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REVIEW REPORT

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Article : Flame retardants in UK furniture increase smoke toxicity more than they reduce fire growth rate.

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SUMMARY

1. GENERAL COMMENTS

This article is well-written and conclusive, however it is not surprising that it was not submitted to a "fire" journal (Fire Technology, Journal of Fire Science, Fire and Materials, Fire Safety Journal mainly) but to a generic journal, because it would probably have been rejected by specialists in the field.

The problem with this article is mainly its attempt to make a generality of very specific cases of upholstered furniture. Fire scenarios are poorly fixed, rendering the interpretation of toxicity very limited. Indeed, given the scenario chosen for full-scale test, the fire is quickly under-ventilated and the tenability conditioned by the temperature. In this case, the emission of fumes has little importance close to the fire. For example, the reference to the stability models of ISO 13571 is very limited, especially because this standard requires evaluation of all the parameters simultaneously. Similar papers published in recent years don't have these flaws[1].

The statistical data used are partial and not objective. They are interpreted only to support the conclusions of this article, and omit much of the information (see below).

Experimental data remain poor in representativeness and kinetic resolution. A use of FTIR would have been much more appropriate.

In conclusion, the publication is not useful and confusing, supported by a poor statistical analysis and weak experimental data and trying to generalize conclusions performed on specific upholstered furniture. The conclusions should be performance-oriented, whatever the technical solutions are (flame retardants, fire barriers, intrinsically good performing materials, etc). The work and conclusions appear more as an advertising for Cottonsafe Natural Mattresses Company than scientific research.

2. DETAILED COMMENTS

2.1 Fire statistics section

Decrease in fatalities are well established and visible since mid-seventies. However, the choice of comparing UK and New-Zealand statistics is strange, and it may be more valuable to compare with continental Europe to support the discussion.

The statistics shown don't separate public buildings with dwellings, and don't focus on the proportion of intentional fires. These two aspects are essential for a proper conclusion.

The link between upholstered furniture fires and fatalities is too limited, and omits very important key parameters, such as: did the fatality occur in the same room as the fire?, what is the proportion of night scenarios?, as examples.

The UK statistics highlighted in the paper don't demonstrate anything as they are the consequence of simultaneous changes in regulation, with increased flammability requirements of furniture and smoke detectors.

The question of use of flame retardants occurs at this point (page 7 of the paper), but all flame retardants are mixed (voluntary?). There is no difference made in the paper on flame retardants that are covalent bonded to the polymer matrix from those that are added by various techniques. The strength of the link between FR and its matrix is however a key parameter. It appears that this section introduces confusion between different kinds of chemicals and between toxicity (or eco-toxicity) of the substance itself and of the toxicity of its effluents in case of fire.

[1] Guillaume, E., Didieux, F., Thiry, A., Bellivier, A. Real-scale fire tests of one bedroom apartments with regard to tenability assessment. Fire Safety Journal, 2014

2.2 Toxic potency of Fire Effluents section

This section relates to toxic potency, which needs to be differentiated from toxic emissions in a given scenario. The reference to ISO 13571 in this section is very questionable, as this standard and ISO 19706 both relate to a scenario-based approach, which combines fire development with gas analysis. Equation 1 is also insufficient alone as both quantities of ISO 13571 (FEC and FED) have to be determined in the version used in this paper. Note that ISO 13571 is in revision, with the intention to align it with the AEGL/SWOT approach and base the assessment on non-lethal endpoint.
For lethality, equation 2 comes from ISO 13344. This is supposed valid if individual ratios of concentration divided by LC50 correspond together. It means that concentrations used in this equation should be averaged concentrations over 30 minutes divided by a LC50 of 30 minutes. The time dimension is neglected in the way the equation is applied here.

2.3 Influence of FRs on fire toxicity section

This section omits in general the importance of the balance between toxic potency and the quantity of product burnt in end-use scenario. For example, it is entirely acceptable for a product to emit potentially very toxic fumes in a given scenario if the total quantity of product burned and therefore fumes produced remains limited. On the contrary, a product that releases only a small amount of toxic fumes per unit mass but burns rapidly and in total will be much more preoccupying. This is the sense of mass loss model of ISO 13571, which is never mentioned here.

2.4 Influence of fire conditions on toxic product yields section

It is true that fire conditions and especially ventilation and heat fluxes influence the generation of gas species. Nevertheless, fire scenarios are not defined here and missing from statistics section: do we focus on fires driven by the ventilation in post-flashover only, which makes no sense and is very restrictive? A common scenario for upholstered furniture is also the small smouldering scenario leading to a lethal environment without large fire development. Another question arising here is the evacuation scenario with the fire development, and again the same questions as for statistical analysis: where is occupant located versus the fire, and what is the time history. This lack of scenario analysis makes the rest the discussion under this section less pertinent.

2.5 Experimental section – materials

No information is given about the choice of materials and products for the study. What are their representative over the UK and continental Europe market, why these particular solutions, etc. Equally, can you reduce the market to 3 products? A large number of technical solutions to enhance fire behavior of upholstered furniture are not listed. No reference is made to previous studies in various systems, including the extensive study CBUF during the nineties. At least cost-benefits analysis makes sense and is missing.
The nature of the covers and of flame retardants used is missing here. This is detailed by chemical analyses presented in the next section. The analyses show only non-reactive flame retardants. Their presence in the sample makes questionable the selection of the products tested and a more extensive study of FR used on the market would have been a benefit.

2.6 Experimental section – cone calorimeter

Test protocol proposed is the CBUF one. A key aspect for using this protocol is the ratio between foams, eventual interlayers and covering. This is not detailed here.

2.7 Experimental section – Large scale tests

The test geometry chosen is totally inconsistent and not representative of any scenario: the “room” (represented by a ship container, not equivalent in size and constituting materials) is too small and too highly ventilated, leading to a post-flashover scenario quite quickly. In real life, volumes are bigger and ventilations often lower, changing greatly the generation of heat and smoke from the fires.
The fire source considered is a crib #7. This is higher than the crib #5 specified for UK regulatory purposes, making the ignition scenario questionable too. Why choose such a source without further justification? And, why not make the link with the initial fire scenario statistical data?. A progressive ignition sequence from cigarette to match, then to crib 5 and finally crib 7 or higher may have been more relevant.
Gas sampling and analysis is very poor. The technology for CO and CO_2 analysis is not detailed, as well as the uncertainty. The kinetics of HCN is poorly resolved, with 7 slots. The method used is also not detailed but it is well known that wet chemistry methods such picric acid colorimetry for HCN present also a lot of interferences, e.g. from aldehydes. See ISO 19701 for more details. The chemical method validation is not detailed, nor the expected uncertainties. No irritant is measured. As a consequence, acute toxic assessment is so partial that it makes little sense. FTIR analysis would have been more suitable. See examples of ISO TR 13571-2 as examples of proper sampling and analysis conditions (annexes A and B of the standard). Please note that sampling point is not defined, for example on figure 5.
In conclusion, for this section, the test scenario is not linked to the statistical analysis. Analyses are too poor to be described, conclusive, or validated.

2.8 Results

For both the small-scale tests (cone calorimeter) and the large scale tests, the results are poor and chemical analyses not enough evaluated to be conclusive. A plot of CO/CO_2 ratio is needed to interpret them, and at least the time resolved concentration curves for each species should have been made Reconstruction of HCN kinetics from CO kinetics makes no sense.
In the large scale test, for the large majority of cases studied, tenability is driven first by thermal conditions, making the considerations of smoke toxicity not useful. Why consider smoke toxicity when you are breathing smoke over 200°C? This is again linked to the questions of scenario. For 3 of 4 products, tenability is impaired a long time before CO drops. CO drops when fire starts to be under-ventilated post-flashover. It is true that the “FRfreeCS” composition behaves well, but the representativeness of all other compositions is questionable as seen previously. Technical solutions of equivalent price probably easily exist – this is never detailed.
Figure 9 is an artificial mathematical treatment and makes no sense. The approach is very approximate and should not be used.
Considerations on page 22 on flow vents are out-of-date and should be made with fire modeling, especially because enclosure used is metallic, which is not compatible with flow equations of reference 41 [2].
Considerations on irritants and on thermal FEDs are missing leading to incorrect conclusions, limited to the selected scenario (small room, large ignition source) and limited to the selected products.

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[2] Tanaka, T. Vent flows, (2016) SFPE Handbook of Fire Protection Engineering, Fifth Edition, pp. 455-485