



Fire Toxicity of Building Products

Presented by:-

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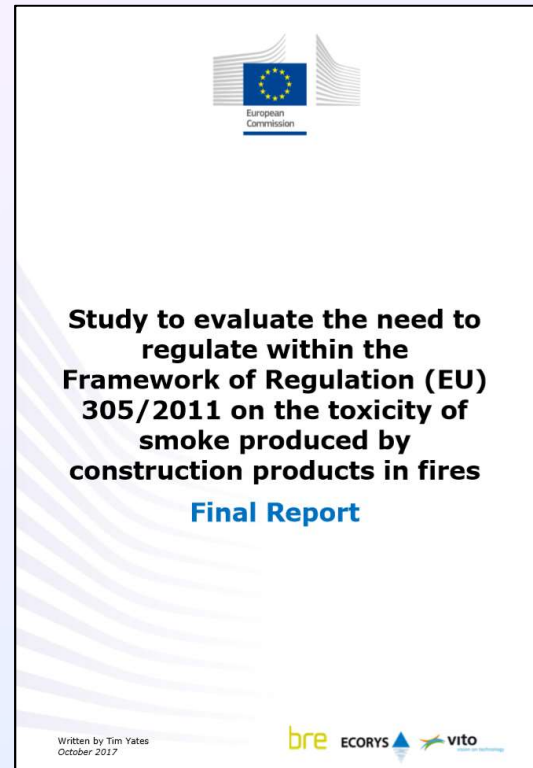


Modern Methods of Construction and Fire Safety

- Fire smoke is the biggest killer in fires, yet outside mass transport, it is completely unregulated.
- Research focuses on preventing ignition and fire growth, shifting the focus of the fire safety towards reducing peak heat release rates.
- Widespread use of combustible materials increases growth and severity of fires. They also produce higher concentrations of toxicants.
- Plastics has led to an increased dependence on flame retardants.



Fire Toxicity Regulation in Construction Products



9. The potential dangers of smoke in general, including toxic smoke, leaking into or being generated in areas that are considered to be safe zones and / or escape routes need to be considered in new or amended existing regulations.



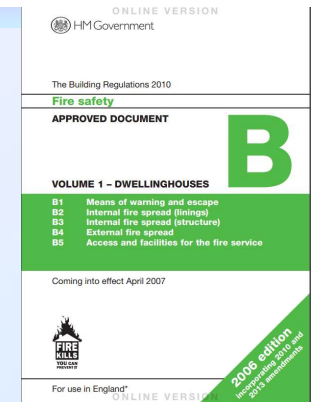
UK Fire “Regulations” Approved Document B

The Approved Documents are intended to provide guidance for some of the more common building situations. However, there may well be alternative ways of achieving compliance with the requirements.

Thus there is no obligation to adopt any particular solution contained in an Approved Document if you prefer to meet the relevant requirement in some other way.

Means of warning and escape

B1. The building shall be designed and constructed so that there are appropriate provisions for the early warning of fire, and appropriate means of escape in case of fire from the building to a place of safety outside the building capable of being safely and effectively used at all material times.





Toxic product yields in fires

Depend upon:

1. **Ventilation** (fire scenarios/conditions)

- Flaming/non-flaming, ventilation, temperature

2. **Chemical composition of material** (fuel type)

- C, N, Cl, Br, S, (Fire Retardants)
- Organic composition (Aliphatic or aromatic)



Fire Toxicity: Fuel

Building Materials will have huge influence on released fire gases: escape and survivability

Rigid Polyurethane foam (Contains Nitrogen)



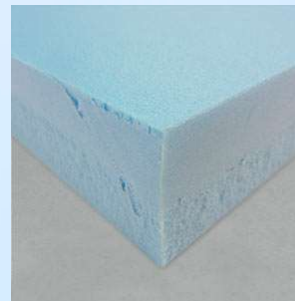
Polyisocyanurate Foam (Contains Nitrogen)



Phenolic Foam (Contains Oxygen, Nitrogen)



Expanded Polystyrene (Contains Benzene)



Stone Wool





Harmful Effects: Acute Toxicity

- **Smoke obscuration** - impaired vision due to the smoke and particulates presence
- **Irritant gases**
 - HCl, HBr, HF, NO_x, Acrolein, Formaldehyde
 - Depending upon the concentration cause painful stimulation of the eyes, nose, mouth, throat and lungs with some hypoxia due to breathing difficulties which impedes escape and can be fatal
 - Depending upon dose inhaled cause lung inflammation and oedema which may be fatal usually some hours after exposure



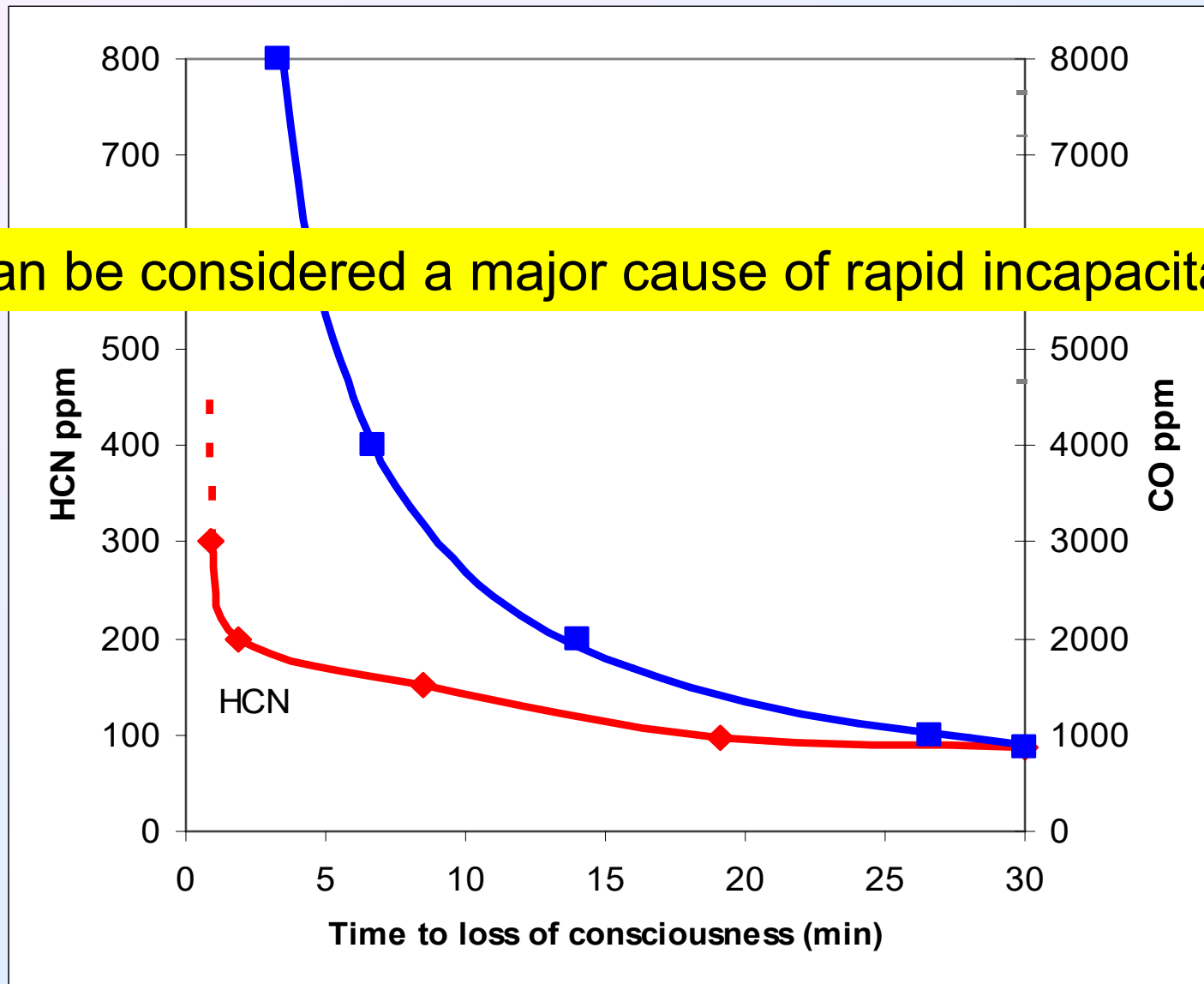
Harmful Effects: Acute Toxicity

- **Asphyxiant gases**
 - CO, HCN, Low Oxygen
 - Cause confusion and loss of consciousness followed by death from asphyxia when a sufficient dose has been inhaled
 - For asphyxiants effects depend upon an exposure dose. There is little effect until a threshold dose is inhaled after which confusion occurs rapidly followed by collapse



Asphyxiants: CO and HCN

HCN can be considered a major cause of rapid incapacitation.





Estimation of fire toxicity- ISO 13344

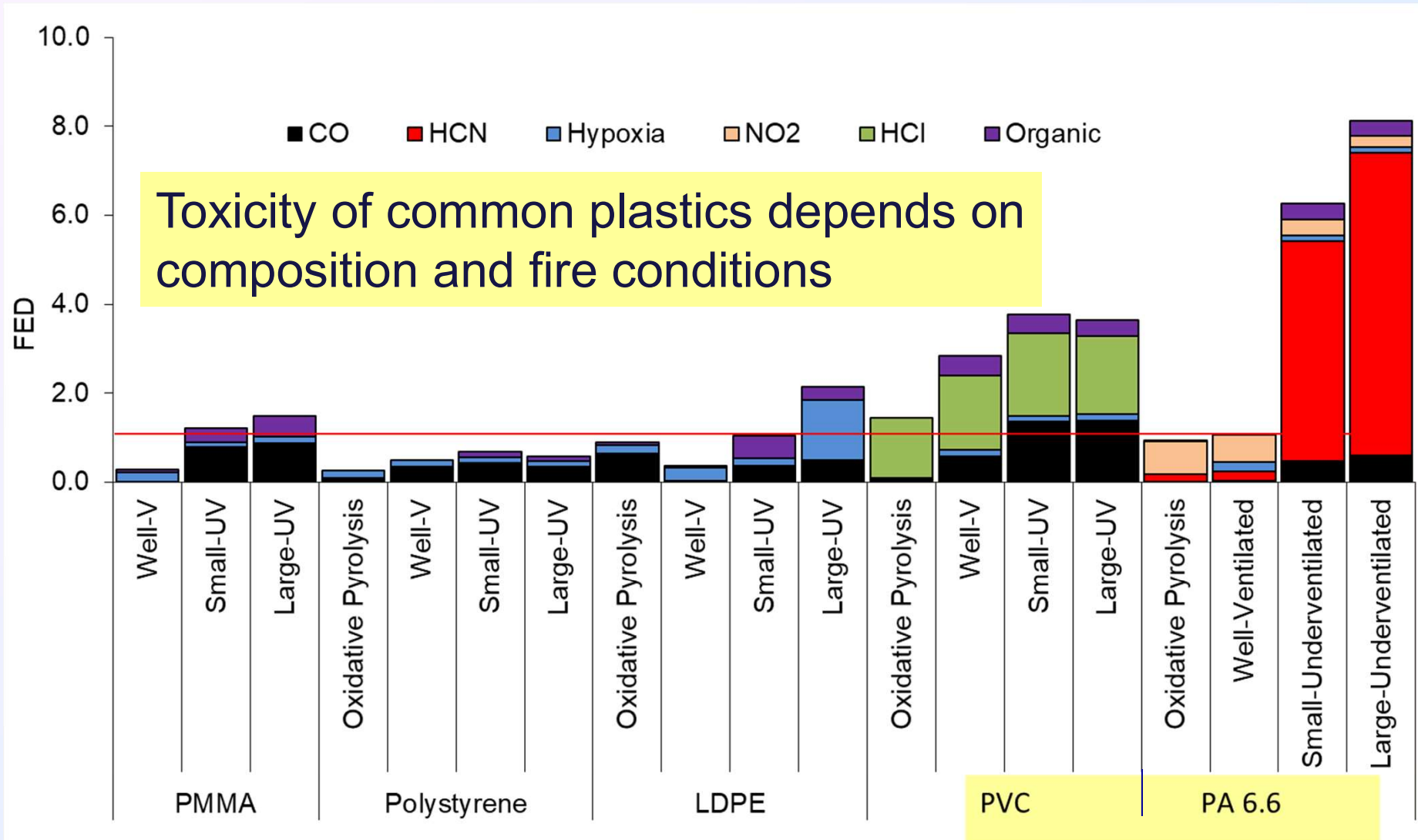
FED - the fraction of a lethal dose (for 50% of the population)
When FED = 1 then 50% of the population will die.

$$FED = \frac{m[CO]}{[CO_2] - b} + \frac{21 - [O_2]}{21 - LC_{50,O_2}} + \frac{[HCN]}{LC_{50,HCN}} + \frac{[HCl]}{LC_{50,HCl}} + \frac{[HBr]}{LC_{50,HBr}} + \frac{[SO_2]}{LC_{50,SO_2}} \dots$$

$$FED = \frac{m[CO]}{[CO_2] - b} + \frac{21 - [O_2]}{(21 - 5,4)\%} + \frac{[HCN]}{150} + \frac{[HCl]}{3700} + \frac{[HBr]}{3000}$$



Fire Toxicity of Common Polymers



Hull, T.R., Stec, A.A., Lebek, K., Price, D. Factors affecting the combustion toxicity of polymeric materials(2007) Polymer Degradation and Stability, 92 (12), pp. 2239-2246



Fire Toxicity of Insulation Materials

Polyisocyanurate Foam (PIR)

Polyurethane Foam (PUR)

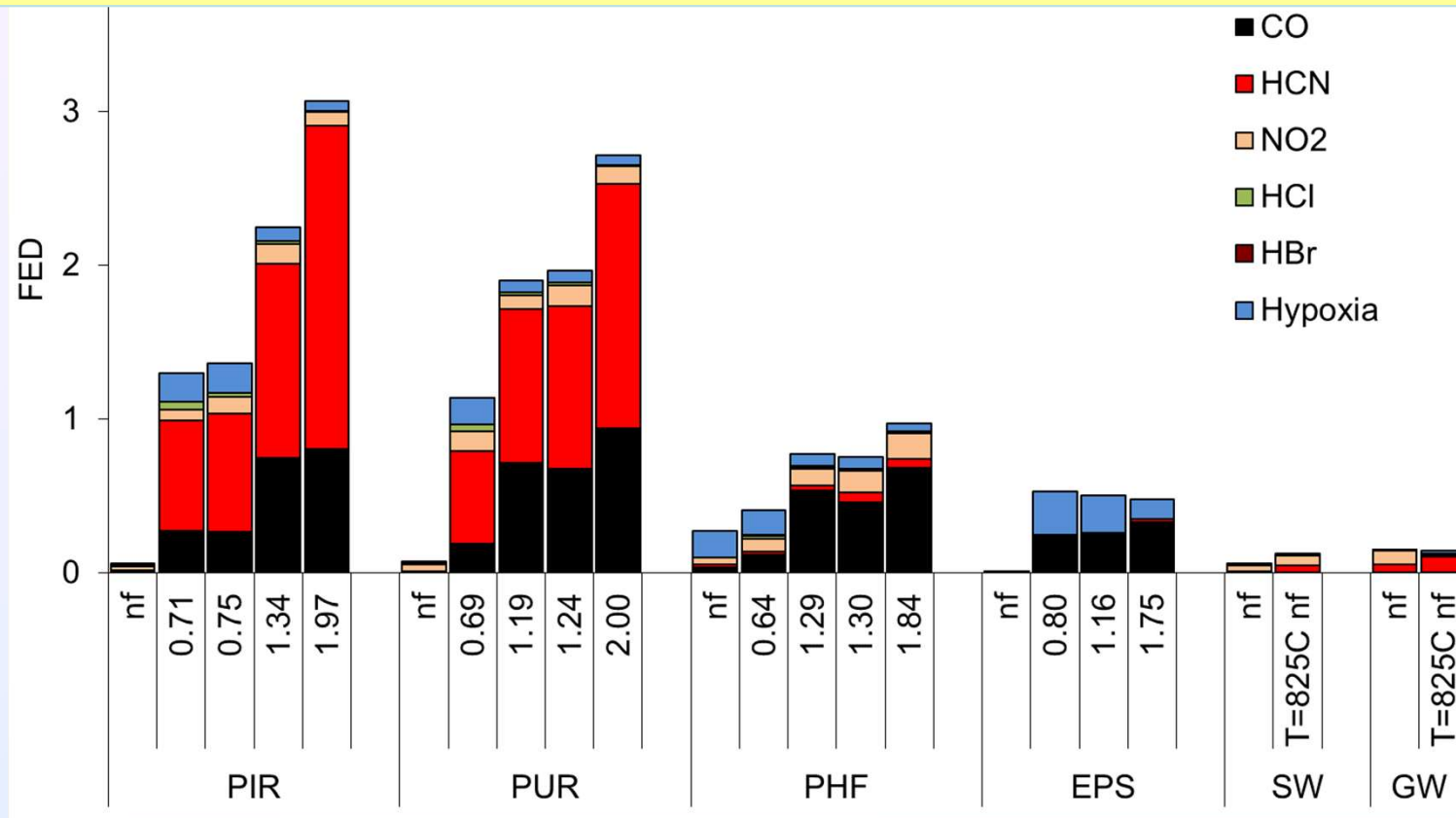
Expanded Polystyrene Foam (EPS),

Phenolic Foam (PhF)

Stone Wool (SW)

Glass Wool (GW)

Different insulation materials have very different fire toxicities!

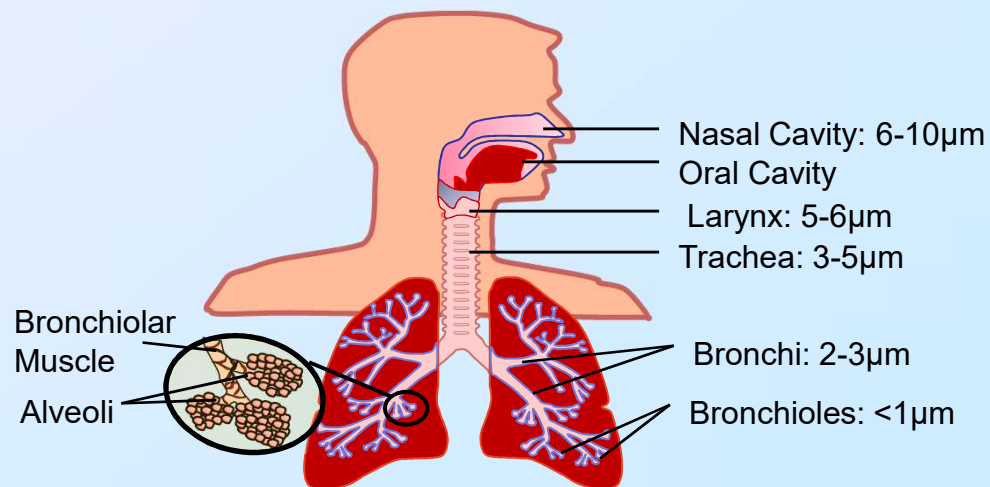


A.A. Stec and T.R. Hull, *Assessment of The Fire Toxicity of Building Insulation Materials*, Energy and Buildings, 43, pp. 498-506, 2011.



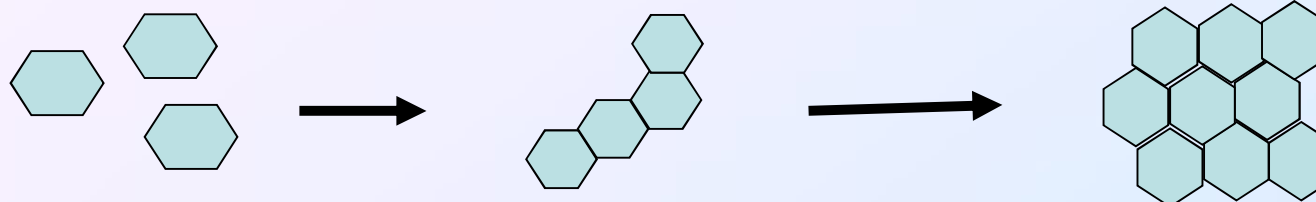
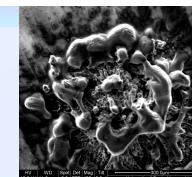
Chronic Toxicity


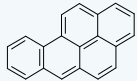
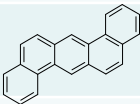
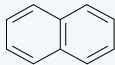
- Particulates
- Polycyclic aromatic hydrocarbons
- Polychlorinated and polybrominated dioxins and furans
- Flame Retardants (organophosphates)
- Metals





Particles: Toxic smoke products

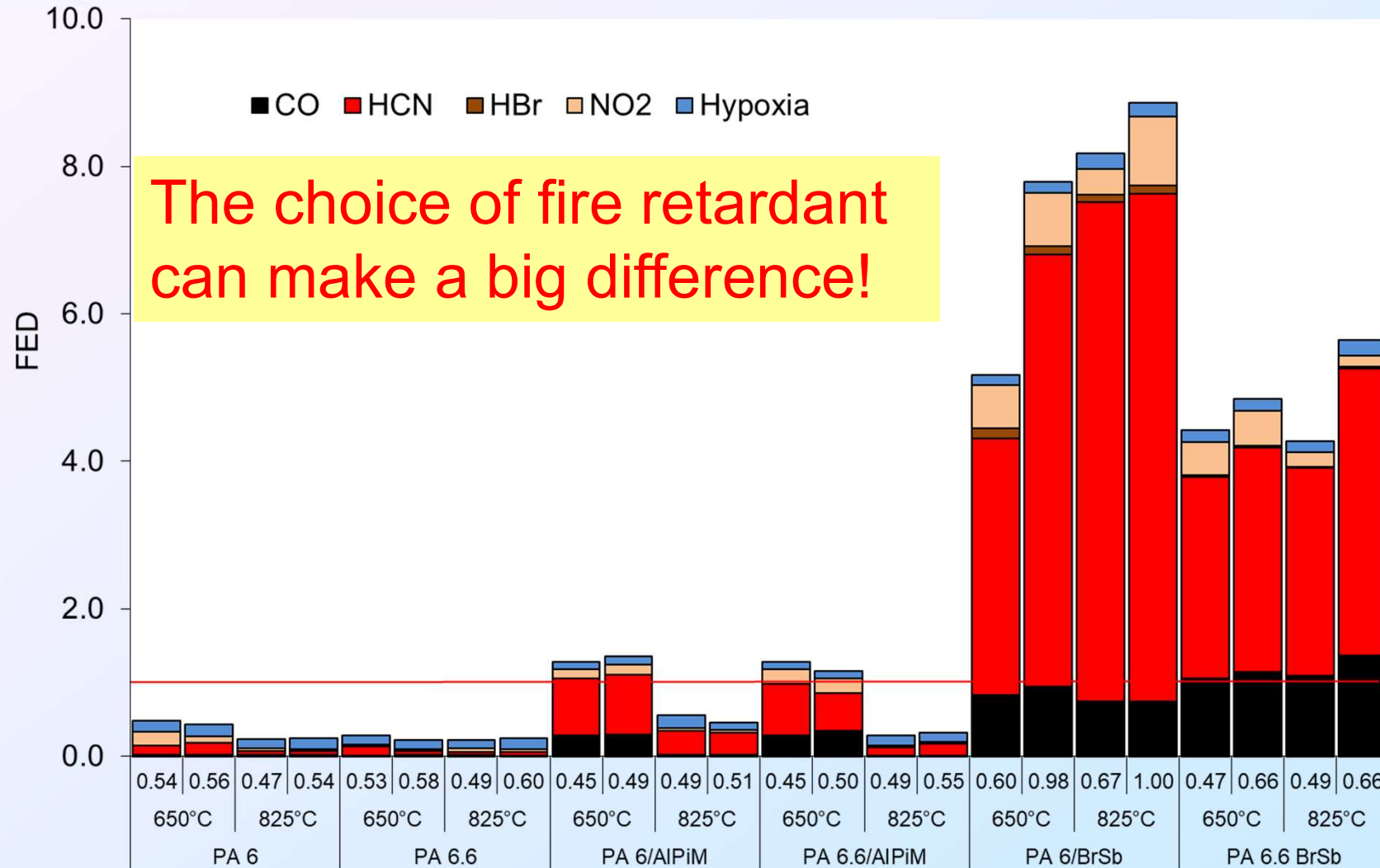


Cyclic and Polycyclic Aromatic Hydrocarbons	Structure	IARC
Benzene		1 (2012)
Benzo[a]pyrene		1 (2012)
Dibenzo[ah]anthracene		2A (2010)
Naphthalene		2B (2002)

Group	General description	Bases of evaluation
1	Carcinogenic to humans	Sufficient evidence of carcinogenicity in humans.
2A	Probably carcinogenic to humans	Limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals.
2B	Possibly carcinogenic to humans	Limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals.



Effect of Fire Retardants on Polyamides (20 g/m³)



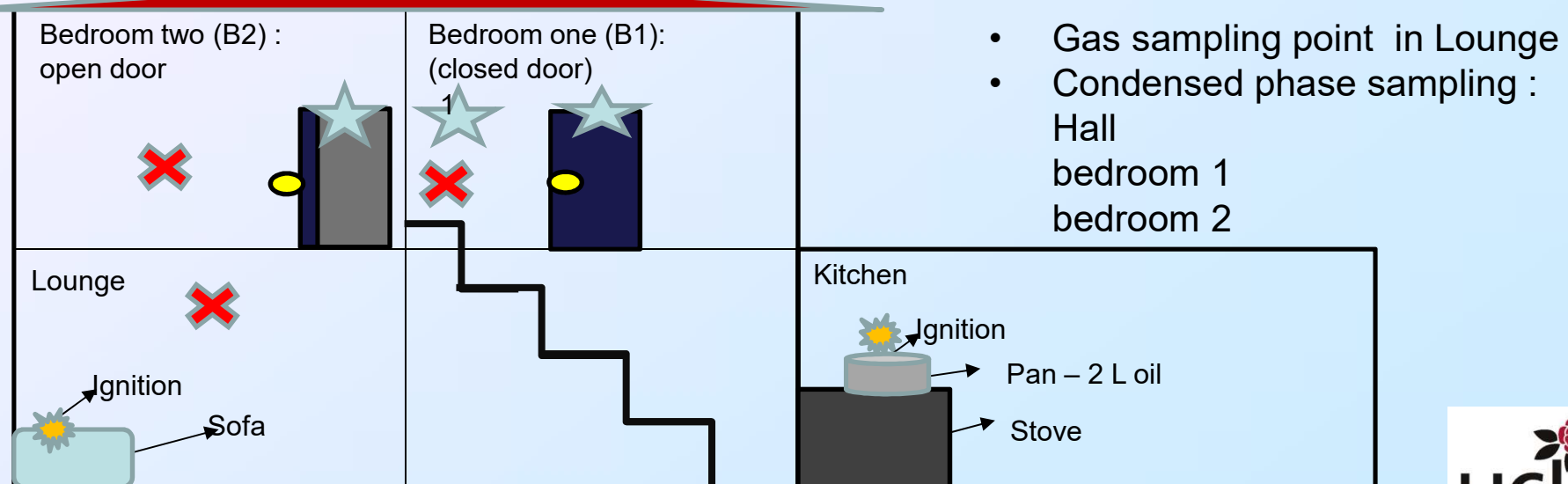
S. Molyneux, A.A Stec, T Richard Hull, *The effect of gas phase flame retardants on fire effluent toxicity*, Polymer Degradation and Stability 106, 36-46, (2014).



PAHs and OPFRs Release



- New sofas, meeting the UK furniture flammability regulations, were used either solely or with additional furnishings
- The ventilation conditions were varied (well- to under-ventilated).
- OPFRs were detected in the gas phase for all tests with sofa and fully furnished room.
- TCPP, TCP, TEP, TPHP, TBEP were detected in both the gaseous effluents and condensed particulate samples.





Large Scale Fire Tests



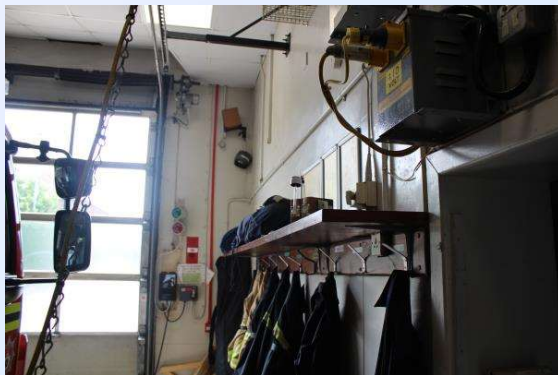
There has been a total limit for **TCEP** as a flame retardant in textiles in EN71-9 for toys and accessible components of toys intended for children under 3 years of age.

TCEP is also listed as a substance of very high concern and should be banned in Europe under Annex XIV of reach by the sunset date of 21st August 2015.

ECHA has recommended that a restriction proposal is prepared on the flame retardants **TCEP, TCPP and TDCP** in flexible polyurethane (PUR) foams in childcare articles and residential upholstered furniture.

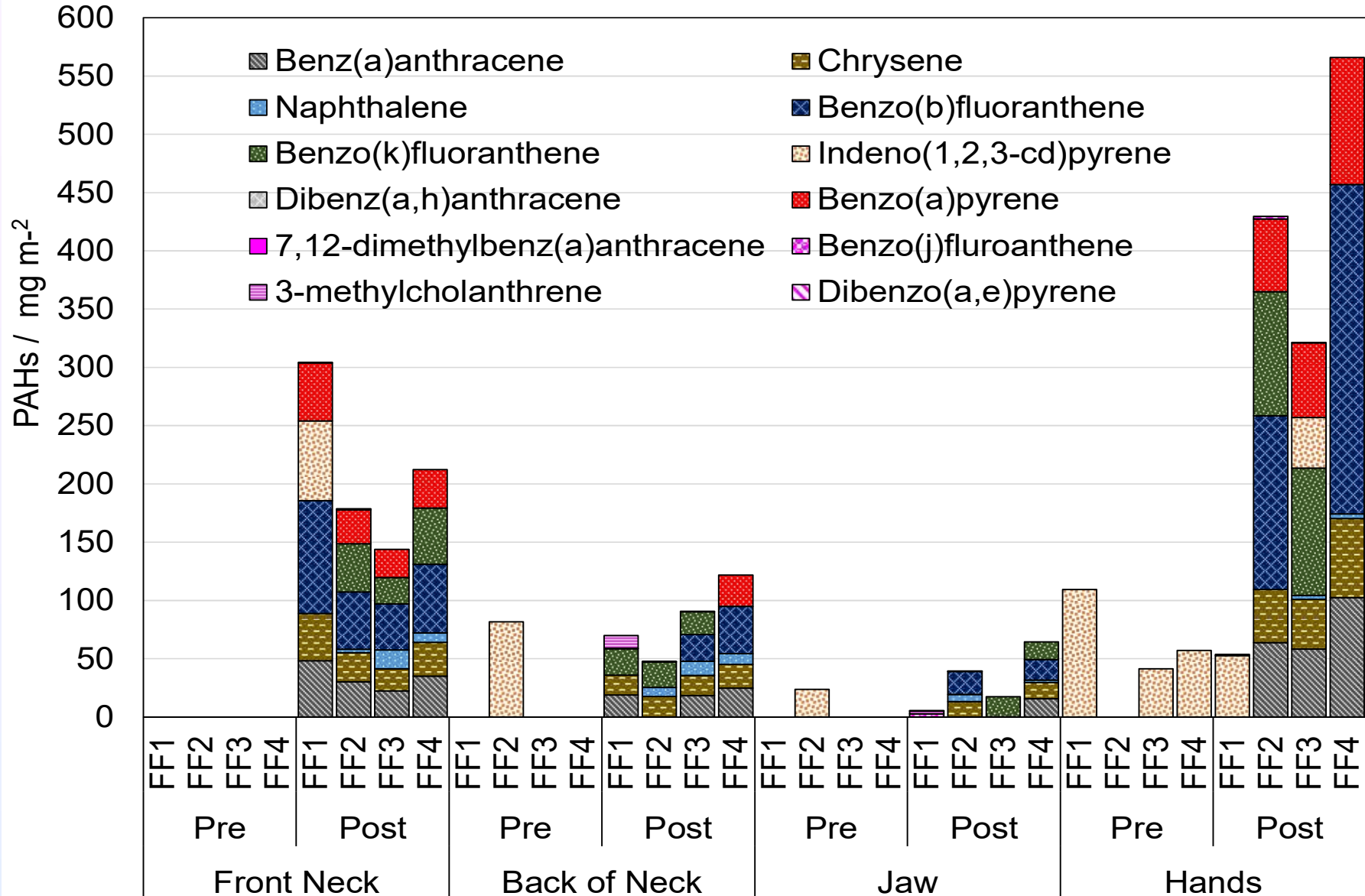


Firefighters Exposure and (Post)contamination???



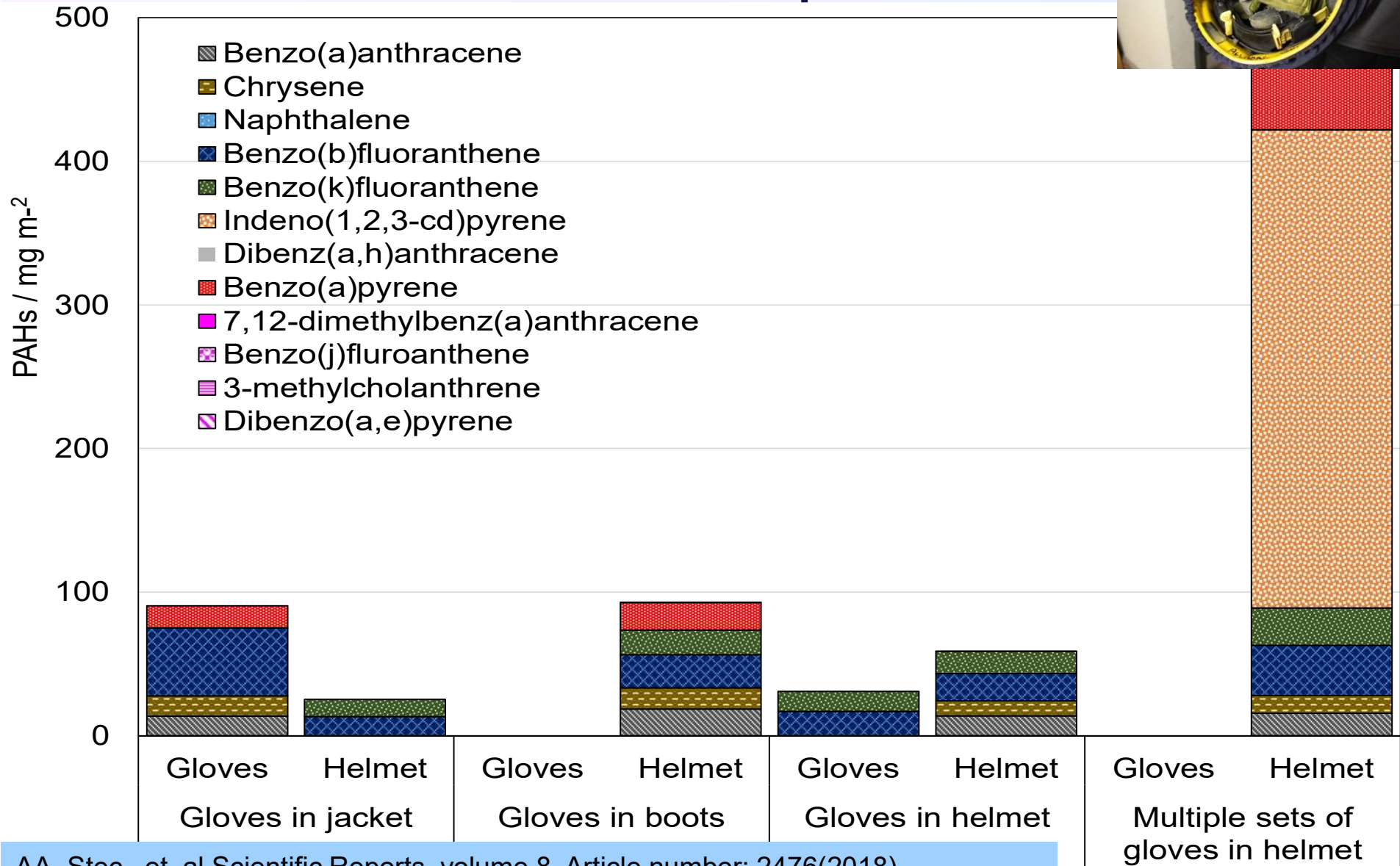


Firefighters and routes of exposure: Inhalation or Absorption or both?





Firefighters and routes of exposure: Inhalation or Absorption





Conclusions

- Fire toxicity is the biggest cause of death and injury in fires, but is unregulated.
- Material composition has a big effect on fire toxicity.
- CO is a good indicator of incomplete combustion however, it is not always the major and only toxicant contributing to the death.
- Yields of CO and HCN increase dramatically as the fire grows.
- It is found that there is no fire safety advantage of adding halogenated flame retardants – the reduction in fire growth rate is compensated by an increase in fire toxicity.



Conclusions

- The emphasis on insulation over fire safety has left the Building Regulations behind modern building practice.
- Assessing fire toxicity is easy, and an essential component of fire hazard assessment.



Consultation: Approved Document B

<https://www.gov.uk/government/consultations/technical-review-of-approved-document-b-of-the-building-regulations-a-call-for-evidence>

DEADLINE TOMORROW

Open consultation

Technical review of Approved Document B of the building regulations: a call for evidence

Published 18 December 2018

From: [Ministry of Housing, Communities & Local Government](#)

Summary

Call for evidence seeking views on the future technical guidance contained within Approved Document B (fire safety).

This consultation closes at
11:45pm on 1 March 2019

Area of fire safety	ADB area
General	<i>Scope of fire safety</i>
	<i>Purpose Groups</i>
	<i>Specialised housing and care homes</i>
	<i>Trigger heights and thresholds</i>
	<i>Age Distribution</i>
	<i>Smoke and Toxicity</i>
	<i>Construction Technologies and Designs</i>
	<i>Construction details</i>
	<i>Other issues - please specify theme</i>



ANY QUESTIONS?

Flame retardants in UK furniture increase smoke toxicity more than they reduce fire growth rate
Chemosphere, 2018, 196:429-439



Fire behaviour of modern façade materials – Understanding the Grenfell Tower fire
McKenna *et al.* Journal of Hazardous Materials, 2019, 368:115-123



Fire Performance of Sandwich Panels
Crew *et al.* Fire Technology, 2018, 54(4): 819–852
<https://www.youtube.com/watch?v=AimeolqReEs>
(youtube: Sandwich Panel Fire Tests (*if*))

