Environment International 173 (2023) 107782

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Short communication

A new consensus on reconciling fire safety with environmental & health impacts of chemical flame retardants

Jamie Page[a,*], Paul Whaley[b,*], Michelle Bellingham[c], Linda S. Birnbaum[d], Aleksandra Cavoski[e], Delyth Fetherston Dilke[f], Ruth Garside[g], Stuart Harrad[h], Frank Kelly[i], Andreas Kortenkamp[j], Olwenn Martin[k], Anna Stec[l], Tom Woolley[m]

[a] *The Cancer Prevention & Education Society, UK*
[b] *Lancaster Environment Centre, Lancaster University, UK*
[c] *School of Biodiversity, One Health and Veterinary Medicine, University of Glasgow, UK*
[d] *National Institute of Environmental Health Sciences and National Toxicology Program, Scholar in Residence, Nicholas School of the Environment, Duke University, USA*
[e] *Birmingham Law School, University of Birmingham, UK*
[f] *Guild of Traditional Upholsterers, UK*
[g] *University of Exeter Medical School, University of Exeter, UK*
[h] *School of Geography, Earth and Environmental Sciences, University of Birmingham, UK*
[i] *Faculty of Medicine, School of Public Health, Imperial College, London, UK*
[j] *College of Health, Medicine and Life Sciences, Brunel University, UK*
[k] *Department of Arts and Sciences, University College London, UK*
[l] *Centre for Fire and Hazards Sciences, University of Central Lancashire, UK*
[m] *Ecological Design Association Northern Ireland, NI, UK*

A R T I C L E I N F O

Handling Editor: Adrian Covaci

Keywords:
Flame retardants
Fire safety
Furniture
Upholstery
Policy
Regulation

A B S T R A C T

Flame retardants are chemical substances that are intended to mitigate fire safety risks posed by a range of goods including furniture, electronics, and building insulation. There are growing concerns about their effectiveness in ensuring fire safety and the potential harms they pose to human health and the environment. In response to these concerns, on 13 June 2022, a roundtable of experts was convened by the UKRI Six Clean Air Strategic Priorities Fund programme 7. The meeting produced a Consensus Statement that summarises the issues around the use of flame retardants, laying out a series of policy recommendations that should lead to more effective fire safety measures and reduce the human and environmental health risks posed by these potentially toxic chemicals.

Flame retardants are a diverse group of substances, including both inorganic and organic chemicals, that are used in a wide range of applications including furniture, building materials, and electronic goods. They can be designed as monomeric or polymeric molecules, and be mixed or reactively combined with the materials to which they are added. Many molecules acquire flame retardant properties through the addition of halogens such as bromine and chlorine. The inclusion of halogens often renders molecules more persistent and bioaccumulative. This becomes particularly problematic for organic flame retardants, leading to the phase-out of several compounds including polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecane (HBCDD), and increasing concern about others including tetrabromobisphenol-A (TBBPA). Many flame retardants present problems after phase-out, remaining in old furniture and building materials and continuing to contaminate the wider environment.

The United Kingdom has some of the highest use of flame retardants in the world (Brommer and Harrad, 2015; Harrad, Brommer and Mueller, 2016; Kademoglou et al., 2017). These are added to textiles and furniture to pass open flame ignition tests which are an integral part of the Furnishing and Fire Regulations (Fire) (Safety) 1988 (henceforth "FFRs"). Open flame ignition testing involves applying a lighted source such as a burning crib or a small flame to the item being tested for a defined length of time. Flame retardants are used to meet these tests by preventing full flaming.

* Corresponding authors.
E-mail addresses: jpage@cancerpreventionsociety.org (J. Page), p.whaley@lancaster.ac.uk (P. Whaley).

https://doi.org/10.1016/j.envint.2023.107782
Received 21 November 2022; Received in revised form 19 January 2023; Accepted 25 January 2023
Available online 28 February 2023

The rationale for using flame retardants is to delay time to full burning when an ignition source initiates a fire. Whilst this appears a logical thing to do, particularly given changes in the material design of furnishings and building materials that have led to increased use of flammable materials, there is a need to examine whether the open flame ignition test is fit for purpose. This examination should focus on the extent to which the test truly leads to reduced fire risks, and the balance of this purported benefit against the widespread exposure to flame retardants that results from meeting the ignition tests.

Many flame retardants are bioaccumulative and persistent, particularly those containing bromine and chlorine (Segev, Kushmaro and Brenner, 2009). They are found in air and dust, food and drinking water, and on indoor surfaces and textiles where they can be absorbed through dermal contact (Abdallah and Harrad, 2018; Abou-Elwafa Abdallah and Harrad, 2022). They are found in homes, offices, schools, public buildings, vehicles, and natural environments (in rivers, lakes, oceans, sediments and mammals, fish, and birds) from the poles to the equator (Brommer and Harrad, 2015; Tao, Abdallah and Harrad, 2016; Dodson et al., 2017; Persson et al., 2018; Wemken et al., 2019; Hou et al., 2021; Yao et al., 2021). Small children are particularly exposed to flame retardants because of their crawling and mouthing behaviours (Sugeng et al., 2020).

Humans are also exposed to these substance at all stages of the lifecycle of the products to which they are added: during manufacture and assembly of products, throughout their normal use, and at the end of their life when they are disposed of or recycled. Recycling causes particular difficulties for waste managers and recyclers (Ma et al., 2021; Balasch et al., 2022) because, due to issues such as a lack of product labelling, it is very difficult to identify which products contain flame retardants Consequently, these chemicals can inappropriately end up in recycled goods such as cookware (Straková et al, 2018). Even if they could be identified, the presence of problematic flame retardants anyway creates a significant hurdle to implementing a circular economy by limiting how products containing them can be recycled (Straková et al. 2018). Additionally, there is evidence that, during a fire, some flame retardants may exacerbate yields of toxic gases and smoke formed by burning foams which are a major cause of death (Stec, 2017; McKenna et al., 2018).

There are hundreds of scientific papers reporting deleterious effects of flame retardants (*in vitro, in vivo,* and human studies). These effects include developmental, behavioural, and neurotoxic effects, endocrine disrupting effects, impact on sex and thyroid hormones, carbohydrate & lipid metabolism, diabetes risk, adipogenesis, obesity, and reproduction (Hendriks and Westerink, 2015; Blum et al., 2019; Doherty et al., 2019; Xiong et al., 2019; Patisaul et al., 2021). Some flame retardants are reported to be carcinogenic (van der Veen and de Boer, 2012; Wei et al., 2015) and some studies report effects on DNA damage or changes in DNA methylation (Soubry et al., 2017; Bukowski et al., 2019; Yuan et al., 2019). Other studies have reported cardiotoxicity and cardiac abnormalities, hepatotoxicity, hearing, corneal cell damage, allergic, immune, and kidney effects (Park et al., 2016; Xiang et al., 2017; Alzualde et al., 2018; Araki et al., 2018; Mitchell et al., 2018; Ait Bamai et al., 2019; Kang et al., 2019; Wang et al., 2019; Sun et al., 2020).

The UK FFRs have been under government review for their fitness for purpose since at least 2014 in a process initiated by the UK Department of Business, Innovation and Skills (now Business, Energy, and Industrial Strategy). To date no revised policy has been formally proposed. Following the Grenfell Tower fire, there has been understandable concern not to weaken fire regulations. The critical question, however, relates to the overall effectiveness of the existing regulations. The concerns that have resulted in calls for their re-evaluation include the following: an over-reliance on flame retardants, a failure to address the key issue of the intrinsic flammability and fire toxicity of many upholstery and insulation foams used today, and insufficient demonstration of the true effectiveness of ignition tests in comparison to other fire safety interventions. The situation is analogous to diesel fuel, once considered as environmentally friendly, but only because of a narrow focus on fuel efficiency and disregard of non-CO_2 pollutants such as particulate matter.

Over-reliance on flame retardants inevitably creates serious and largely unconsidered problems for future generations. Over time, flame retardants are released into homes, offices, buildings, and vehicles through a combination of volatilization, abrasion of fibres and particles from treated fabrics, and as a result of foam degradation. Because products are not labelled or bar-coded, it is not known what flame retardants are used in foams and, even if it were, a flame retardant considered safe today may be found not to be in the future. Currently it takes years or even decades to restrict chemicals under both REACH and the Stockholm convention (POPs).When this happens there is no easy and economical way of identifying and removing the affected items, especially when they are used in building insulation. It would be much more sensible to use materials that are intrinsically fire resistant and safe.

The 2019 UK Environmental Audit Committee (EAC) report *Toxic Chemicals in Everyday Life* identified many concerns regarding the use of flame retardants that motivate urgent legal reform and wider policy changes in this sector (Environmental Audit Committee, 2019). The report highlights several examples of policies aimed at reducing the use of flame retardants. These include: the revision in 2014 of California's revised domestic furniture standard, Technical Bulletin 117, leading to reduced use of flame retardants in upholstered furniture and children's products; California banning in 2018 the sale of furniture, baby products, and mattresses containing flame retardants, and repealing its open flame test standard for upholstered furniture in public spaces, with several other states adopting similar measures; and in 2017 the U.S. Consumer Product Safety Commission passing guidelines recommending that manufacturers refrain from adding non-polymeric organohalogen flame retardants to children's products, mattresses, electronic casings, and furniture (CPSC 2017). The EU has also proposed a ban on halogenated flame retardants in electronic displays under the Eco-design Directive. The European Chemicals Agency (ECHA) has proposed a restriction on the sale of children's products and upholstered furniture with polyurethane foams containing the flame retardants TCEP, TCIPP, and TDCIPP[1], pending the results of on-going studies by the US National Toxicology Program.

With these considerations in mind, a roundtable of experts was convened by the UK Research and Innovation Clean Air Strategic Priorities Fund programme on 13 June 2022, to discuss these many issues and to make strategic recommendations that would explore effective reform of UK fire safety policy (Whaley et al. 2022). The result of these deliberations is in the Consensus Statement below, signed by the authors of the present paper.

The aim of the Consensus Statement is to call for a thorough re-evaluation of how fire safety should be achieved. The Statement summarises the issues posed by flame retardants (in particular, additive organic flame retardants), materials and current approaches; and lays out a series of policy recommendations that should lead to more effective fire safety measures and reduce the human and environmental health risks posed by these potentially toxic chemicals. It is the sincere hope of the authors and signatories of the statement that these concerns and recommendations be heeded and acted upon now.

[1] TCIPP = tris(2-chloro-1-methylethyl) phosphate; TDCIPP = tris[2-chloro-1-(chloromethyl)ethyl] phosphate; and TCEP = tris(2-chloroethyl) phosphate.

Consensus Statement on the Use of Flame Retardants in the United Kingdom

Whereas:

i. The UK is one of the highest users of flame retardants in the world.
ii. Flame retardants are found in many goods used in everyday life such as furniture foams and fabrics, electrical items, and building insulation.
iii. Flame retardants migrate out of the goods to which they are added and are found in homes, classrooms, offices, public buildings, vehicles, and the wider environment.
iv. Flame retardants are ubiquitous environmental chemical pollutants and are present in rivers, lakes, sediments, soil, air, mammals, birds, and fish throughout the world.
v. Humans are exposed via air, dust, skin, food, water, and breast milk.
vi. Exposure is unavoidable.
vii. Infants and young children are disproportionately exposed because of hand-to-mouth and mouthing behaviours.
viii. A large and rapidly-expanding evidence base shows that exposure to flame retardants increases risks of deleterious health effects including developmental and behavioural disorders, neurotoxicity, endocrine disruption, metabolic disruption, cancer, and many other effects.
ix. Scientific evidence of harm typically accumulates only after the introduction of flame retardants to market and exposure has already become widespread.
x. Flame retardants found to be harmful will continue to be released from products such as furniture decades after manufacture. This disproportionately affects lower socioeconomic groups.
xi. There is significant uncertainty about whether and to what extent flame retardants contribute to fire safety.
xii. The UK's approach to securing fire safety is narrowly focused on passing ignition tests. This incentivises the addition of large amounts of fire retardants to furniture and other items and materials, without a clear net benefit in reduction of harm.
xiii. There is evidence that flame retardants exacerbate smoke and fire toxicity. A significant proportion of fire deaths are caused by inhalation of toxic fumes, including cyanide gas and carbon monoxide.
xiv. Flame retardants are problematic at all stages of the lifecycle: in manufacturing, everyday use, during fires, recycling (thereby compromising the circular economy) and disposal.

The following signatories call on the UK government to:

a. Minimise the need for chemical flame retardants by incentivising industry to develop benign-by-design furniture, building materials, and other goods. These should be made from materials that are inherently less flammable and less likely to produce toxic smoke than conventional, highly flammable foams and other products that require significant addition of flame retardants in order to comply with fire safety standards. Fire safety standards should actively encourage fire safety by innate product design, rather than by chemical flame retardant usage.
b. Adopt a systemic approach to fire safety standards, evaluating the contribution of flame retardants to fire safety in the context of behaviours that initiate fires, factors that affect fire propagation, smoke generation, and toxicity during fires, and vulnerabilities that make people more likely to be harmed in a fire. This includes stepping away from a reductionist view that the passing of ignition tests is sufficient to ensure fire safety. Where ignition tests are used as part of a fire safety system, their effectiveness in improving fire safety, impact on product design innovation, and their consequences for flame retardant usage, should be fully evaluated.
c. Improve the governance of standards, regulation, and testing of flame retardants and fire safety. Fire safety needs to be recognised as a complex, multi-disciplinary problem that requires joined-up thinking and strategic oversight; inclusive, broadly representative, open processes that represent different stakeholder views and expertise; and ensuring that decision-making and integrity of deliberative processes are not compromised by conflicted interests.
d. Promote a culture of and funding for human environmental health research in the UK, to support the development, synthesis, and interpretation of the multi-disciplinary evidence base that is required for making evidence-informed decisions in complex regulatory environments.
e. Ensure that a very high level of certainty about the human and environmental safety of flame retardants is demonstrated before they are approved for use, and that pro-active, systematic evidence generation and monitoring systems are in place to flag unanticipated issues and ensure rapid replacement of problematic flame retardants with safer alternatives.
f. Develop a labelling system for tracking the use of chemicals in products, including flame retardants, that allows undesirable substances to be easily identified and diverted away from the circular economy.

CRediT authorship contribution statement

Jamie Page: Conceptualization, Writing – original draft, Writing – review & editing. **Paul Whaley:** Conceptualization, Writing – original draft, Writing – review & editing. **Michelle Bellingham:** Writing – original draft, Writing – review & editing. **Linda S. Birnbaum:** Writing – original draft, Writing – review & editing. **Aleksandra Cavoski:** Writing – original draft, Writing – review & editing. **Delyth Fetherston Dilke:** Writing – original draft, Writing – review & editing. **Ruth Garside:** Writing – original draft, Writing – review & editing. **Stuart Harrad:** Writing – original draft, Writing – review & editing. **Frank Kelly:** Writing – original draft, Writing – review & editing. **Andreas Kortenkamp:** Writing – original draft, Writing – review & editing. **Olwenn Martin:** Writing – original draft, Writing – review & editing. **Anna Stec:** Writing – original draft, Writing – review & editing. **Tom Woolley:** Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: JP is Chief Executive of the Cancer Prevention and Education Society, a registered charity with a mission of raising awareness of the health impacts of environmental exposures. PW is a researcher and consultant and declares receiving financial compensation from University of Central Lancashire for conducting research commissioned by the UK Office of Product Safety and Standards to inform potential revisions to the UK FFRs. DFD is an upholsterer focusing on natural, sustainable materials. TW is an architect focusing on housing using renewable materials. MB, LB, AC, RG, SH, FK, AK, OM, AS are researchers investigating exposure to, health impact of, and regulation of chemical products, holding academic employment and a range of grants relating thereto.

Data availability

No data was used for the research described in the article.

References

Abdallah, M.-A.-E., Harrad, S., 2018. Dermal contact with furniture fabrics is a significant pathway of human exposure to brominated flame retardants. Environ. Int. 118, 26–33. https://doi.org/10.1016/j.envint.2018.05.027.

Abou-Elwafa Abdallah, M., Harrad, S., 2022. Dermal uptake of chlorinated organophosphate flame retardants via contact with furniture fabrics; implications for human exposure. Environ. Res. 209, 112847 https://doi.org/10.1016/j.envres.2022.112847.

Ait Bamai, Y., et al., 2019. Multiple exposures to organophosphate flame retardants alter urinary oxidative stress biomarkers among children: The Hokkaido Study. Environ. Int. 131, 105003 https://doi.org/10.1016/j.envint.2019.105003.

Alzualde, A., et al., 2018. Toxicity profiling of flame retardants in zebrafish embryos using a battery of assays for developmental toxicity, neurotoxicity, cardiotoxicity and hepatotoxicity toward human relevance. Neurotoxicol. Teratol. 70, 40–50. https://doi.org/10.1016/j.ntt.2018.10.002.

Araki, A., et al., 2018. Associations between allergic symptoms and phosphate flame retardants in dust and their urinary metabolites among school children. Environ. Int. 119, 438–446. https://doi.org/10.1016/j.envint.2018.07.018.

Balasch, A., et al., 2022. Exposure of e-waste dismantlers from a formal recycling facility in Spain to inhalable organophosphate and halogenated flame retardants. Chemosphere 294, 133775. https://doi.org/10.1016/j.chemosphere.2022.133775.

Blum, A., et al., 2019. Organophosphate Ester Flame Retardants: Are They a Regrettable Substitution for Polybrominated Diphenyl Ethers? Environ. Sci. Technol. Lett. 6 (11), 638–649. https://doi.org/10.1021/acs.estlett.9b00582.

Brommer, S., Harrad, S., 2015. Sources and human exposure implications of concentrations of organophosphate flame retardants in dust from UK cars, classrooms, living rooms, and offices. Environ. Int. 83, 202–207. https://doi.org/10.1016/j.envint.2015.07.002.

Bukowski, K., et al., 2019. DNA damage and methylation induced by organophosphate flame retardants: Tris(2-chloroethyl) phosphate and tris(1-chloro-2-propyl) phosphate in human peripheral blood mononuclear cells. Hum. Exp. Toxicol. 38 (6), 724–733. https://doi.org/10.1177/0960327119839174.

CPSC Consumer Product Safety Commission, (2017). Guidance Document on Hazardous Additive, Non-Polymeric Organohalogen Flame Retardants in Certain Consumer Products. 82 FR 45268. CPSC Docket No. CPSC-2015-0022. Available at: https://www.federalregister.gov/documents/2017/09/28/2017-20733/guidance-document-on-hazardous-additive-non-polymeric-organohalogen-flame-retardants-in-certain.

Dodson, R.E., et al., 2017. Flame Retardant Chemicals in College Dormitories: Flammability Standards Influence Dust Concentrations. Environ. Sci. Tech. 51 (9), 4860–4869. https://doi.org/10.1021/acs.est.7b00429.

Doherty, B.T., et al., 2019. Organophosphate Esters: Are These Flame Retardants and Plasticizers Affecting Children's Health? Curr. Environ. Health Rep. 6 (4), 201–213. https://doi.org/10.1007/s40572-019-00258-0.

Environmental Audit Committee, UK House of Commons, (2019). Toxic Chemicals in Everyday Life. HC1805. Available from: https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/1805/1805.pdf.

Furniture and Furnishings (Fire) (Safety) Regulations, (1988). (SI 1988/1324), Parliament of the United Kingdom. Available at: https://www.legislation.gov.uk/uksi/1988/1324/made.

Harrad, S., Brommer, S., Mueller, J.F., 2016. Concentrations of organophosphate flame retardants in dust from cars, homes, and offices: An international comparison. Emerg. Contam. 2 (2), 66–72. https://doi.org/10.1016/j.emcon.2016.05.002. Available at:

Hendriks, H.S., Westerink, R.H.S., 2015. Neurotoxicity and risk assessment of brominated and alternative flame retardants. Neurotoxicol. Teratol. 52 (Pt B), 248–269. https://doi.org/10.1016/j.ntt.2015.09.002.

Hou, R., et al., 2021. Occurrence, bioaccumulation, fate, and risk assessment of novel brominated flame retardants (NBFRs) in aquatic environments - A critical review. Water Res. 198, 117168 https://doi.org/10.1016/j.watres.2021.117168.

Kademoglou, K., et al., 2017. Legacy and alternative flame retardants in Norwegian and UK indoor environment: Implications of human exposure via dust ingestion. Environ. Int. 102, 48–56. https://doi.org/10.1016/j.envint.2016.12.012.

Kang, H., et al., 2019. Urinary metabolites of organophosphate esters (OPEs) are associated with chronic kidney disease in the general US population, NHANES 2013–2014. Environ. Int. 131, 105034 https://doi.org/10.1016/j.envint.2019.105034.

Ma, Y., et al., 2021. Human exposure to halogenated and organophosphate flame retardants through informal e-waste handling activities - A critical review. Environ. Pollut. 268 (Pt A), 115727 https://doi.org/10.1016/j.envpol.2020.115727.

McKenna, S.T., et al., 2018. Flame retardants in UK furniture increase smoke toxicity more than they reduce fire growth rate. Chemosphere 196, 429–439. https://doi.org/10.1016/j.chemosphere.2017.12.017.

Mitchell, C.A., et al., 2018. 'Disruption of Nuclear Receptor Signaling Alters Triphenyl Phosphate-Induced Cardiotoxicity in Zebrafish Embryos'., *Toxicological sciences : an official journal of the Society of*. Toxicology 163 (1), 307–318. https://doi.org/10.1093/toxsci/kfy037.

Park, C., et al., 2016. Tetrabromobisphenol-A induces apoptotic death of auditory cells and hearing loss. Biochem. Biophys. Res. Commun. 478 (4), 1667–1673. https://doi.org/10.1016/j.bbrc.2016.09.001.

Patisaul, H.B., et al., 2021. Beyond Cholinesterase Inhibition: Developmental Neurotoxicity of Organophosphate Ester Flame Retardants and Plasticizers. Environ. Health Perspect. 129 (10), 105001 https://doi.org/10.1289/EHP9285.

Persson, J., Wang, T., Hagberg, J., 2018. Organophosphate flame retardants and plasticizers in indoor dust, air and window wipes in newly built low-energy preschools. Sci. Total Environ. 628–629, 159–168. https://doi.org/10.1016/j.scitotenv.2018.02.053.

Segev, O., Kushmaro, A., Brenner, A., 2009. Environmental impact of flame retardants (persistence and biodegradability). Int. J. Environ. Res. Public Health 6 (2), 478–491. https://doi.org/10.3390/ijerph6020478.

Soubry, A., et al., 2017. Human exposure to flame-retardants is associated with aberrant DNA methylation at imprinted genes in sperm. Environ. Epigenetics 3 (1), p. dvx003. https://doi.org/10.1093/eep/dvx003.

Stec, A.A., 2017. Fire toxicity – The elephant in the room? Fire Saf. J. 91, 79–90. https://doi.org/10.1016/j.firesaf.2017.05.003.

Straková, J., DiGangi, J., Jenson,G.K., (2018). Toxic Loophole: Recycling hazardous waste into new products. Available at: https://ipen.org/sites/default/files/documents/TL_brochure_web_final.pdf.

Sugeng, E.J., et al., 2020. Toddler behavior, the home environment, and flame retardant exposure. Chemosphere 252, 126588. https://doi.org/10.1016/j.chemosphere.2020.126588.

Sun, Y., et al., 2020. Hepatotoxicity of decabromodiphenyl ethane (DBDPE) and decabromodiphenyl ether (BDE-209) in 28-day exposed Sprague-Dawley rats. Sci. Total Environ. 705, 135783 https://doi.org/10.1016/j.scitotenv.2019.135783.

Tao, F., Abdallah, M.-A.-E., Harrad, S., 2016. Emerging and Legacy Flame Retardants in UK Indoor Air and Dust: Evidence for Replacement of PBDEs by Emerging Flame Retardants? Environ. Sci. Tech. 50 (23), 13052–13061. https://doi.org/10.1021/acs.est.6b02816.

van der Veen, I., de Boer, J., 2012. Phosphorus flame retardants: properties, production, environmental occurrence, toxicity and analysis. Chemosphere 88 (10), 1119–1153. https://doi.org/10.1016/j.chemosphere.2012.03.067.

Wang, X., et al., 2019. Evaluation of development, locomotor behavior, oxidative stress, immune responses and apoptosis in developing zebrafish (Danio rerio) exposed to TBECH (tetrabromoethylcyclohexane). Comp. Biochem. Physiol. C Toxicol. Pharmacol. 217, 106–113. https://doi.org/10.1016/j.cbpc.2018.12.004.

Wei, G.-L., et al., 2015. Organophosphorus flame retardants and plasticizers: sources, occurrence, toxicity and human exposure. Environmental pollution 196, 29–46. https://doi.org/10.1016/j.envpol.2014.09.012.

Wemken, N., et al., 2019. Concentrations of Brominated Flame Retardants in Indoor Air and Dust from Ireland Reveal Elevated Exposure to Decabromodiphenyl Ethane. Environ. Sci. Tech. 53 (16), 9826–9836. https://doi.org/10.1021/acs.est.9b02059.

Whaley, P., Page, J., Holgate S., (2022). Understanding and managing health risks from exposure to flame retardants, and the broader implications for UK chemicals policy. Available at: https://www.ukcleanair.org/2022/06/29/understanding-and-managing-health-risks-from-exposure-to-flame-retardants-and-the-broader-implications-for-uk-chemicals-policy/.

Xiang, P., et al., 2017. Effects of organophosphorus flame retardant TDCPP on normal human corneal epithelial cells: Implications for human health. Environ. Pollut. 230, 22–30. https://doi.org/10.1016/j.envpol.2017.06.036.

Xiong, P., et al., 2019. A Review of Environmental Occurrence, Fate, and Toxicity of Novel Brominated Flame Retardants. Environ. Sci. Tech. 53 (23), 13551–13569. https://doi.org/10.1021/acs.est.9b03159.

Yao, C., Yang, H., Li, Y., 2021. A review on organophosphate flame retardants in the environment: Occurrence, accumulation, metabolism and toxicity. Sci. Total Environ. 795, 148837 https://doi.org/10.1016/j.scitotenv.2021.148837.

Yuan, S., et al., 2019. Aryl-phosphorus-containing flame retardants induce oxidative stress, the p53-dependent DNA damage response and mitochondrial impairment in A549 cells. Environ. Pollut. 250, 58–67. https://doi.org/10.1016/j.envpol.2019.03.109.