Institution: University of Central Lancashire		
Unit of Assessment: 12 - Engineering		
Title of case study: ***Incorporating smoke toxicity into fire safety assessment***		
Period when the underpinning research was undertaken: 2007-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Richard Hull Anna Stec	Professor Professor	Sept 2007 - Present Oct 2007 - Present
Period when the claimed impact occurred: 2017 - 2020		
Is this case study continued from a case study submitted in 2014? Y/N N		

1. Summary of the impact (indicative maximum 100 words)

Most fire deaths and most fire injuries result from inhalation of toxic smoke. Outside the mass transport industries, the toxicity of this smoke is completely unregulated, allowing materials to be selected which produce so much toxic smoke that they trap and kill fire victims. In 2016 this led the European Commission to initiate a study on the need to regulate smoke toxicity of construction products. Immediately after the Grenfell Tower fire, our 2011 study showing the toxicity of burning insulation was quoted across UK media, alerting politicians, regulators and later, the Grenfell Inquiry, to the dangers of toxic smoke. This led the UK government to commission a larger experimental project to see how smoke toxicity could be regulated, and for the Inquiry to appoint experts, including Stec, to investigate smoke toxicity at Grenfell.

2. Underpinning research (indicative maximum 500 words)

Recognising that the toxicity of smoke kills most people in fires, and causes most injuries, the team at the University of Central Lancashire tackled the obstacles to regulating smoke toxicity, which, outside the mass transport industries, remains completely unregulated. Some manufacturers believe that regulating smoke toxicity would adversely affect their businesses, arguing that it is too difficult to measure smoke toxicity reliably. Hull and Stec's research addresses their concerns, providing solutions to these challenges, by demonstrating:

- ***a systematic relationship between smoke toxicity, fuel chemistry and fire conditions***

Our first big breakthrough came in establishing the relationship between the yields of carbon monoxide (CO) and hydrogen cyanide (HCN), responsible for smoke toxicity deaths, and the ventilation condition, when expressed as a chemical equivalence ratio [1]. This allowed us to demonstrate that the smoke toxicity from burning materials increased by factors between 5 and 20 as the oxygen availability decreased.

- ***that the high toxic product yields of large fires can be replicated on a bench-scale***

Large-scale fires (e.g., involving fully furnished rooms) are known to produce much more carbon monoxide (CO) and hydrogen cyanide (HCN) than most bench-scale fire tests. We developed the steady-state tube furnace (SSTF) to replicate large fires by forcing flaming in under-ventilated conditions. During our research into smoke toxicity, the SSTF has progressed from an

in-house development project to a national (BS 7990) and international (ISO/TS 19700) standard. We demonstrated the repeatability and interlaboratory reproducibility of the SSTF with five internationally leading smoke toxicity laboratories thereby undermining any claims that smoke toxicity could not be measured consistently [2].

- that the toxicity of individual large fires matches those in the SSTF on a laboratory bench-scale.

Our research demonstrated consistent correlations between the bench-scale SSTF and large-scale fires [3, 4] involving identical single fuels. This involved the design of a specialised, large-scale fire enclosure allowing precise measurement of ventilation [5]. The SSTF is the only technique for which such validation exists.

- that it is feasible to undertake rigorous assessment of smoke toxicity without recourse to unethical animal exposure experiments

Stec and Hull's 725-page reference book, *Fire Toxicity*, published by Elsevier/Woodhead (2010) provides a critical review of the main contributions to smoke toxicity, the conditions in which particular toxicants were generated and their effects on living organisms. Much of the data originates from animal exposure and chemical analysis experiments conducted before 2000. *Fire Toxicity* was recognised as the **"best currently available understanding and application of fire toxicity"** by the editor of the *Journal of Fire Sciences*, Dr G Hartzell.

- that smoke toxicity varies with both fire condition and material composition

We investigated the smoke toxicity of a range of materials and products, from simple polymers with and without flame retardants to complex products such as thermal insulation materials [6] and whole energy and data cables. We demonstrated that the smoke toxicity was a function of both material composition and the fire conditions.

- an easily applicable methodology to incorporate smoke toxicity in fire safety risk assessments

The generation of toxic smoke from a fire will depend on both its burning rate (or mass loss rate) and the yield (as a mass of toxicant generated by a given mass of material). For fire safety engineers to be able to undertake meaningful risk assessments, they need to access both pieces of information when a particular product is installed. We have proposed a simple methodology which uses existing product classification and SSTF data to undertake such assessments [7].

3. References to the research (indicative maximum of six references)

[1] Stec, Anna A, Hull, T Richard, Lebek, K., Purser, J. A. and Purser, D. A. (2008) 'The effect of temperature and ventilation condition on the toxic product yields from burning polymers.' *Fire and Materials*, 32 (1). pp. 49-60. https://doi.org/10.1002/fam.955.

[2] Purser, J.A., Purser, D.A., Stec, Anna A, Moffatt, Colin, Hull, T Richard, Su, J.Z., Bijloos, M. and Blomqvist, P. (2013). 'Repeatability and reproducibility of the ISO/TS 19700 steady state tube furnace,' *Fire Safety Journal*, 55. pp. 22-34. https://doi.org/10.1016/j.firesaf.2012.10.002.

[3] Stec, Anna A, Hull, T Richard, Purser, J A and Purser, D A (2009). 'Comparison of toxic product yields from bench-scale to ISO room.' *Fire Safety Journal*, 44 (1). pp. 62-70. https://doi.org/10.1016/j.firesaf.2008.03.005.

[4] Anna A. Stec and T. Richard Hull, 'Fire Toxicity Assessment: Comparison of Asphyxiant Yields from Laboratory and Large-Scale Flaming Fires,' *Fire Safety Science*, 11: 404-418, (2014). https://www.iafss.org/publications/fss/11/404/view/fss_11-404.pdf https://doi.org/10.3801/IAFSS.FSS.11-404.

[5] Crewe, Robert J., Lyons, Ashleigh G., Hull, T. Richard, Stec, Anna A., (2017) Asphyxiant yields from common polymers in under-ventilated fires in the large instrumented fire enclosure (LIFE), *Fire Safety Journal*, 91, pp. 982-988., https://www.doi.org/10.1016/j.firesaf.2017.03.026.

[6] Stec, Anna A and Hull, T Richard. 'Assessment of the fire toxicity of building insulation materials.' *Energy and Buildings*, 43 (2-3). pp. 498-506 (2011). https://doi.org/10.1016/j.enbuild.2010.10.015.

[7] Hull, T Richard, Brein, Dieter and Stec, Anna A (2016) 'Quantification of toxic hazard from fires in buildings.' *Journal of Building Engineering*, 8.pp. 313-318. https://doi.org/10.1016/j.jobe.2016.02.014.
All references peer reviewed.

4. Details of the impact (indicative maximum 750 words)

Addressing policy makers in the EU

In June 2015 Hull summarised the University of Central Lancashire's work on the need to quantify smoke toxicity at a meeting in the European Parliament. The participants included MEPs and Mr Gwenole Cozigou, the Director from the European Commission's Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (DG Grow) responsible for Construction Product Regulation (CPR). In January 2016 Hull was one of 30 scientists selected from over 300 for the Scientist-MEP pairing scheme, where he discussed the issue of smoke toxicity on a one-to-one basis with 12 MEPs and their researchers [A]. In March 2016, Mr Cozigou was an invited speaker at an international symposium on Fire Toxicity, organised by the University of Central Lancashire where, in front of 150 experts, he announced the launch of a study considering regulation of smoke toxicity of construction products. The study was limited to a pre-selected group of contractors, and the project started in December 2016. Hull was the only academic, amongst predominantly industry and trade association representatives, on the project steering group. During the study, but after the Grenfell Tower fire, Reuters reported that the study would not recommend regulation amid concerns that regulation **"could increase product costs and potentially remove some products from the market."** [B]. Between September 6-7th 2017, Stec and Hull explained the Grenfell tragedy to a further 15 MEPs. The following week, the European Parliament had an hour-long debate on fire safety. Of the 25 MEPs who spoke, over 20 said that the European Commission needed to regulate smoke toxicity of construction products. Baron Khan of Burnley, then MEP for North West England, met with Hull and Stec before contributing to the European Parliament debate on fire safety in buildings. He said, **"…that while fire toxicity in trains, planes and ships is regulated, there is a real lack of regulation in the construction sector. Renovation works at Grenfell were inspected 16 times by the local authority, showing current rules simply aren't fit for purpose."** [C]. The Commission recognised that much more work was needed in fire safety of buildings and

responded by announcing the Fire Information Exchange Platform (FIEP) to address these issues. The EC Smoke Toxicity study was finally published in January 2018 and concluded on page 101 that **"regulation 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."** [D] However, with the ongoing review of the Construction Product Regulation, how to enact this proposal is still under consideration.

Raising awareness of the risk of smoke toxicity following the Grenfell Tower fire

On the 14th June 2017, the recently refurbished Grenfell Tower was engulfed in flames spreading around its external façade, leading to the deaths of 72 residents. In the aftermath, Hull described his relevant 2011 study showing the very high toxicity of burning insulation material that had been used on the Tower [6] on BBC's Newsnight, Radio 4's World at One, ITV, Channel 4 and Sky News [E]. Hull's research was also reported in over 20 national newspapers. He explained that a 1 kg (50 cm x 50 cm) piece of polyisocyanurate (PIR) insulation was sufficient to fill an entire apartment with toxic fumes of carbon monoxide and hydrogen cyanide when burning, and, as *Planning and Building Control Today* reported, the government had no regulations to control it [F]. Hull's work with the media after the Grenfell tragedy highlighted the importance of the combustible insulation in the disaster, and particularly the high toxicity of burning PIR insulation, alongside reports that several survivors had been treated for cyanide poisoning [E]. This led to a general recognition that smoke toxicity, rather than burns, had led to much of the tragic loss of life. As a consequence, the world-leading specialist in fire toxicity, Professor David Purser, was invited to join the team of expert witnesses to the Grenfell Inquiry in May 2018, followed by Stec as an expert in fire toxicity, in September 2018. [G]

Informing policy makers in the UK

Our high-profile media activity around the Grenfell Tower fire was followed by invitations to present our research to the UK's *Parliamentary and Scientific Committee*, an All-Party Parliamentary Group, at the Houses of Parliament in September 2017. This was followed by two presentations to the All-Party Parliamentary *Fire Safety and Rescue* Group. Stec was invited to join Dame Judith Hackitt's Review of Building Fire Safety Regulations, Working Group 6, Products and Classifications, which recommended including smoke toxicity in the Building Regulations [H]. The results were also presented to the Royal Institute for British Architecture Expert Group on Fire Safety who then presented their conclusions to the Parliamentary Select Committee on Communities, Housing and Local Government [J]. Between December 2018 and March 2019, a Ministry of Housing, Communities and Local Government (MHCLG) consultation document on the review of Approved Document B (Fire Safety) [I] had four questions on the incorporation of smoke toxicity into the UK's fire regulations. The University of Central Lancashire's response to the consultation in a letter to MHCLG included urging 'the government to review the existing guidelines on smoke, including the major hazard of its acute toxicity and the longer term toxicity of fire smoke and residue.' The conclusion of the consultation was that a discrete research programme was needed to address smoke and toxicity [K]. In May 2020 MHCLG released a tender for research to underpin smoke toxicity regulation in England. This provided GBP605,000 funding, for a three-year partly experimental project to assess the need and methodology for assessing smoke toxicity of construction products, awarded in September 2020 to a consortium led by OFR Consultants.

5. Sources to corroborate the impact (indicative maximum of 10 references)

A. Scientist-MEP Pairing Scheme, 2015URL: https://www.europarl.europa.eu/cmsdata/148486/31%20Scientists_MEP-Pairing-Scheme_2015%20-%20Website.pdf [Accessed 12 February 2021]

B. Exclusive: EU dismisses smoke regulation, looks into tougher fire safety tests, Reuters, 23rd October 2017 URL: https://www.reuters.com/article/us-britain-fire-eu/exclusive-eu-dismisses-smoke-regulation-looks-into-tougher-fire-safety-tests-idUSKBN1CS1DY, [Accessed: 20 January 2021]

C. Debate on the Council and Commission statements on fire safety in buildings (2017/2764(RSP)), European Parliament. URL: http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+CRE+20170913+ITEM-015+DOC+XML+V0//EN&language=EN [Accessed 12 February 2021]

D. EC Final Report: Study to evaluate the need to regulate within the Framework of Regulation (EU) 305/2011 on the toxicity of smoke produced by construction products in fires. Tim Yates. October 2017. URL: https://ec.europa.eu/docsroom/documents/27346/attachments/1/translations/en/renditions/native [Accessed 12 February 2021]

E. Examples of media appearance following Grenfell Tower including BBC News article on cyanide poisoning: Grenfell survivor was diagnosed with cyanide poisoning, BBC News, 13th July 2017 URL: https://www.bbc.com/news/uk-40568640, [Accessed: 20 January 2021]

F. FPA calls on Government to consider smoke toxicity in building products (2018) Planning and Building Control Today. URL: https://www.pbctoday.co.uk/news/building-control-news/smoke-toxicity-in-building-products/49655/ [Accessed 3 March 2021]

G. Grenfell Tower Inquiry – Expert Witnesses URL: https://www.grenfelltowerinquiry.org.uk/about/expert-witnesses [Accessed 2 March 2021]

H. Recommendations from Working Group 6 of the *Review of Building Regulations* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/707785/Building_a_Safer_Future_-_web.pdf [Accessed 12 February 2021]

I. Ministry of Housing Communities and Local Government Review of Approved Document B (Fire Safety) Consultation. URL: https://www.gov.uk/government/consultations/technical-review-of-approved-document-b-of-the-building-regulations-a-call-for-evidence [Accessed 12 February 2021]

J. Adrian Dobson, Executive Director, Royal Institute of British Architects (RIBA), London.

K. Technical Review of Approved Document B - workplan overview URL: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/877365/Technical_review_of_Approved_Document_B_workplan.pdf [Accessed 12 February 2021]