Can sustainability be compatible with fire safety?

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Introduction

- Climate Emergency
- Chemistry and Fire

…but all is not quite as it seems

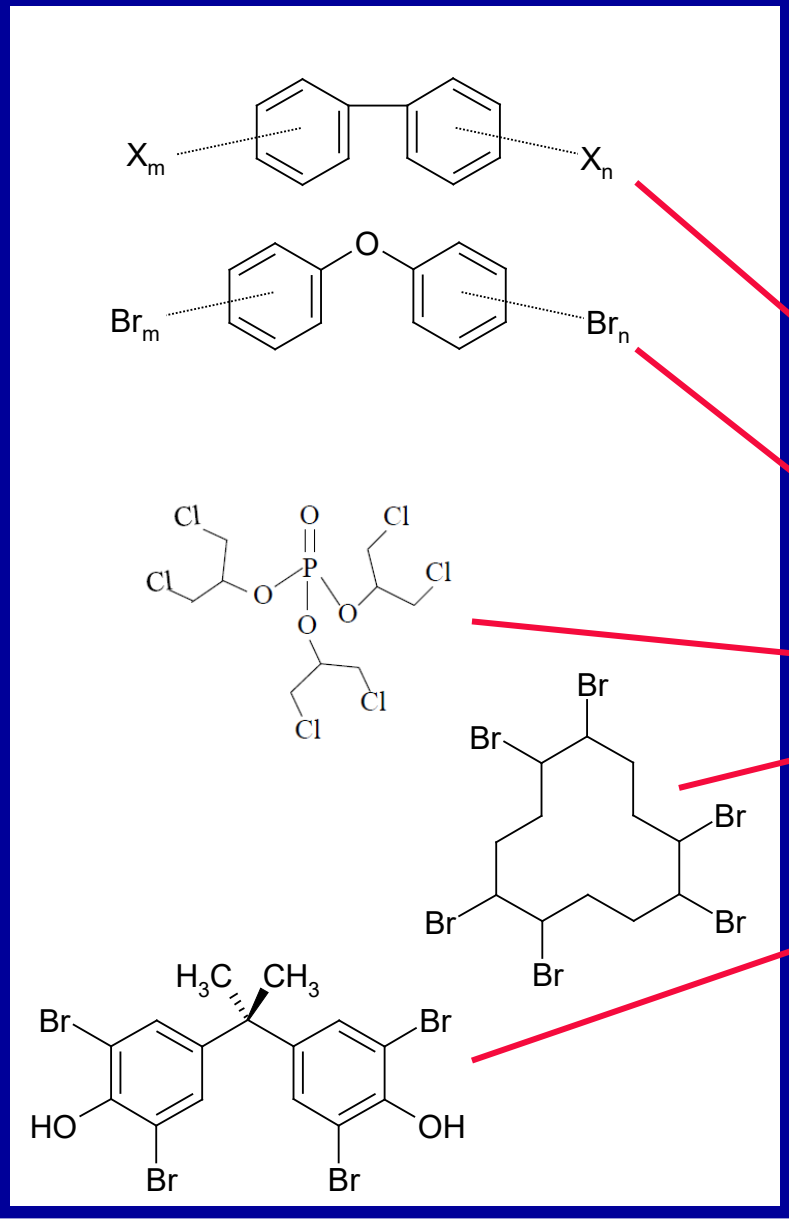
Risks and Benefits of Fire Retardants

- Fire Retardants introduced following widespread availability of cheap plastics
- Fire retardants only used where regulators specify level of flammability resistance (transport, E&E, construction, and furniture (UK & Ireland only))
- Fire retardants allow cheaper plastics to be used in high risk situations
- Fire retardants are optimised to pass regulatory tests, and don’t always make the product safer
- Certain fire retardants make smoke much more toxic

Potential toxic hazards from fire retardants

1. Fire retardant is toxic when it separates from the polymer during normal use (e.g. certain halogenated flame retardants)
2. Fire retardant (or its decomposition products) are toxic when released during a fire (e.g. certain organophosphates and halogenated dioxins)
3. Fire retardant increases the toxicity of the fire effluent (e.g. more CO or HCN)

Brominated Flame Retardants considered toxic



Name	Abbreviation	Problems	Action
Polychlorobiphenyls	PCB	High toxicity	Banned 1960s
Polybromobiphenyls	PBB	High toxicity (Michigan)	Banned 1970s
Pentabromodiphenylether	PentaBDE	High toxicity	Banned 1990s
Octabromodiphenylether	OctaBDE	High toxicity	Banned 1990s
Decabromodiphenylether	DecaBDE	PBT	Banned in EU (2019)
tris-1,3-dichloropropyl phosphate	TDCPP	Mutagenic, carcinogenic	Banned for high risk applications
Hexabromocyclododecane	HBCD	PBT	Listed by Stockholm Convention
Tetrabromobisphenol A	TBBPA	Persistent and Bioaccumulative. Harmful to aquatic organisms. Often used as comonomer. Potential carcinogen (CA)	Under consideration – NIH

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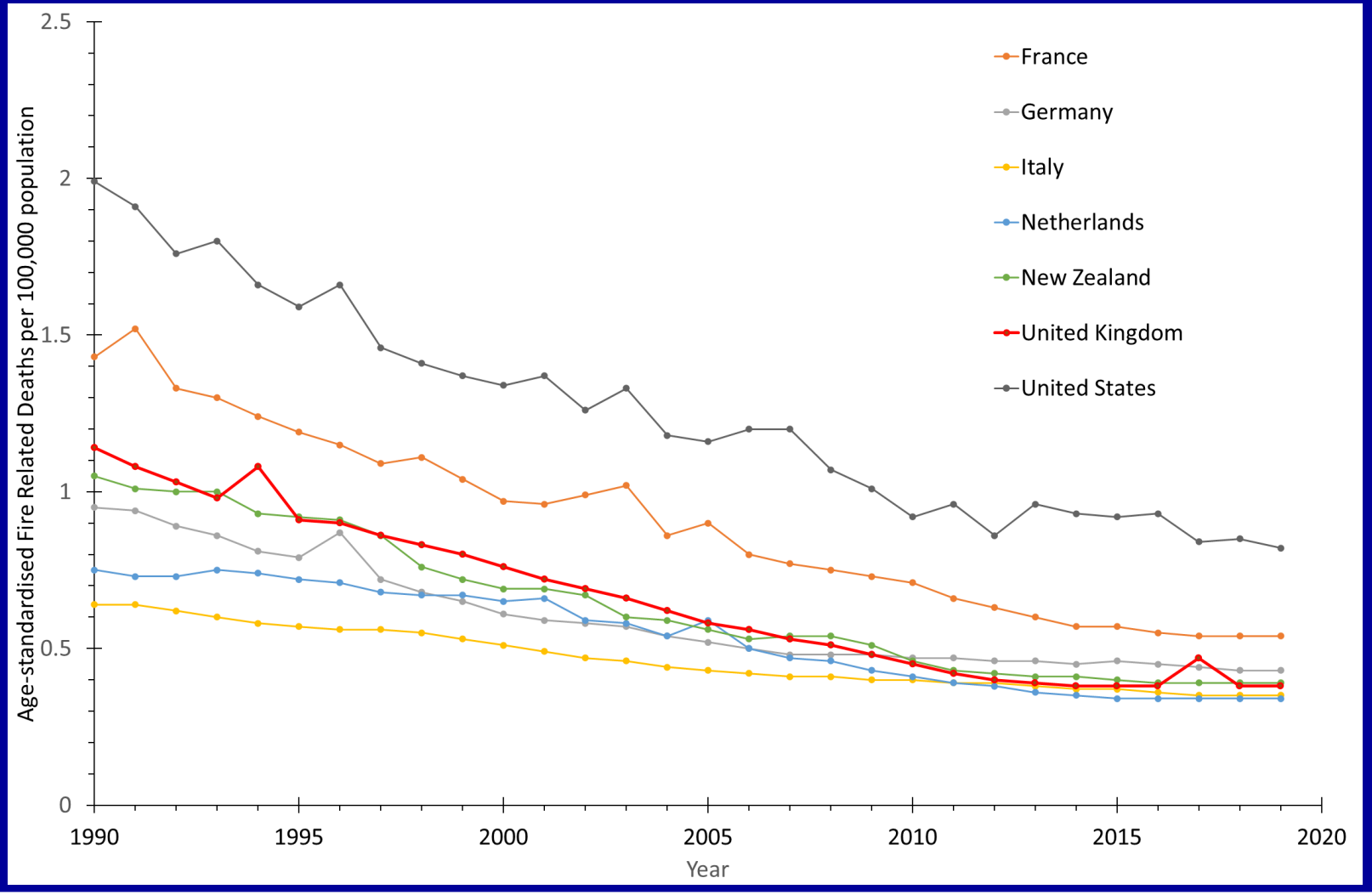
The UK's Fire Safety Paradox

- UK Furniture Flammability Regulations are the most severe in the world.
- In the UK domestic furniture fires are the biggest killers!
- The flame retardants used in furniture appear to increase the yields of CO and HCN.

Fire death rate comparison with other countries



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Various mattresses tested on steel sofa-bed frame

Main Reference:

S. T. McKenna et al, *Flame retardants in UK furniture increase smoke toxicity more than they reduce fire growth rate*, Chemosphere, **196**, 429-439 (2018).

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Sofa-beds tested

Sample ID	Construction
UKFR	Combustion modified flexible polyurethane foam; polyester comfort layer; fire retardant fabric cover (sourced from the UK).
ChFR	Combustion modified flexible polyurethane foam; polyester comfort layer; fire retardant fabric cover (sourced from China).
EUMat	Flexible polyurethane foam; polyester comfort layer; untreated fabric cover (sourced from Europe).
FRfreeCS	Polycotton pad surrounded by woollen comfort layer; technically woven cotton and wool cover. No chemical fire retardant treatments (made in the UK).

Inside the Test Facility.

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The sofa bed burning

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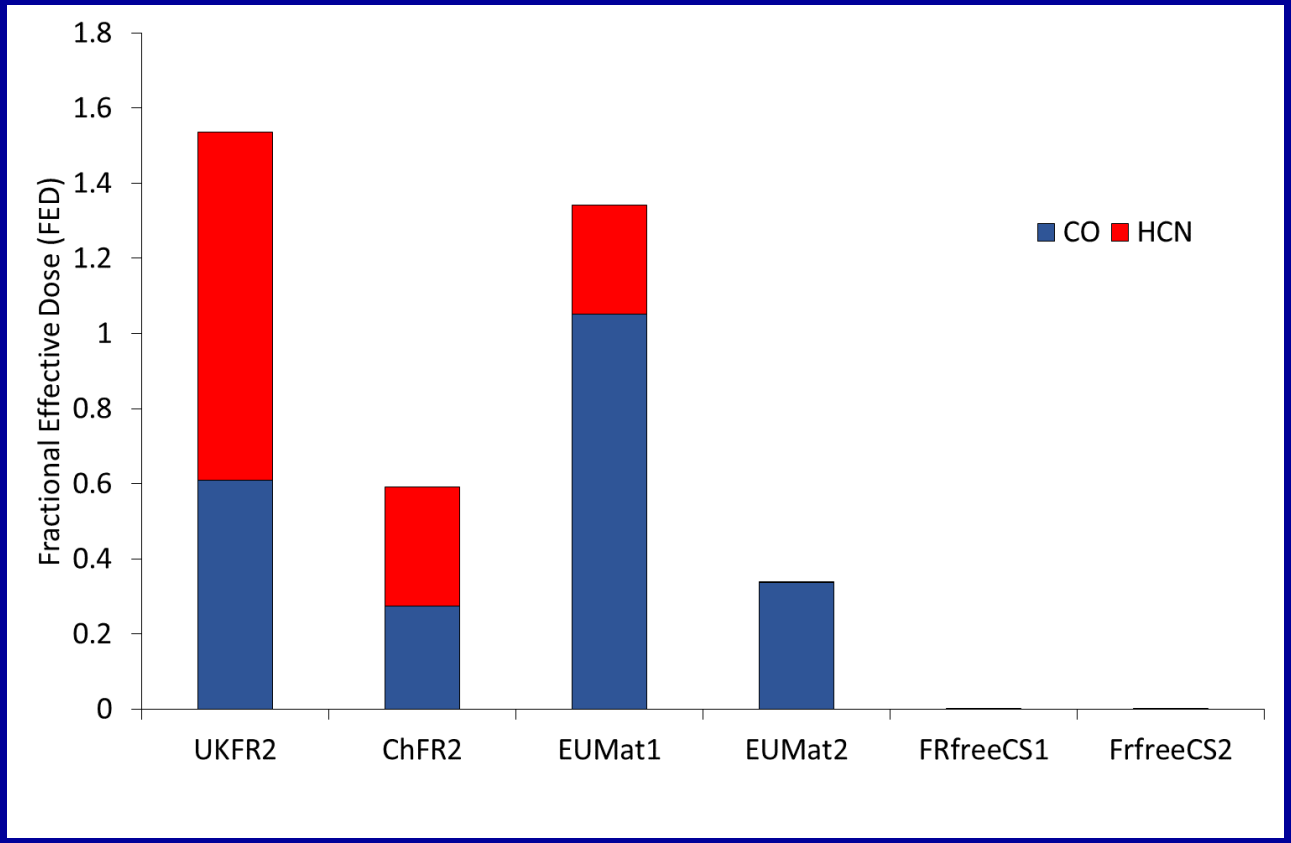
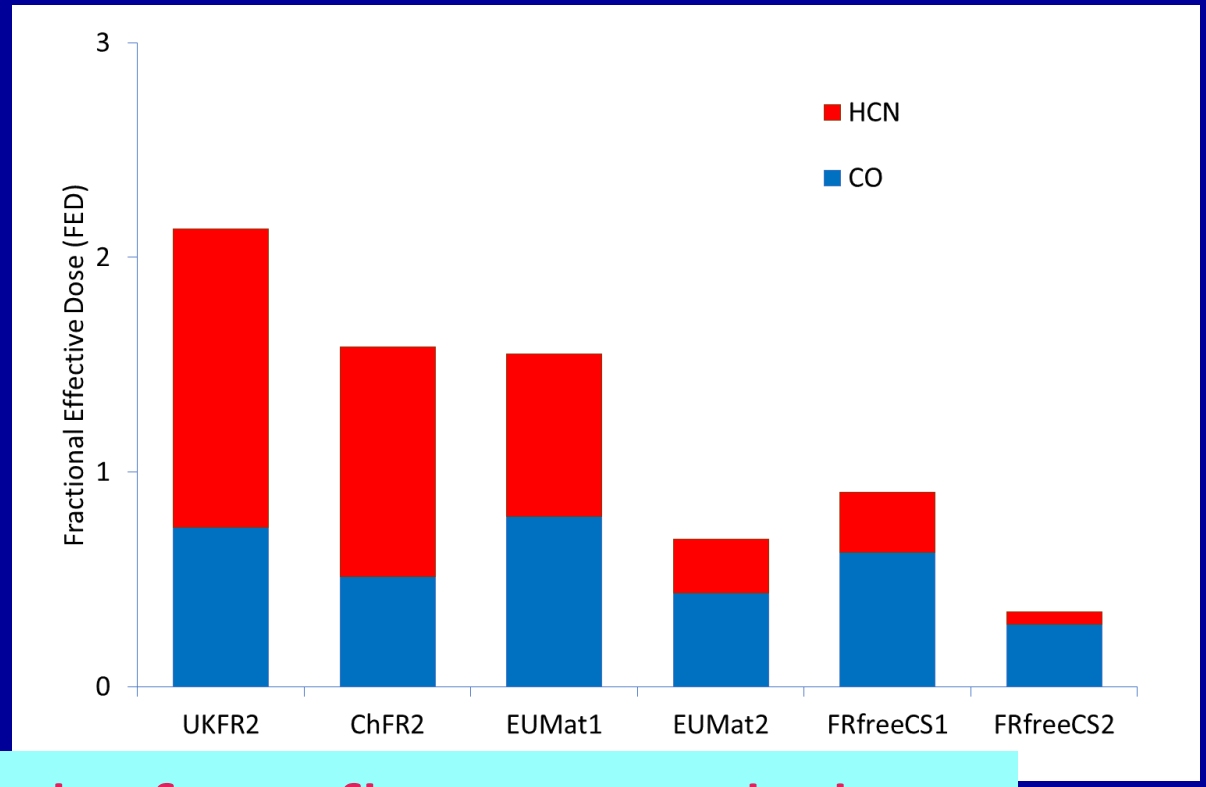
Incapacitation

16.7 min exposure in 500 m^3 (ISO 13571)



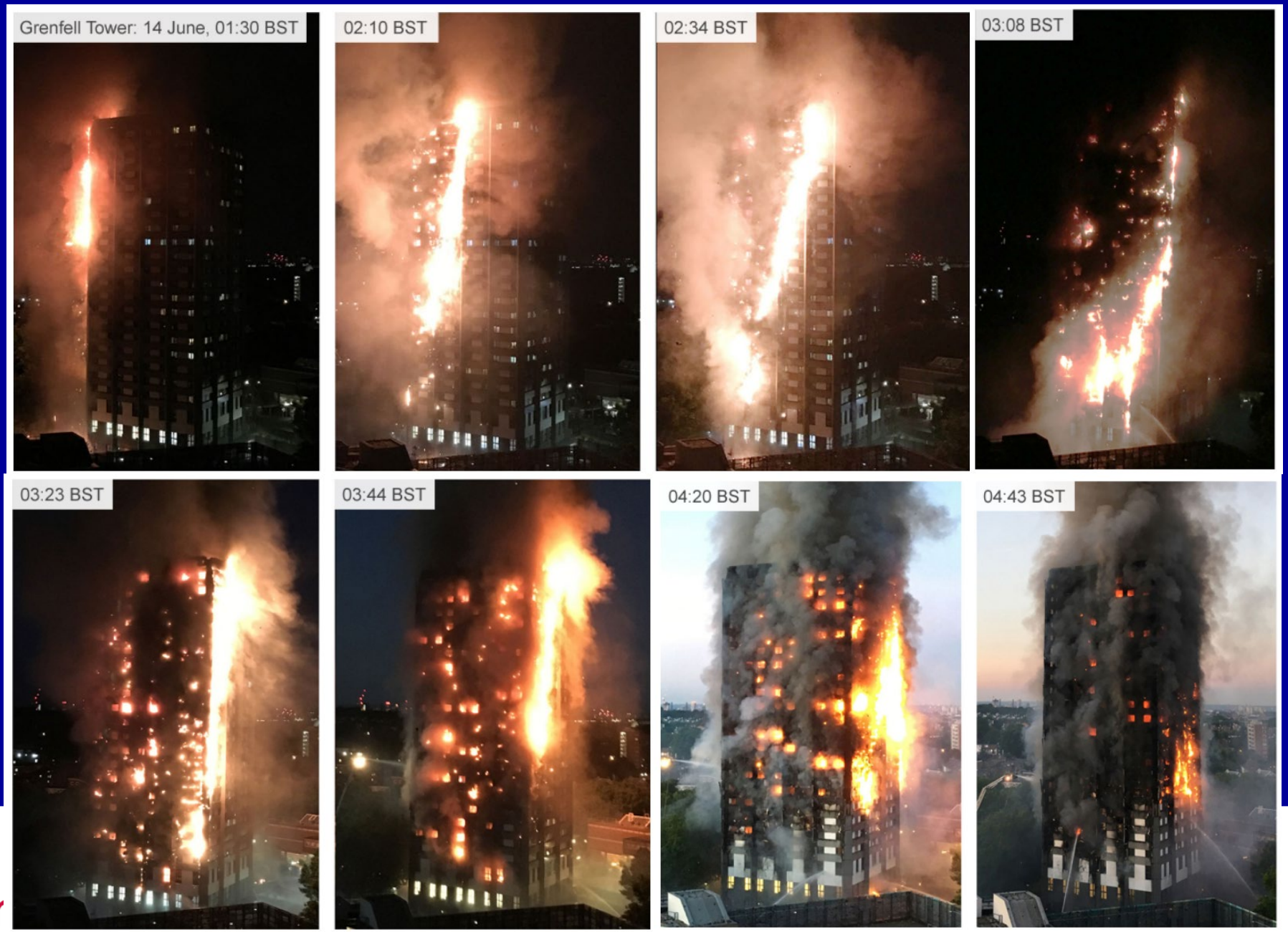
Predicted lethality

30 min exposure in 500 m^3 (ISO 13344)



For the limited range tested, the smoke from flame retarded furniture is more toxic than from non-flame retarded furniture

The Grenfell Tower Fire



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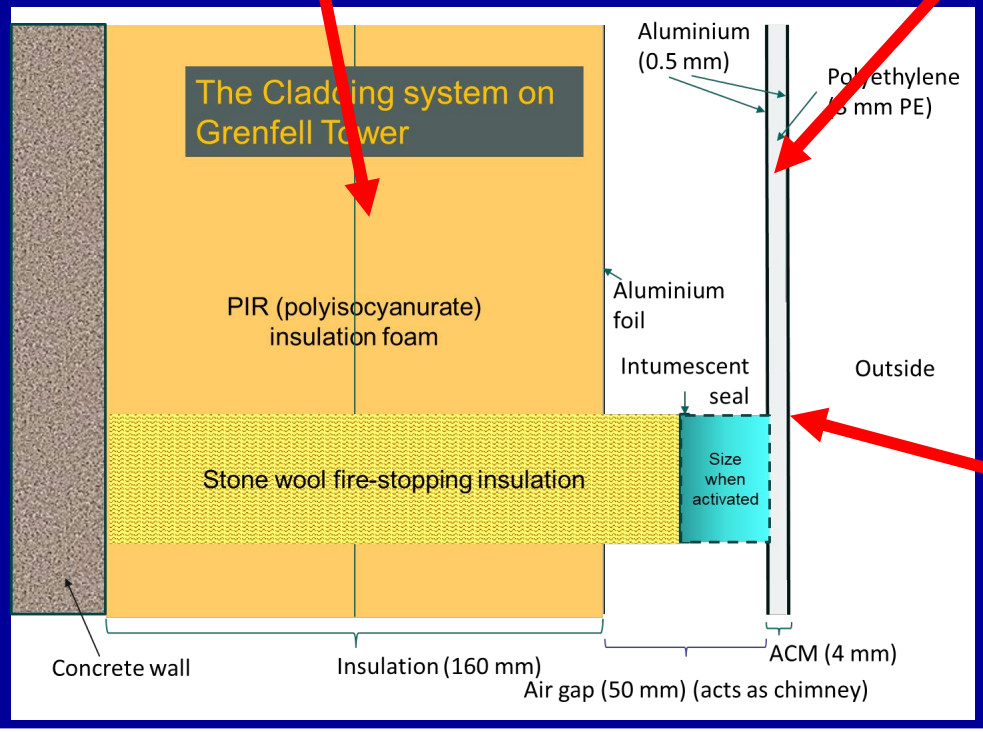
Calculated Heat Release from Façade

$\Delta H_c(PIR) = 132$ MJ m^{-2}

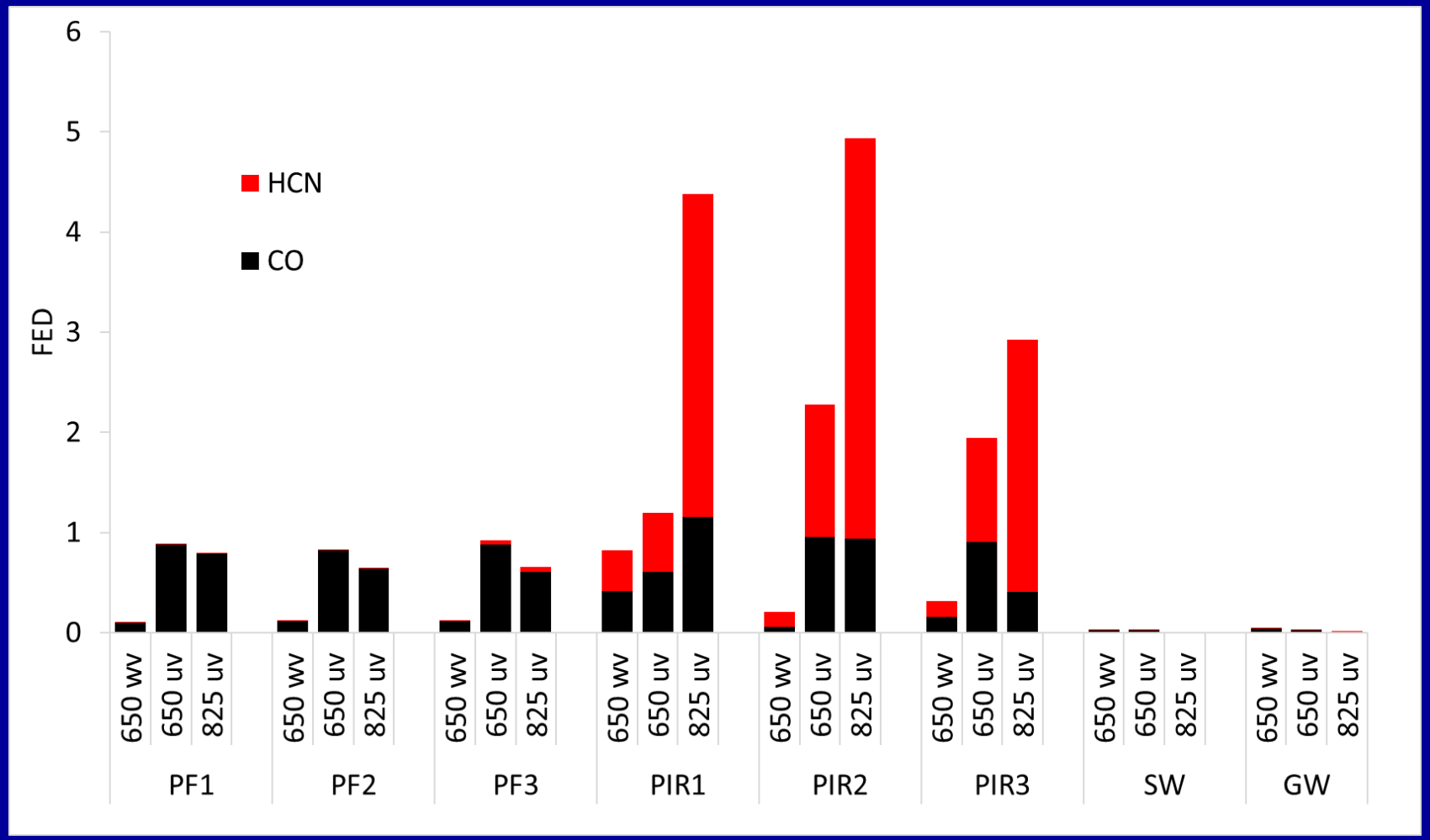
$\Delta H_c(PE) = 122$ MJ m^{-2}



$\Delta H_c(Al) = 84$ MJ m^{-2} (assuming Al burned completely)

Fire Toxicity – Incapacitation

5 minutes exposure from burning 1 kg with the effluent dispersed in a volume of 50 m^3



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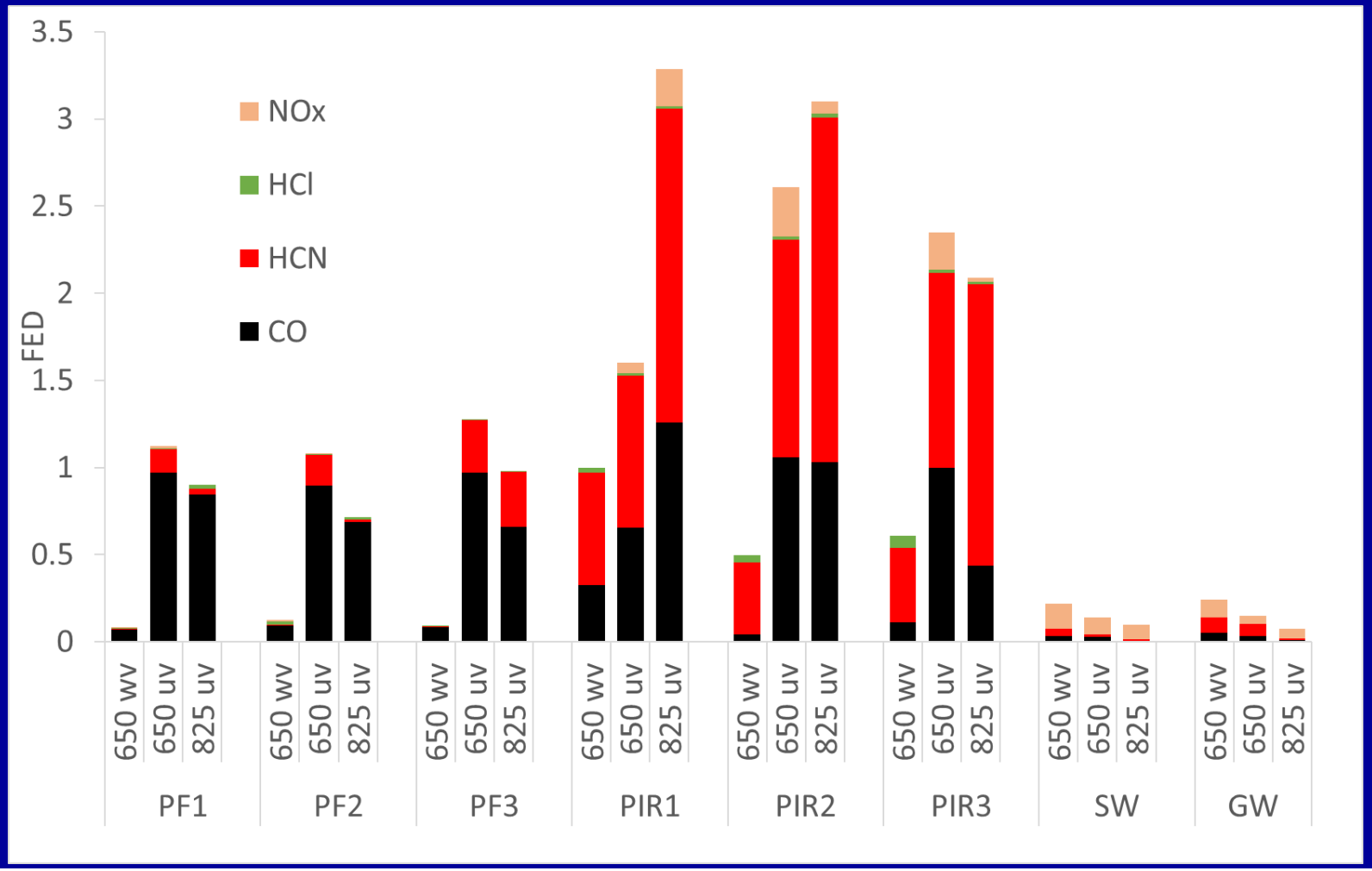
Fire Toxicity – Lethality

30 min exposure from burning 1 kg dispersed in a volume of 50 m^3.



S. T. McKenna, N. Jones, G. Peck, K. Dickens, W. Pawelec, S. Oradei, S. Harris, A. A. Stec, T. R. Hull, Fire behaviour of modern façade materials – Understanding the Grenfell Tower fire, Journal of Hazardous Materials, **368**, 2019, 115-123, https://doi.org/10.1016/j.jhazmat.2018.12.077

Cross-Laminated Timber (CLT)

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Timber Rainscreen Cladding

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Barking Riverside Estate, London

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15.30 Sun 9th June 2019

More detail of fire hazard

Cladding on Barking Riverside

- MetsaWood's "ThermoWood D"
- Euroclass D-s2, d0
- Reassurance before fire: "*materials were fire retardant and residents would have half an hour to escape*".
- Video shows fire spread from ground to 6th floor in 3 min.
- Building believed to be compliant with current UK fire regulations.

Fire Protection of Wood

1. Cladding
2. Coating
3. Sub-surface treatment
4. Penetrative treatment

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1. Cladding

1. CLT clad with brick
2. Gypsum Board etc.

Adds to cost (materials and labour) while losing attractiveness of wood.

2. Coating

- Traditional Intumescents – better FR, problem of moisture uptake.
- Non-Intumescents - better physical resilience, less FR.

Also adds to cost while losing attractiveness of wood.

3. Sub-surface treatment

- Brush applied (~1 mm)

- Envelope penetration (~3 mm) (0.1 bar then 1 bar, then 0.1 bar)

4. Penetrative Treatment

- Full penetration (~20 mm) (0.1 bar 30 min; 10 bar 60 min; 0.1 bar 30 min)

Hazards from Unwanted Fires (estimated 5 000 UK deaths/year)

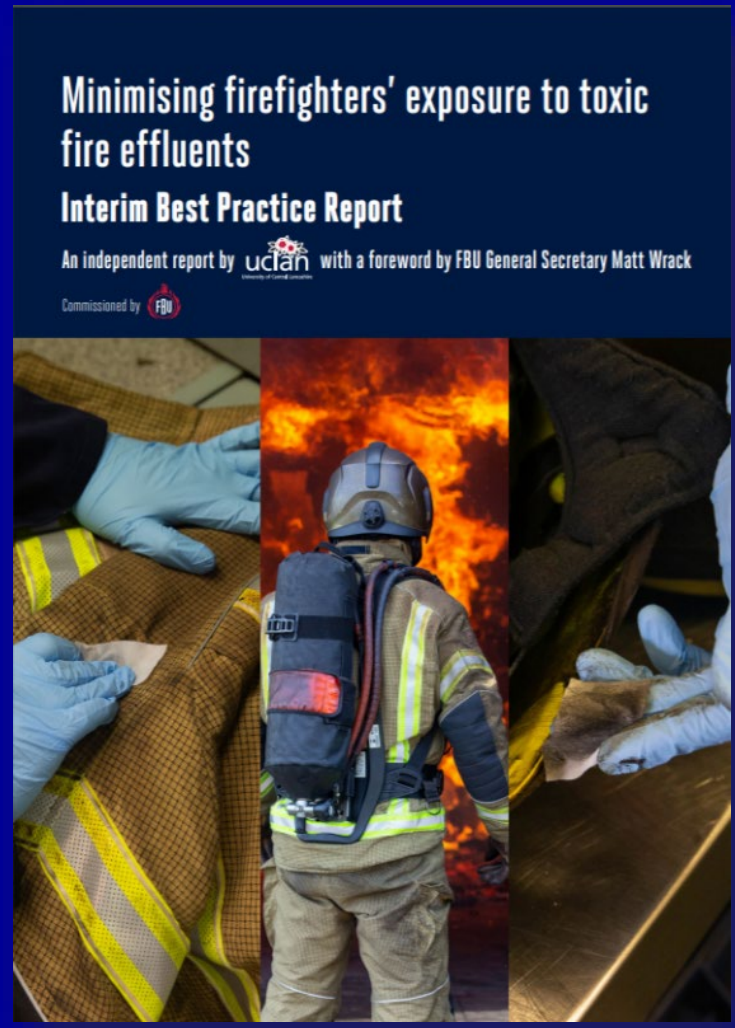
- **Short-term hazards**
  - Burns (100)
  - Smoke toxicity (200)
  - Other injuries (50).
- **Long-term hazards**
  - Particulates (4000)
  - Carcinogens (600)
  - Respiratory sensitisers etc (long term disabilities),
  - Environmental contamination (???)

The UK Firefighter Contamination Survey

- Run for 3 months in 2020
- 64 questions
- Open to serving firefighters
- 10, 649 participants (~24% of UK's firefighters)

Covered:

- Demographics
- PPE/workplace contamination
- Health (Cancer and Mental Health)
- Culture and awareness



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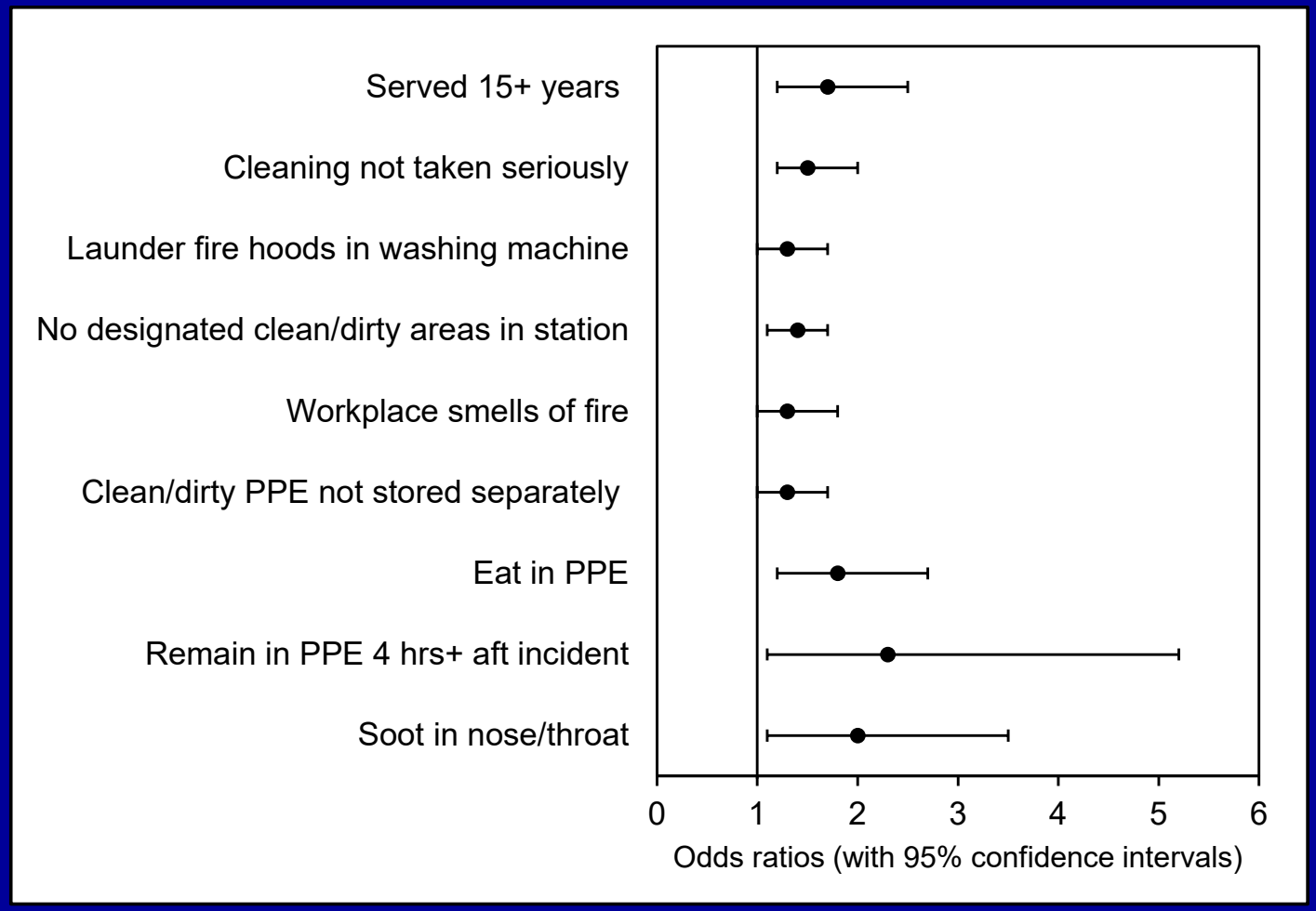
Cancer incidence amongst UK firefighters



Wolffe, et al., *Cancer incidence amongst UK firefighters*, Scientific Reports, 2023

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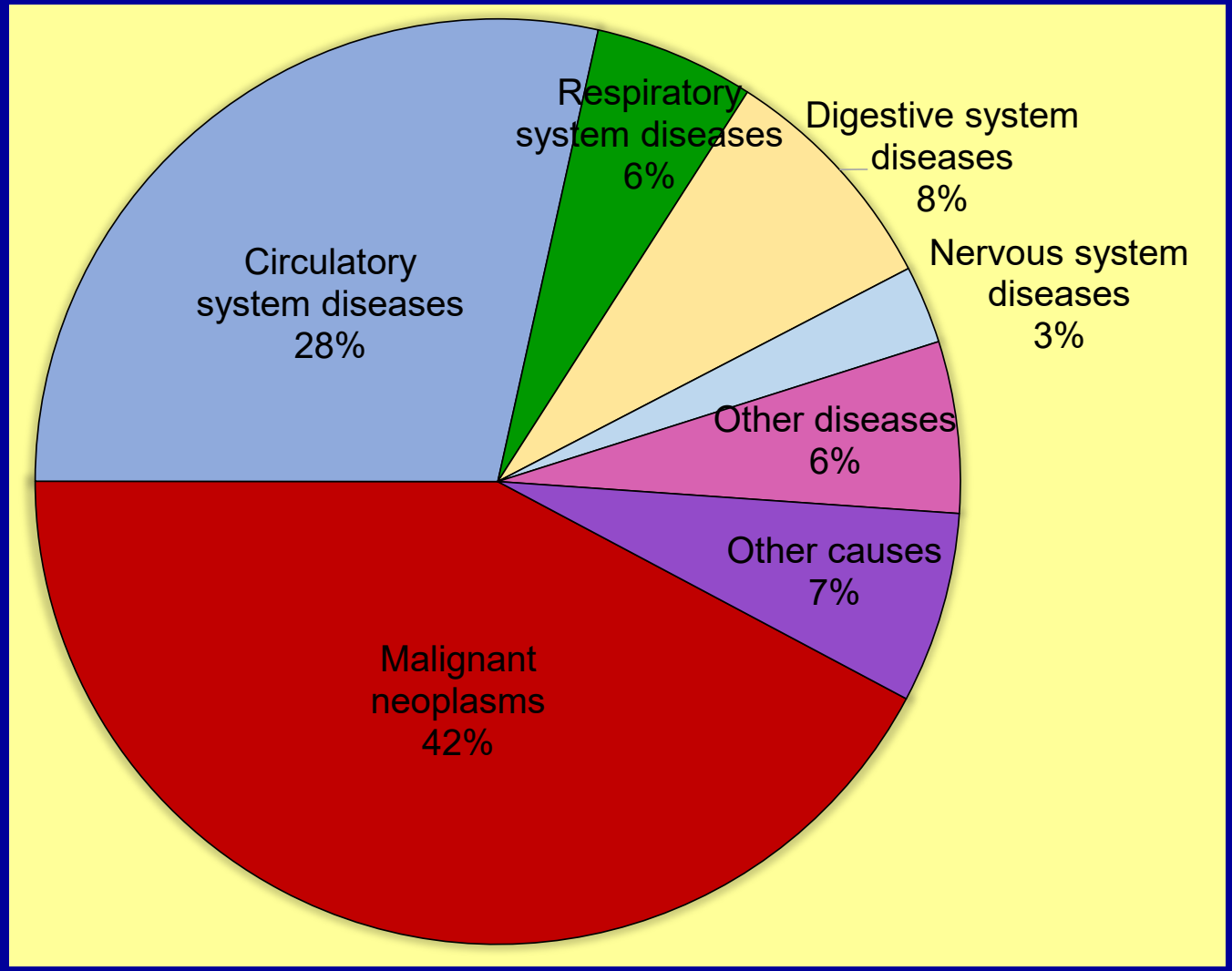
Scottish male firefighter deaths for 2000-2020.



Stec et al., Scottish Firefighters Occupational Cancer and Disease Mortality Rates: 2000-2020, Occupational Medicine, 2023

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Conclusions

- Beware of “regrettable substitution”!
- Diesel cars, wood-burning stoves, toxic flame retardants and combustible insulation were all presented as solutions, but are now causing worse problems
- In the future, demolition may be a cheaper option that redecoration, following a fire
- Unwanted fires cause significant short and long-term hazards and deaths
- Smoke toxicity is the biggest cause of death and injury in fires, but is unregulated!

Thanks for your attention

Any Questions?

Or

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