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Tall Buildings Fire Safety Network

Smoke Toxicity – Grenfell Implications

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Smoke toxicity of rainscreen façades

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Then and now

- The majority of lives that are lost to fire in the UK are from persons '***overcome by toxic smoke***', a move from '***death from burns***' which is attributed largely to the introduction of modern furnishing materials.

- The key assumption made is that the source of fuel, and by definition the source of potentially toxic smoke, stem from the contents we introduce to the spaces we occupy and to this end the fire resistance of furnishings are regulated and electrical and gas supplies are subject to strict controls.

Then and now

A fresh look at the list of assumptions inferred from the above reads as follows:

- Fires only start and travel within the building
- Only the contents of the living space provide fuel and are relevant to human health
- The empty living space itself is non-combustible
- Construction materials do not participate in fire to cause harm to occupants before evacuation
- That the ‘compartmentation’ integrity of external walls is irrelevant to any likely fire scenario
- Windows and penetrations through exterior walls do not compromise fire safety or reduce time available for escape

Then and now

In the Grenfell Phase 2 reports an assessment is made of the immediacy of threat to occupants from toxic smoke and most importantly its origins.

Contrary to the accepted 'contents first' model, first exposure to toxic smoke by those seeking to flee had its origins within the insulation and window frame materials of the external wall, introduced through fire-soft features (windows and detailing).

Only later did the contents of the living spaces act to threaten the lives of those still trapped

Then and now

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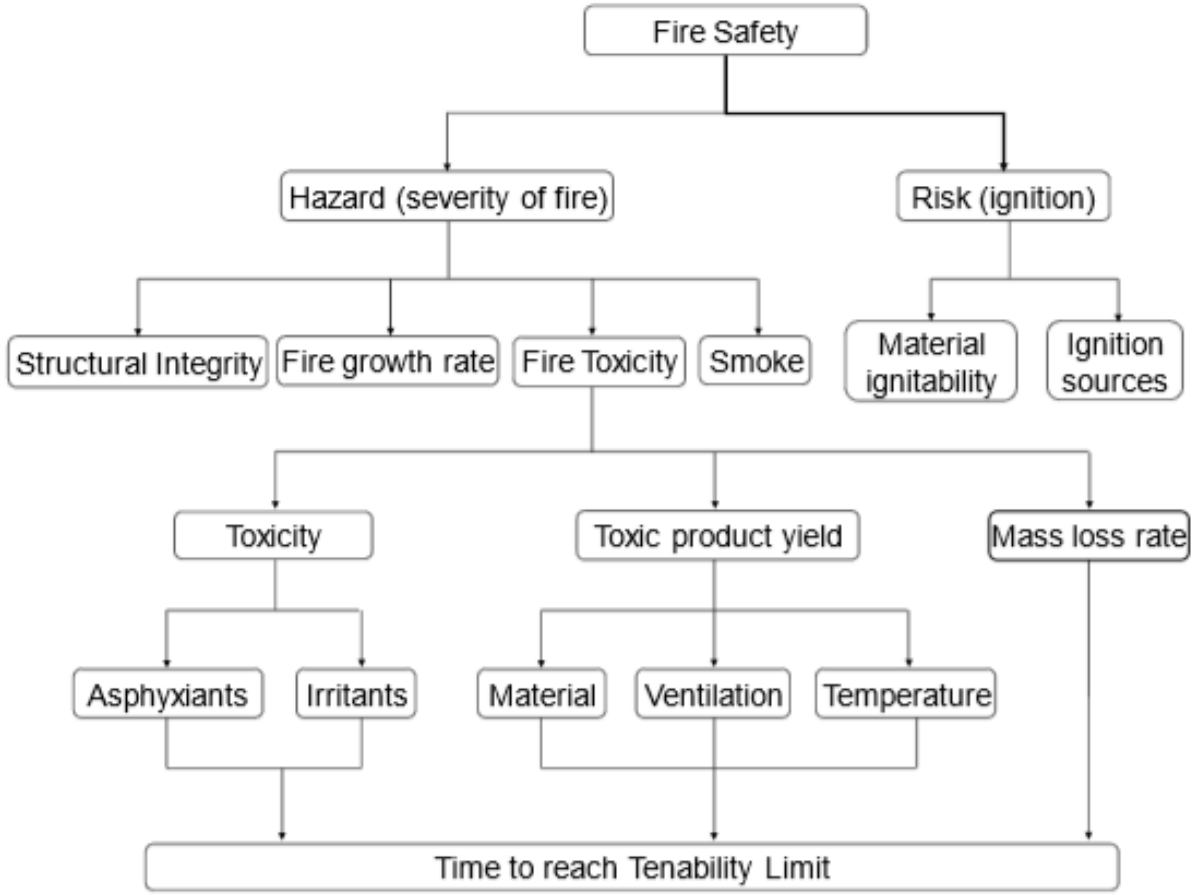
Toxicity is complicated

- What are the source materials?
- Where and how are they burning?
- What are the toxic components?
- What are the routes for contact?
- What factors impact:
  - Ability to escape
  - Time to incapacitation
  - Time for lethality



Toxic threat

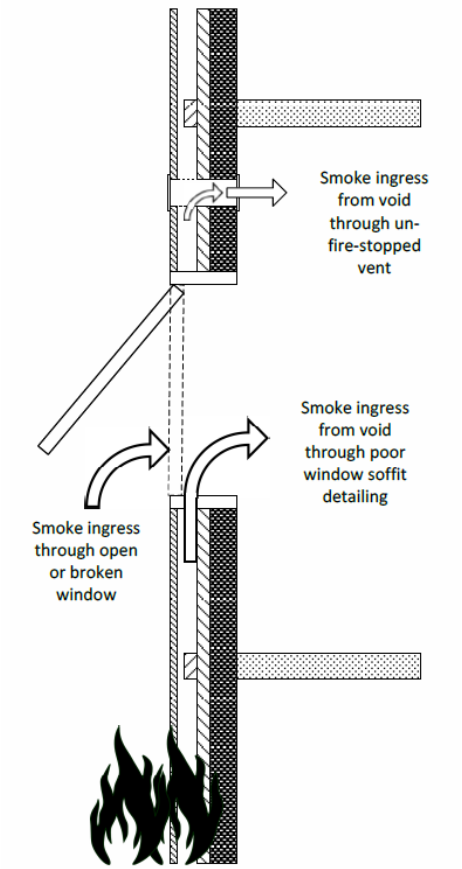
- Loss of visibility which may hinder escape
- Substances irritant to the eyes and lungs which may hinder escape (hydrochloric acid, formaldehyde, acrolein)
- Poisons that cause asphyxiation (preventing oxygen getting to the body) by:
  a) preferential combination with haemoglobin (carbon monoxide)
  b) by inhibiting cytochrome oxidase which prevents the use of oxygen by the body's cells (hydrogen cyanide)
- Gases that stimulate respiration thereby increasing the impact of other toxicants (carbon dioxide)
- Reduced oxygen availability as it is consumed by the fire
- Substances that exhibit longer-term toxicity to humans (particulates, carcinogens, and endocrine disruptors)

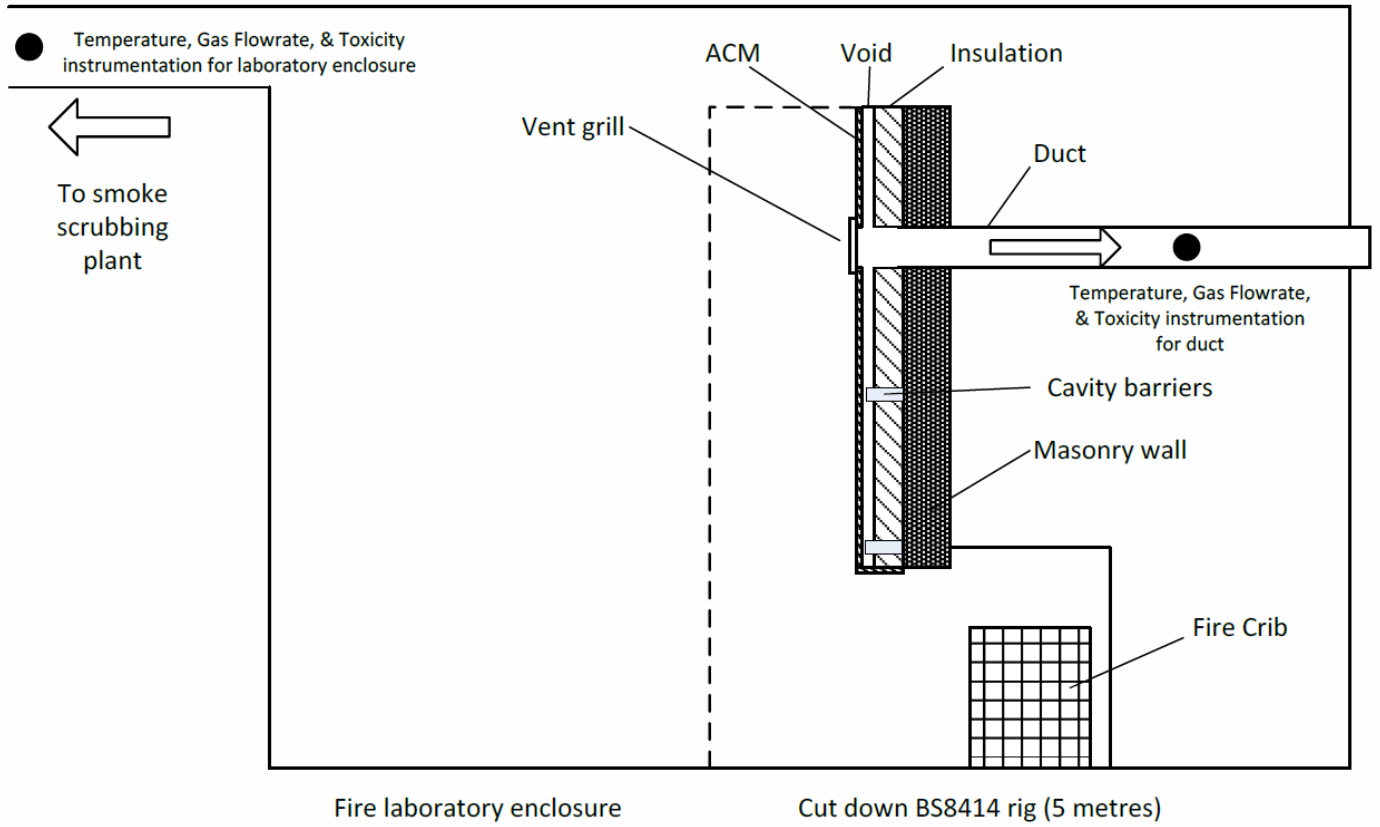
Windows & detailing

- The external envelope of a building is not considered a fire compartment boundary and as such there is NO requirement to fire stop penetrations.

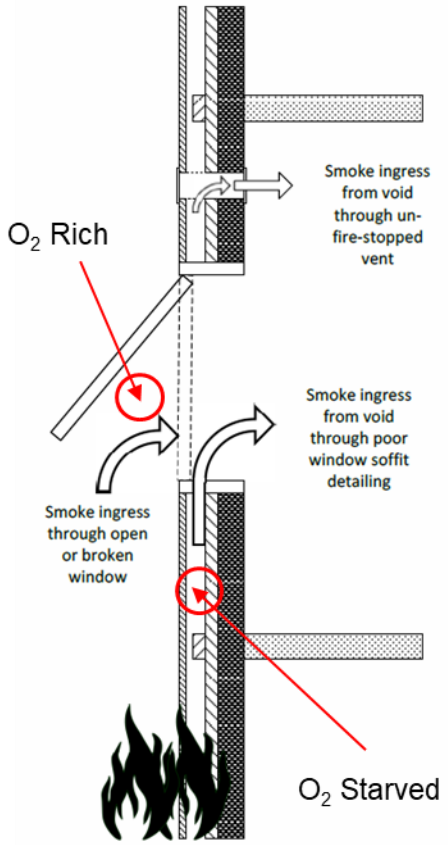
- There is NO requirement to understand how penetration of the cladding by ducts and vents will impact a fire test (BS8414).

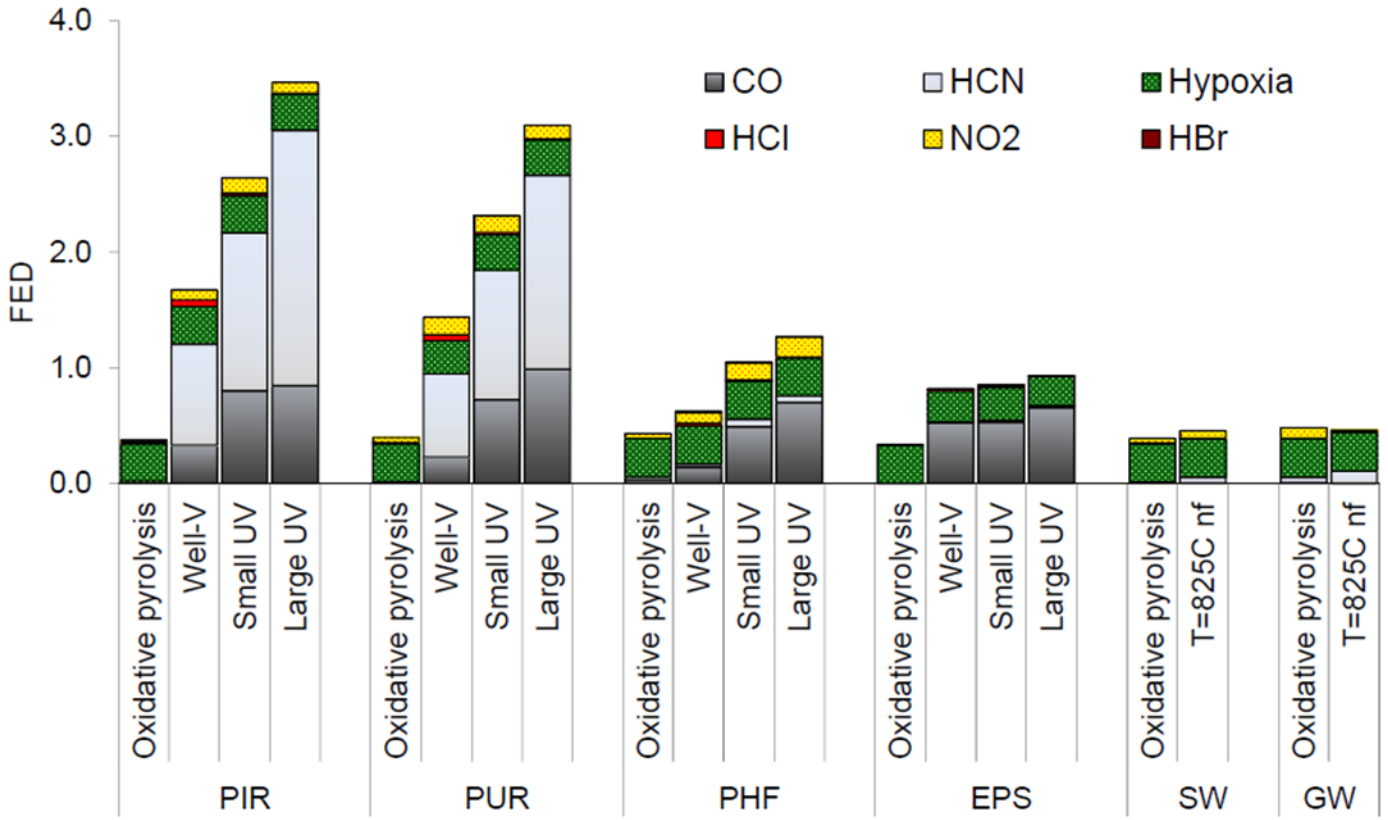
Ventilated Rain-screen scenario (ABI / UCLan / FPA research)





The impact of ventilation on toxicity





Ref: Stec & Hull

Mini 8414 Scale testing

Four typical rainscreen cladding systems were tested on a 5m high version of the BS 8414 rig, with a vent included for toxicity measure from the void:

- Stone Wool insulated system with A2 ACM panels
- PIR insulated system with A2 ACM panels
- Phenolic insulated system with A2 ACM panels
- PIR insulated system with PE ACM panel (Grenfell replication)

Figure 3 - Stone wool insulated system with A2 ACM panels

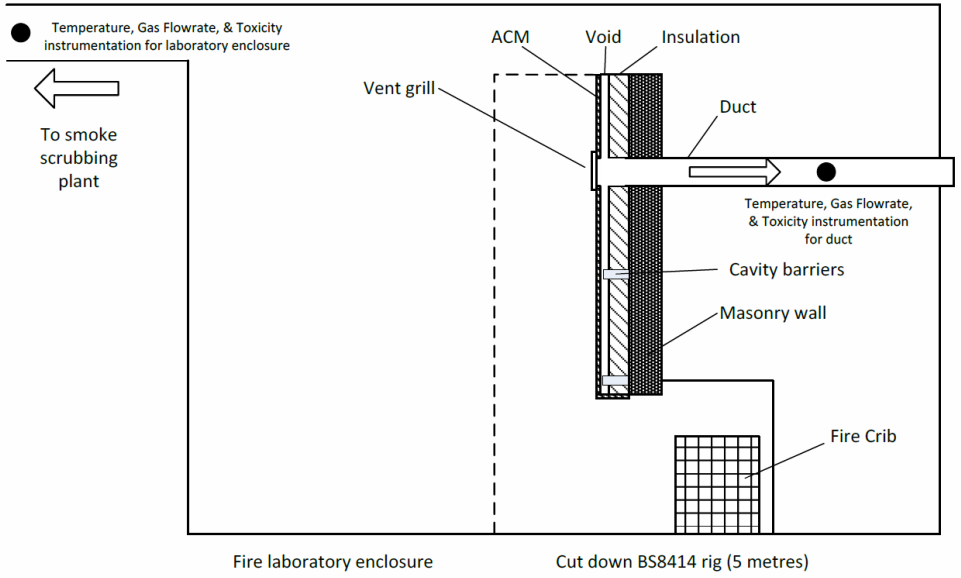
Figure 4 - PIR insulated system with A2 ACM panels

Figure 5 - Phenolic insulated system with A2 ACM panels

Figure 6 - PIR insulated system with PE ACM panels (note test had to be stopped early, after 12 minutes)

Carbon monoxide

- Concentration in ‘kitchen duct’ up to x100 that measured from ‘open burning’
- Oxygen starvation in the void -> severe toxic challenge
- No requirement for vent penetrations to be fire stopped
- A route for exposure of occupants to the highest concentration effluent into the smallest internal volume of space



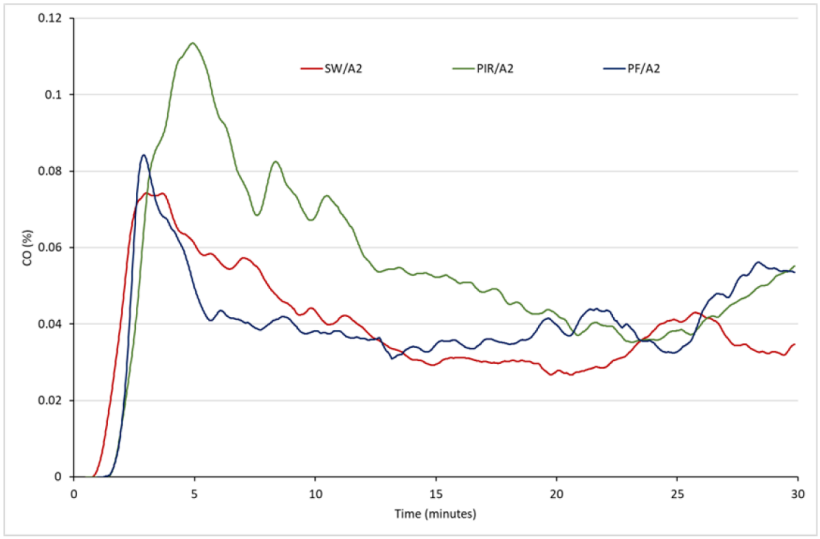


Figure 11 – Carbon Monoxide concentrations measured in laboratory extract system

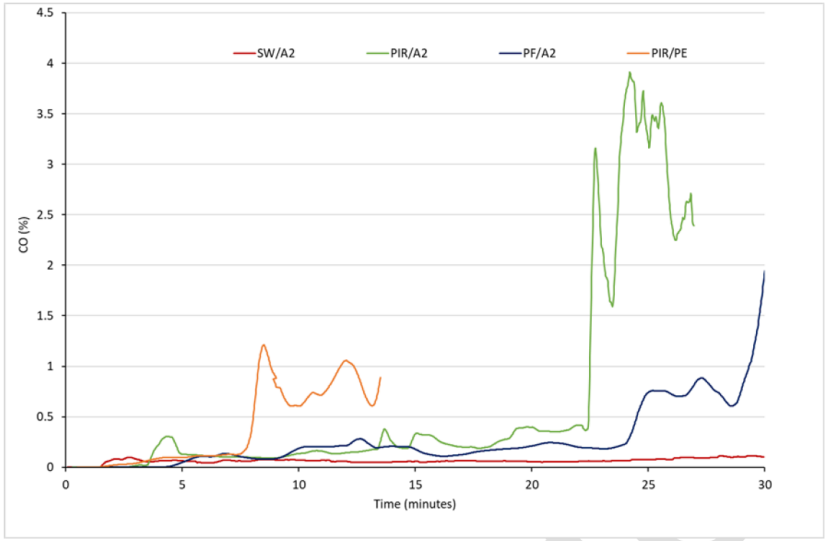
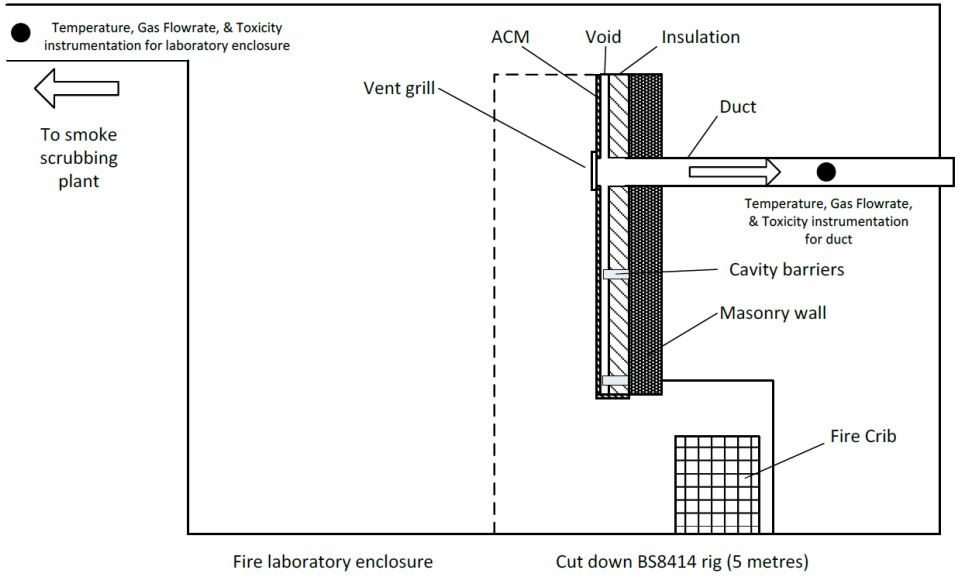


Figure 12 – Carbon Monoxide concentrations measured in cladding system duct

Hydrogen cyanide

- Concentration in ‘kitchen duct’ up to x28 that measured from ‘open burning’
- Oxygen starvation in the void -> severe toxic challenge
- No requirement for vent penetrations to be fire stopped
- A route for exposure of occupants to the highest concentration effluent into the smallest internal volume of space



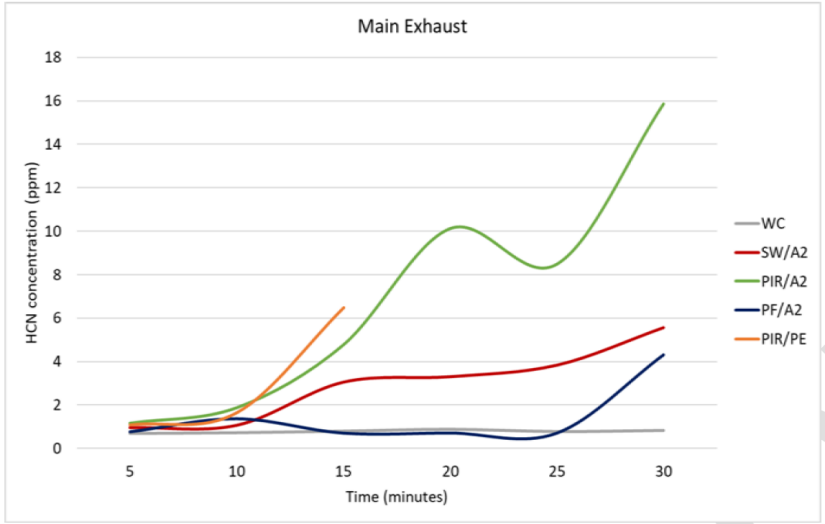


Figure 13 – Hydrogen Cyanide concentrations measured in laboratory extract system

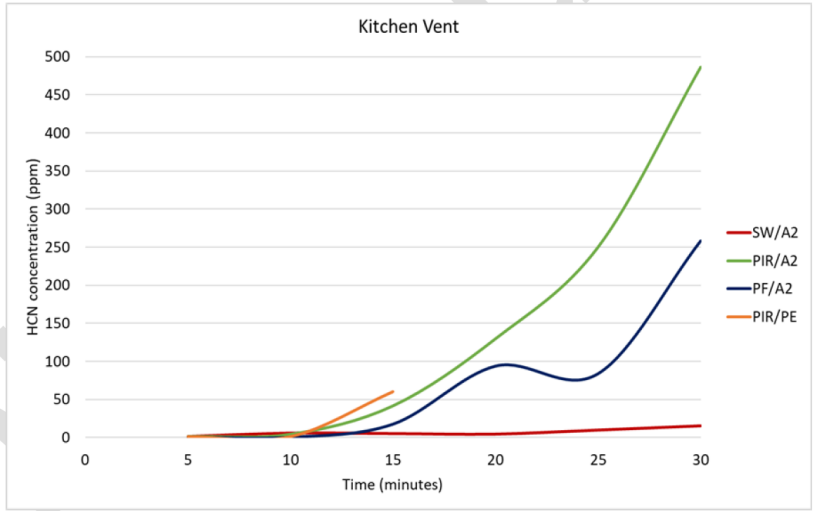


Figure 14 – Hydrogen Cyanide concentrations measured in cladding system duct

Fractional Effective Dose (FED)

- Toxic effects of fire effluent can be expressed as a Fractional Effective Dose (FED), based on the chemical composition of the effluent.
- When the FED is equal to one, 50% of a healthy, adult exposed population would be predicted to suffer incapacitation or death.

For a 50m^3 room, connected to the rain-screen void via a 100mm vent, the results suggest that for some material combinations (ones with higher combustible content) **incapacitation can occur in around 10 minutes** after the fire breaks into the location of the cladding system containing the vent (at around 7, 22, and 29 minutes for PIR/PE, PIR/A2, and PF/A2, respectively), and, if they cannot escape before becoming unconscious, that **death may follow within 30 minutes** if they are not rescued.

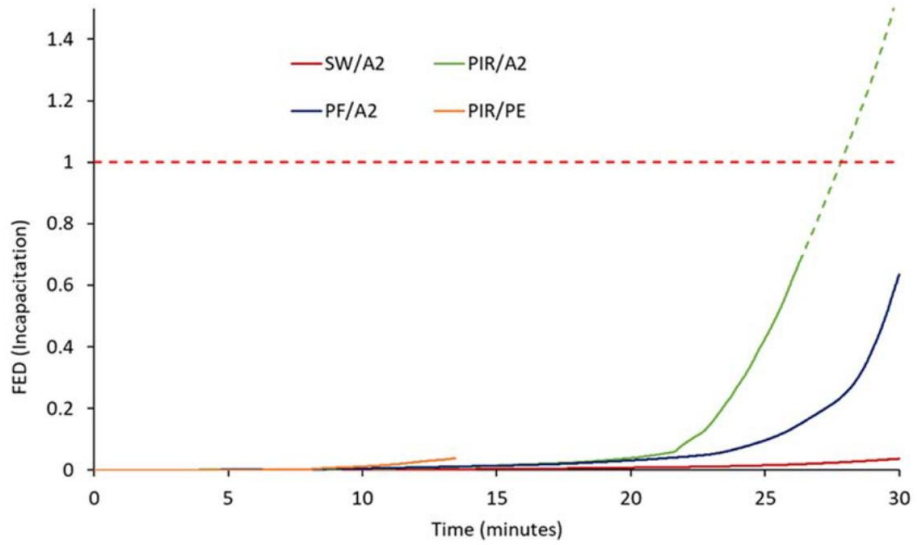


Figure 10 Cumulative FED (incapacitation)

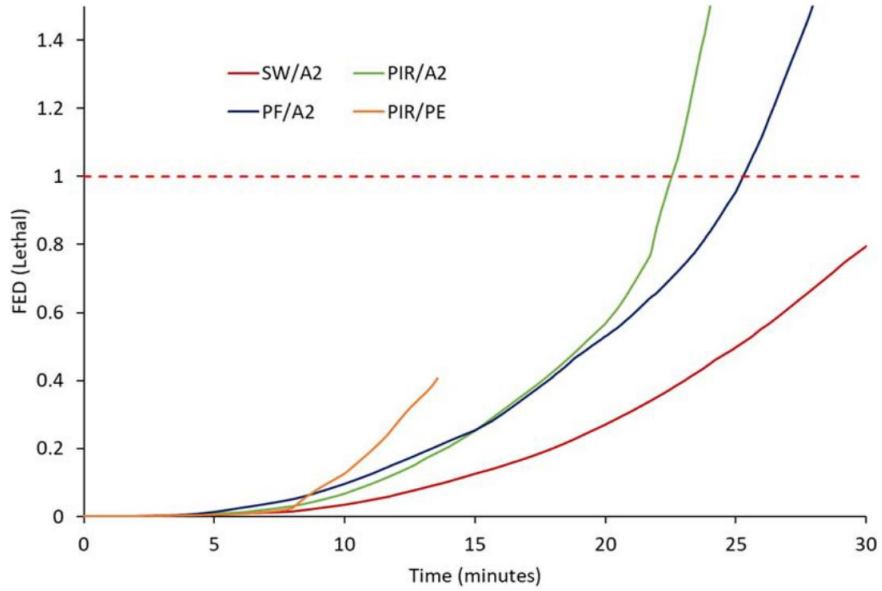


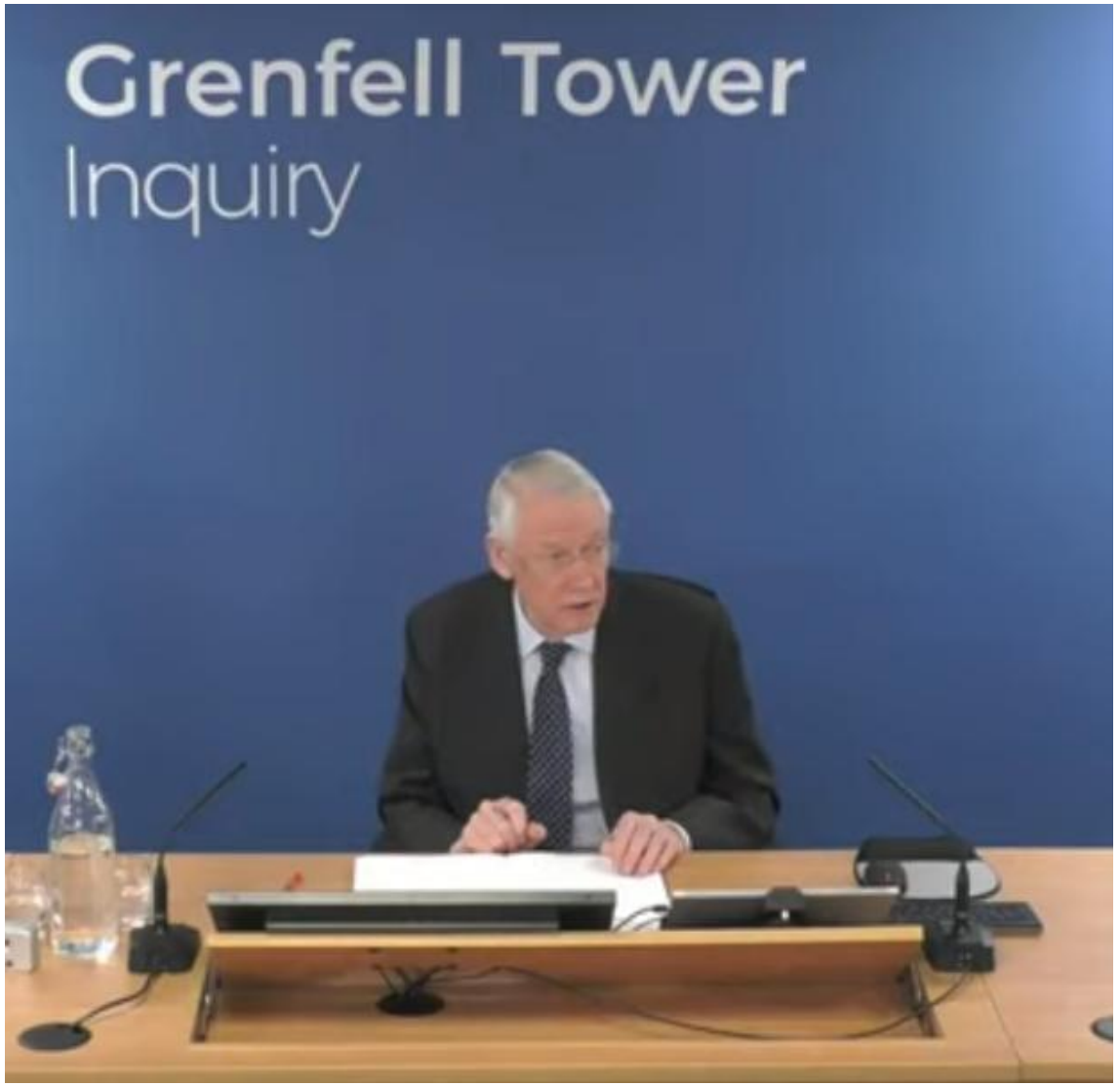
Figure 12 Cumulative lethal FED for 30 minutes exposure

Conclusions

The Grenfell Phase 2 findings tell us that at a height:

- where evacuation is difficult
- where help is remote

Circumstances can arise where there is a need for building material selection to better support life than in situations where escape is easier



Conclusions

- Material toxicity specification is already commonplace in other occupied environments.
- Is it time to consider it for Tall Buildings?

16th July 2025

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