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1 Authors' response to comments on
2 "Flame retardants in UK furniture
3 increase smoke toxicity more than they
4 reduce fire growth rate"

5

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15

16 Introduction

17 The publication "Flame retardants in UK furniture increase smoke toxicity more than they reduce fire
18 growth rate" (McKenna et al., 2017) has drawn responses from two individuals expressing concerns

19 that such studies could lead to a reduction in flame retardant use in furniture. Such debate is very
20 welcome, and unlike the “fake news” currently in the media spotlight, peer-reviewed publications
21 provide a permanent and definitive record of what was said and what was not. By setting the
22 evidence out openly, scientists are in a position to draw appropriate conclusions.

23

24 The authors of both responses have recently published work funded by the flame retardant industry
25 (Hirschler, 2015; Blais et al., 2013). It is unfortunate that both respondents appear to have missed
26 key passages in the original paper, necessitating quotes from it to address the responses.

27

28 Both responses refer to the work as a series of *tests*, suggesting pass/fail or quantifying some
29 performance criteria. We believe it is better to consider it as a series of *experiments* designed to
30 understand why the fire death rate in the UK had not fallen more sharply than that of countries
31 without furniture flammability regulations. The working hypothesis was that gas-phase flame
32 retardants used in upholstered furniture may increase the yields of the main asphyxiants, carbon
33 monoxide and hydrogen cyanide (Molyneux et al., 2014a). We believe this was adequately
34 demonstrated in the paper for the sofa-bed compositions investigated.

35

36 Dr Blais complains that the term “chemical flame retardants” is “is not a scientific description but an
37 attempt to declare all flame retardants (FRs) as “chemicals” in order to create an emotional
38 perception of chemicals being generally bad.”. We believe it is a useful distinction. The special weave
39 of CottonSafe, or the use of an interliner are two methods of reducing the flammability which do not
40 use chemical flame retardants. As the majority of our authors are professional chemists (the
41 remaining three being fire safety engineers), we do not see the use of chemicals as pejorative,
42 merely a useful distinction between substances of homogeneous chemical composition
43 (“chemicals”), rather than the diverse mixtures of compounds found elsewhere.

44

45 After discussing aspects of the paper, Dr Hirschler makes a series of value judgements which are
46 incorrect and unjustified. They seem designed to lull the reader who doesn't follow his arguments
47 into accepting his perspective. For example:

48 “The large-scale fire tests conducted do nothing more than demonstrate that a severe enough
49 ignition source will cause virtually any combustible material to ignite.” The fire tests did a great deal
50 more than that, showing: similar times to ignition; different toxic product yields; different maximum
51 temperatures; and somewhat different mass losses for fire retardant and non-fire retardant
52 furniture formulations. They also contribute to our understanding of why the UK has a high rate of
53 upholstered furniture fire related deaths.

54

55 “For all the reasons stated above, clearly all the large-scale fire test results are severely faulty and
56 should be discarded.” The large scale tests were the most significant part of this work and raise
57 important questions about the value of adding flame retardants to furniture. At the very least the
58 evidence presented should make it clear that further work is needed.

59

60 “Thus, this severely flawed work contradicts not just the publish literature but its own results.” This
61 statement refers to the comparative performance of UK and US furniture in the crib 5 test which the
62 UK furniture was designed to pass. It makes no reference to our original paper or contradictions
63 therein, and is therefore completely without justification.

64

65 “This means that the equation used to predict incapacitation in this article has been shown to
66 exaggerate the effects of heteroatoms, such as halogen atoms.” Within ISO TC 92 SC3, which deals
67 with smoke toxicity, there is an industry-backed campaign to ignore experimental data showing the
68 level of hydrogen cyanide at which baboons become unconscious, and increase the tenability limit
69 for other toxicants. The equations used in the original paper have been in the existing standard for

70 over a decade, and are current and still valid, unlike the industry-backed approach proposed by
71 Professor Pauluhn and lauded by Dr Hirschler.

72

73 One aspect that neither correspondent made any comment on was the large body of work showing
74 the harmful effects of many flame retardants, which were briefly summarised in the original paper.
75 Given the obvious need to balance the risks and benefits of flame retardants, it is unclear whether
76 the data on health and environmental risks are now accepted by those in favour of wider
77 deployment of flame retardants, or whether they are dismissing such research as irrelevant.

78 Fire Statistics

79 Dr Hirschler asks why we did not use the report by Gary Stevens. This was described in the original
80 paper.

81 “In a report commissioned by the flame retardant industry (Emsley et al., 2005), and a subsequent
82 report for the UK government (Greenstreet Berman Ltd, 2009), it was argued that “*the introduction*
83 *of fire-safe furniture [in the UK] from 1988 onwards is estimated to have resulted in at least 50% of*
84 *the estimated 2002 savings in injuries and domestic fire deaths*”, the other 50% being attributed to
85 low cost smoke detectors. Factors such as changes in cigarette smoking habits, the change from
86 exposed flame heating sources and a general improvement in standard of living were not considered
87 (Hull et al., 2014).” No justification was provided in either of the Stevens’ reports for attributing 50%
88 of the fire death reduction to furniture flame retardants. It should also be noted that the data in that
89 report is over 20 years old.

90 In the introductory summary, Dr Blais dismisses the work on UK and New Zealand statistics as “of
91 less important and low contribution because it does not lead to meaningful conclusions” but then
92 goes on to discuss it later in the response.

93

94 Dr Blais argues that “Comparison of fire deaths of just two countries in the world for a very specific
95 time span and not including fire injuries, fire losses, and number of fires is of questionable validity as
96 a scientific argument. He goes on to complain that the data was not available on the link provided.
97 The links to the digital yearbook are still valid, but it takes time to find the data from the text.
98 Unfortunately, the University of Canterbury website has been restructured so the original link no
99 longer works, but the thesis is still available (Wong, 2001). Similarly, the New Zealand Fire Service
100 has been renamed Fire and Emergency New Zealand, and the statistical reports do not appear to be
101 available on-line. Similarly, the UK data, from 1955, do not appear in a single document on the fire
102 statistics website, they have been collected from annual reports over that period. In addition to the
103 New Zealand data, our original paper quotes the European Commission report which shows a similar
104 pattern of reduction in fire death rates across the wealthier European countries.

105

106 “A detailed study produced for the European Commission (Arcadis EBRC, 2011) on the risks and
107 benefits of adding fire retardants to furniture, analysed the fire fatality data from individual
108 European countries with different levels of flammability regulation. While the study acknowledged
109 the difficulty in comparing statistics from different countries, it concluded that *“in some instances,*
110 *drops in the number of fire deaths coincide with the introduction of non-flammability requirements*
111 *for domestic consumer products. In other instances, however, there is no change in the on-going*
112 *trend of fire deaths. This suggests that these numbers do not reflect the stringency of non-*
113 *flammability requirements, respectively that non-flammability requirements do not visibly decrease*
114 *the number of fire deaths.”*

115

116 It is a matter of speculation why both respondents chose to ignore the findings of the European
117 Commission study, but it certainly weakens the argument that the New Zealand data had been taken
118 in isolation. Surprisingly, more precise fire death rates do not appear to be readily available for most
119 countries. There are also inconsistencies, such as whether road traffic accident or murder by arson,

120 are recorded as fire deaths in particular jurisdictions. On that basis, New Zealand seemed to be a
121 good choice and the data was available. Within the constraints of the paper there was insufficient
122 space for a fuller statistical analysis.

123

124 Mattress Formulations

125 Both responses draw attention to the fact that the mattresses were not commercial, and therefore
126 not representative of typical furnishings. We deliberately asked the manufacturer to make the
127 mattresses so that they were consistent with each other: the three foam mattresses having the
128 same thickness of foam and the same thickness of polyester comfort layer, using comparable fabric
129 covers with different flame retardant treatments. This would be unlikely to be the case if
130 commercial products had been selected, and would have involved additional purchases to dissect
131 them and determine their composition. Rather tellingly, Dr Blais goes on to say “there are dozens of
132 details that matter to fire behavior in the complex design of furniture”. The implication is that
133 mattresses have to be carefully engineered in order to achieve a pass in a regulatory test. While this
134 is probably true, it is a very unfortunate situation, and goes some way towards explaining why UK
135 furniture is involved in so many fatal fires.

136 Use of a Crib 7 Ignition Source

137 Both respondents express concerns about the use of a “crib 7” ignition source, rather than a “crib 5”.
138 The difference is that the fabric and filling in three of the four mattresses have been designed to
139 resist ignition by a crib 5 source. The crib 5 source is meant to represent two single sheets of
140 newspaper while the crib 7 is meant to represent 4 double sheets of newspaper (BS 5852, 2006). The
141 decision was clearly explained in the original paper.

142

143 “In order to ensure that each mattress ignited first time, a larger, No. 7 crib, containing 125 g of
144 Scots Pine (*Pinus Silvestris*), arranged as an open frame to give adequate ventilation, was employed
145 to ensure sustained ignition, since three of the four compositions were supplied as having already
146 resisted ignition using the No. 5 wooden crib (containing 17 g wood).”

147

148 It was shown in the paper that UK fire deaths are driven by smoke toxicity in living and bedrooms, so
149 it is highly probable that fires involving the UK's flame retarded upholstered furniture are the main
150 cause of death. Since this furniture has to pass a crib 5 test in order to be sold in the UK, using a crib
151 5 source would not have addressed the conundrum of why the UK has a fire death rate to
152 comparable to countries without flame retardant furniture. To describe the crib 7 source as
153 “powerful” in anything but a relative sense is gross exaggeration. How many people consider that
154 leaving four sheets of newspaper on the sofa, is deploying a potentially powerful ignition source?

155 In our study we were surprised to find that “for three of the four formulations, in the large scale test,
156 there was very little difference in the time to ignition or fire growth rate, despite two of the three
157 containing flame retardants.” Dr Blais comments “The observation that there is very little difference
158 in time to ignition is due to the significantly larger ignition source used”. We believe that the general
159 population, or customers purchasing flame retardant furniture, would expect a significantly longer
160 time to ignition from flame retardant furniture (indeed many believe it will not burn at all). Only
161 industry insiders are aware of the marginal benefits they provide.

162

163 Dr Blais asks why another set of eight sofa-beds were not tested using a crib 5 source. Given that the
164 materials were sold on the assumption that they would not ignite using a crib 5 source, such
165 verification seems rather wasteful.

166

167 Bench-Scale Tests

168 Referring to the cone calorimeter work, Dr Hirschler expresses concerns over the thickness of the
169 comfort layer in proportion to a full-scale mattress. This is an inevitable problem of bench scale
170 assessment of real fire behaviour. For the samples to be proportionate, a finer fabric would also
171 have to be woven, and a thinner polyester layer used. In this work we use the same composition as
172 the sofa-bed mattress, to see how they behaved in a small scale test. However, because the bench-
173 scale test supports his view that flame retardants are always beneficial, he says it shows “the UK
174 flame retarded system is vastly superior in fire performance to all others”. Readers can judge for
175 themselves whether they place more faith in a 100 x 100 x 25 mm³ test than they do in a full scale
176 sofa-bed burn, but they produced very clearly different results.

177

178 Performance of Gas Phase Flame Retardants in Large Scale Tests

179 In his introductory summary, Dr Blais asserts that “the lack of clear explanations or visual
180 photography of the fire puts the validity of the results recorded in the paper in doubt.” Typically,
181 furniture is tested in an open calorimeter which is well-ventilated, making it the worst case scenario
182 for flammability but minimising smoke toxicity. This study was designed to simulate a fire in a real
183 room, as found in a typical European dwelling, where most UK fire deaths are reported to occur.
184 Thus, the fire was in a test room, not in the open, hence detailed photographic records are not
185 available. The original paper explains that the fire room was in a steel shipping container with a low
186 level circular ventilation duct and a high level open window, and says “Ignition was observed
187 through a small viewing port in the plasterboard wall.” Compared to measured concentrations of
188 carbon monoxide and hydrogen cyanide, the “lack of visual photography” is a weak argument to cast
189 doubt on the validity of the work reported in the paper.

190

191 In the original paper it explains that “data from large scale fires (Andersson et al., 2005; Blomqvist et
192 al., 2001) in enclosures show much higher levels of both asphyxiant gases CO and HCN under
193 conditions of developed flaming than those from small, well-ventilated tests, such as the cone
194 calorimeter (ISO 5660-1, 2015). For a particular material, under different fire conditions, the HCN
195 yield has been shown to rise proportionately with the CO yield (Molyneux et al., 2014b; Wang et al.,
196 2011; Purser et al., 2008).”

197 Dr Blais asserts that “The most egregious issue with the paper is comparing the cyanide production
198 as a function of flame retardant when the foams used in the experiments are not even close to
199 comparable. UK/CH foams with flame retardant have 12.88% by weight N while the EU foam is only
200 5.5% N. This limits the total possible HCN that can be produced by the EU foam to less than 50% of
201 that for the UK/CH foam.” With hindsight, the uncertainty of the analysis in Table 3 should have
202 been commented on. In subsequent work we have found inconsistencies in our CHNS measurements
203 of commercial materials (and we doubt that there are commercially available polyurethane foams
204 with such low nitrogen content). Additionally, in a number of other studies (Purser, 2008) it has been
205 shown that typically around 10% of fuel nitrogen remains as hydrogen cyanide in the effluent,
206 although, like carbon monoxide, more hydrogen cyanide is present within the flame. This is indeed
207 why gas-phase flame retardants which quench the flame reactions, such as brominated aromatics
208 used in the fabric or the trichloroalkyl phosphates used in foam, increase the yield of both carbon
209 monoxide and hydrogen cyanide.

210

211 Under the title “Mechanism of action of flame retardants”, Dr Hirschler states that “the addition or
212 incorporation of flame retardants (or the use of any process that lowers flammability) will result in
213 less complete combustion...[because] the exothermic combustion reactions are partially inhibited.”
214 This statement fails to make the important distinction between gas phase *flame* retardants, which
215 favour the formation of key toxicants, including carbon monoxide and hydrogen cyanide, and
216 condensed phase *fire* retardants, which often work by forming a protective layer, keeping the fuel in

217 the condensed phase, where it will not burn, which do not usually have an adverse effect on the fire
218 toxicity.

219

220 Dr Blais observes that “inclusion of FR in the materials results in a smaller fire that does less tissue
221 damage [through burns etc] but still produces toxic smoke. It becomes a race as to which kills you –
222 heat or toxic smoke. FR slowed down the heat release resulting in toxicity winning the race. This is
223 demonstrated well in the heat, CO and HCN graphs in figures 7, 8 and 9 in this paper.” This is a valid
224 point, and one that we as authors of this study would like to see debated further, based on further
225 experimental data. However, the argument will not be resolved if ignition sources are selected that
226 *just* ignite one item, while *just* failing to ignite another.

227

228 Dr Blais then amplifies a fourth benefit of flame retardants, that there is “a reduction in the amount
229 of materials consumed which affects the total heat release and total smoke produced. FR-protected
230 materials often are not completely consumed resulting in lower total heat release and lower total
231 toxic smoke.” This is a valid point and makes another useful contribution to the debate. Indeed, in
232 conducting comparative fire hazard assessments on any two sofas, by knowing the extent of
233 burning, and the toxic potency of the smoke is the only way a valid assessment could be undertaken.
234 Unfortunately, while this is information that is probably well-known by test laboratories such as
235 SWRI, it is not generally available in the public domain.

236

237

238 Funding

239 Dr Hirschler incorrectly describes CottonSafe as the project sponsor, while Dr Blais maintains that
240 funding of senior academics has not been disclosed. As University academics we have a degree of
241 autonomy to pursue research, such as this, following our own instincts. As stated in the

242 acknowledgements, “We would all like to thank Mark Downen of Cottonsafe Natural Mattress for
243 provision of samples, help and advice”. CottonSafe did manufacture and supply, at our request, the
244 eight sofa-bed mattresses, and samples of the foams and fabrics for our bench scale testing. They
245 also loaned a steel frame in order to avoid the complication of a wood frame burning to help
246 differentiate the different mattress formulations. Apart from that outlined in the
247 Acknowledgements, no funding was received from any source, other than our respective employers.

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