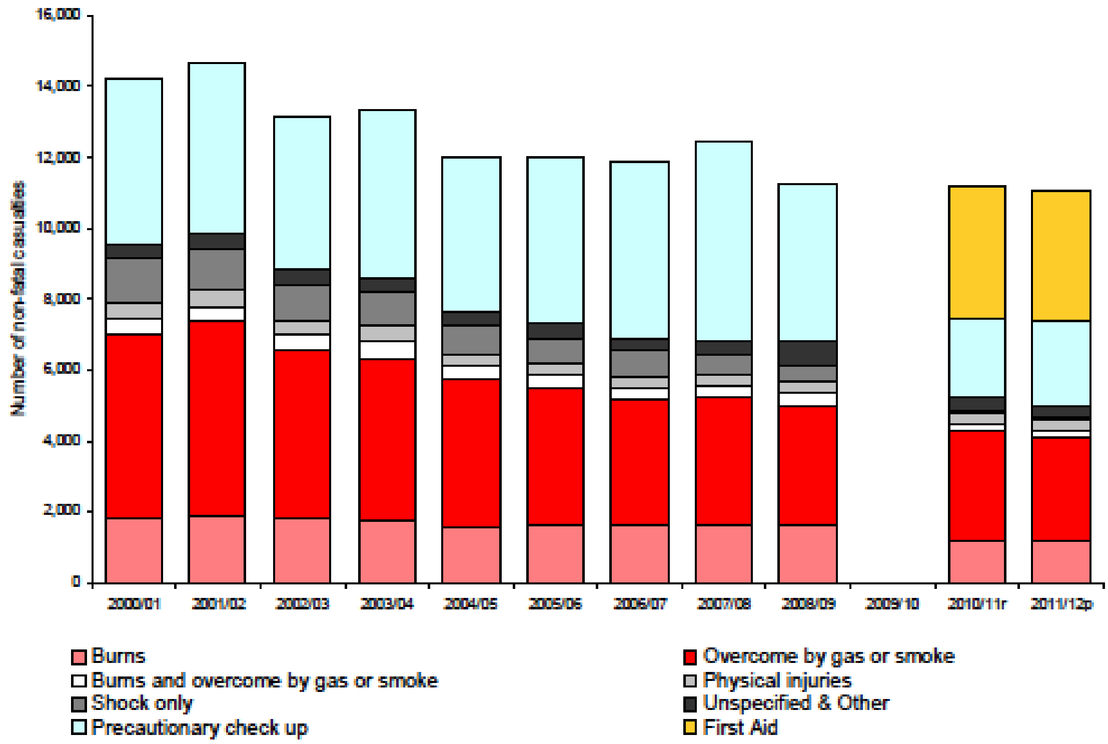
[1] Department for local communities and government, Fire Statistics Great Britain 2011 – 2012, December 2012.

Smoke is also the major contributor to non-fatal injuries with 26% of these being from suffering from the effects of gas and smoke.

<u>Figure 2</u>: Non-fatal casualties from fires (excluding firefighter casualties) by nature of injury[1], Great Britain, 2000/01-2011/12



[1] There was no category for 'first aid' prior to the introduction of the new Incident Recording System (see explanatory note 3)

2009/10 figure was not shown due to incomplete record from one fire and rescue authority

p=provisional; r= revised

Smoke hazard

Smoke is a gaseous effluent consisting of solid particles, liquid droplets and heated gases. Every combustion reaction produces effluent that is toxic and in sufficiently high concentrations may present hazardous conditions to exposed humans. Short term hazards are impaired vision due to smoke obscuration and eye irritation, irritation of the upper and/or lower respiratory tracts and narcosis due to the inhalation of asphyxiant gases. These effects, often occurring simultaneously in a fire, contribute to loss of mental acuity and motor coordination, disorientation, panic and eventually physical incapacity.

The resulting delay or prevention of escape may lead to subsequent injury or death from further inhalation of effluent gases and/or the suffering of thermal burns. In the longer term due to the inhalation of toxic gases survivors from a fire also may experience post exposure trauma such as pulmonary (lung) complications that can lead to delayed death."[2]

The composition of the smoke depends primarily on the fire conditions (i.e. temperature and availability of oxygen) and the chemical composition of the fuel. The fire conditions changes as the fire develops. There are three phases to consider.

- The initial smouldering phase is characterized by a low mass yield of potentially hazardous effluent. Normally due to the low mass yield this phase can be overlooked.
- The second phase is a well-ventilated fire development. The hazard during this phase is due to smoke and the composition of the effluent. Building evacuation is best undertaken during this phase.
- As fires grow, they become ventilation controlled, and in enclosures within buildings rapidly change from well ventilated to under-ventilated. Given sufficient combustible fuel these fires will eventually move to a flashover situation involving the spontaneous ignition of all combustible material within the enclosure. For such fires there will always be a significant yield of carbon monoxide (CO), hydrocarbons and smoke. Experimental data from large-scale fires in enclosures show much higher levels of two of the major asphyxiants, carbon monoxide and hydrogen cyanide (HCN). It is generally accepted that humans will not survive exposure to such a fire.

The major risk with flashover fires is that they will breach the initial enclosure and impact occupants over a much wider area of any building. The key need is to effect an evacuation before the building becomes untenable. There are in principal just three hazard scenario to be considered.

Case 1: The initial scenario is with the fire and occupants in the same room. Clearly in case of a fire the occupants would simply leave the room and exit the building.

Case 2: The second scenario is with the occupants in a room unaware of a developing fire in their immediate vicinity (eg. the corridor outside). In this case, a safe evacuation depends on the conditions in the escape path – smoke density and the concentration of irritant and asphyxiant gases.

Case 3: The third scenario is where occupants are in locations throughout the building unaware of the developing fire somewhere else in the building. This scenario is only relevant in large buildings. In this case the first indication of the fire might well be the explosive release of smoke and toxic gases following a flashover in the room of origin. The explosive nature of the fire growth will spread toxic effluent far beyond the immediate fire source. As stated above, it is generally accepted that humans will not survive exposure to such effluent, and safe escape from other parts of the building will depend on how far the toxic gases have spread.

The added complexity is that the building occupants may have impaired mobility due to age, illness or substance abuse. In general, Cases 2 & 3 are considered the most hazardous.

[2] G. Hartzell, "Smoke toxicity test development and use: Historical perspectives relevant to today's issues", 10 —11 November 2008, The Royal Society of London, Interscience Communications.

Reducing smoke hazard

Passive smoke reduction strategies

'Materials incapable of combustion due to a very low organic content, or products failing to contribute to flaming combustion under high radiant heat fluxes in small-scale tests, are unlikely to support the formation of a large growing, hazardous fire in the end-use application. Because of this, they are unlikely to contribute a significant amount of smoke or heat to a rapidly developing fire hazard'.[4]

Reduced fire hazard products offer a lower fire growth, lower yield of smoke and a lower yield of hazardous effluent. These properties are beneficial during the evacuation from the area of fire origin.

Active smoke reduction strategies

In large buildings, especially those with architectural features such as atriums, there are often smoke control system, which in case of fire can clear smoke from a critical area and keep limited areas at a higher pressure preventing smoke from entering. While this is indeed a good solution to control the amount of smoke in escape routes it will not able to protect all occupants from the hazard of toxic smoke. Not all areas will be able to be controlled with such a system and thereby occupants who have not yet made it to a safe area will still be exposed to toxic smoke.

There is also the issue of cost (installation and maintenance) needed to ensure such systems remain reliable for the life of the building.

Euroclass regulation

The European harmonised system for reaction to fire testing and classification, the so-called Euroclass system, is essentially measuring how much a construction product will contribute to a fire in the early stages of a fire development. This means that the scenario being replicated is that of a small fire in a corner of a room with plenty of oxygen available for the combustion process. The system is focused on ignition and flame spread but does also define flaming droplets and smoke obscuration. The Euroclass system does not consider the toxic gases that can be present in the smoke.

The Euroclass system ignores fully developed fires. For large buildings this is a significant simplification as the time to flashover is shown to happen as quickly as 3 minutes in smaller rooms. By definition a fully developed under ventilated fire exhibits a high yield of smoke and hazardous effluents. So for fires in large buildings the smoke produced by a fully developed fire in one part of the building could impede evacuation from the rest of the building. The impact of smoke hazard on evacuation is ignored or poorly described within the Euroclass system.

A further issue is the testing and lack of smoke measurement when testing the fire resisting capability of building elements. These are exposed to a fully developed fire according to a defined time temperature curve.

The classification criteria is solely based on the capability of the building elements to maintain their load bearing capacity, integrity and/or insulation. The measurement of smoke is not included in these tests.

This is despite the fact that some building elements such as metal-faced sandwich panels with a combustible core, can release a significant amount of smoke on the unexposed side well before the classification limit for fire resistance is met.[3]

The Euroclass system ignores smoke toxicity because no member state of the European Union presently regulates for smoke toxicity of construction products. Instead regulations focus on attempting to prevent large fires from developing. The basic principle is that by keeping the fire small and by regulating the reaction to fire properties of construction products, the risk to occupants is kept low. While it is recognised that keeping fires small should be part of the general approach, it should not be the only route to ensure life safety. There are examples of fires where people have died in rooms remote from the fire due to invisible but highly toxic gases. By building regulations focusing primarily on ignition and flame spread properties of construction products, this has encouraged the use of products generating fire effluents having inadvertently increased toxic potency.[4]

Improved regulation

'Since hazards from toxic effluent are the main causes of incapacitation and death in fires it may seem sensible to regulate for toxic hazard or toxicity, with respect to both the overall design and performance of the built environment and the individual products used in their structure and contents'[5].

The only possible way to ensure complete fire safety of a building's environment, without the consideration of smoke toxicity, would be to prescribe the use of only non-combustible products. However, prohibiting the use of all combustible products is not viable and not realistic. Instead a system should be implemented where it is possible to quantify the toxic potential of smoke from fires from different construction products in different fire situation. This would make it possible to make a comprehensive fire risk analysis for both existing and new buildings. ISO has developed both test and calculation methods for smoke toxicity so the methodology is now available to tackle this issue. There are no longer any excuses for ignoring smoke toxicity in fires in EU regulations.

Unfortunately, at this point in time, this is not done in Europe and the Euroclass system does not provide any tool for measuring smoke toxicity. However this approach is changing and the EU sponsored TRANSFEU project will result in new regulations for railway rolling stock including a consideration of all hazards associated with fire, including also smoke toxicity. Further work is in progress to analyse and characterise the effluent from intermediate scale product classification tests. Such initiatives must be supported.

[3] Miroslav Smolka & Y Surrenbroek, "Smoke and heat emissions as measures for interaction of tested elements with test environment in fire resistance testing", Interflam 2013.
[4] A. Stec, "Influence of Fire Retardants on Fire Toxicity", 243rd National Meeting & Exposition of the American Chemical Society (ACS)
[5] D. Purser, "Physiological effects of combustion products; Hazards of combustion products", 10 —11 November 2008, The Royal Society of London, Interscience Communications.