# Managing Chemicals of Concern within a Circular Economy: The Impacts and Solutions for Chemical Flame Retardant Use in UK Mattresses

An Evidence Review by Fidra

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Fidra

Fidra is a Scottish registered charity and SCIO no.SC043895

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# Executive Summary

It is widely accepted that the current linear economic model is not sustainable. To achieve long-term environmental and economic security, societies must transition towards a circular approach in which products and services are designed to be in use for as long as possible, maximising their value and minimising waste. However, the impact of chemical content within a circular economy is often overlooked. Numerous case studies have demonstrated how lack of chemical transparency, coupled with regrettable substitution, can leave recycling efforts vulnerable to contamination with newly restricted or otherwise harmful chemicals. These include Bisphenol-A (BPA) found in recycled napkins and toilet paper, Per- or Poly-Fluorinated Alkyl Substances (PFAS) found in paper and cardboard food packaging labelled suitable for recycling or composting, and Brominated Flame Retardants (BRFs) found in recycled plastic products such as kitchen utensils and children's toys. Chemical management practises must therefore evolve to support a safe and successful circular economy.

An estimated 6.4 million mattresses were disposed of in the UK in 2020. To stimulate improved waste management, the National Bed Federation (NBF) are working towards a target of diverting 75% of mattresses from landfill by 2028. Bulky waste items, including mattresses, were also listed as priority items for Extended Producer Responsibility (EPR) schemes in England's 2018 Waste Strategy.

The current UK Furniture and Furnishings (Fire) (Safety) Regulations (FFRs) 1988 have been widely criticized as being outdated and ineffective. Prescriptive requirements within the FFRs have led to large volumes of chemical flame retardants (CFRs) being used within mattresses, contributing to the exceptionally high CFR exposure rates recorded amongst the UK public. Other countries with less prescriptive furniture fire safety requirements have demonstrated similar declines in fire fatality trends to the UK without relying in CFRs. This, combined with increasing evidence of the detrimental health and environmental effects of CFRs, has resulted in a call to amend UK fire safety regulations and reduce reliance on flame retardant chemicals.

CFR use presents a significant barrier to product circularity. This was highlighted in new research commissioned by the Environment Agency which identified high levels of decabromodiphenyl ether (decaBDE), a CFR now restricted under Annex A of the Stockholm Convention, in UK waste upholstered domestic seating. Affected items are now required to be incinerated, rather than reused or recycled. The known use of decaBDE in mattresses prior to its restriction, alongside emerging evidence connecting alternative CFRs, such as tris(2-chloroethyl) phosphate (TCEP) and tris(1,3-dichloroisopropyl) phosphate (TDCPP), with similar human and environmental health effects, demonstrates a significant and ongoing challenge for mattress recycling.

Use of CFRs in mattresses highlights the potential impacts of chemicals of concern within recycling initiatives, as well as an opportunity to demonstrate workable solutions. Options such as EPR schemes, increased chemical transparency and traceability, and changes to the FFRs, could help reduce reliance on CFRs, incentivise innovative and sustainable product design, and support successful long-term recycling initiatives.

# 1. Introduction

## 1.1 About Fidra

Fidra is an SCIO and Scottish registered charity (SC043895) working towards a vision of sustainable societies and healthy ecosystems. Through its projects, Fidra works alongside policy makers and industry representatives to champion best practice for resource efficiency and pollution prevention. With numerous on-going projects focused on sustainable chemical management, Fidra is aware of the essential role chemicals play in modern society, as well as the need for effective chemical regulation. Fidra therefore advocates for a pragmatic and evidence-based approach to chemical management that addresses the well documented need for improved human and environmental health protection, whilst continuing to drive competitive markets through more sustainable product innovation.

## 1.2 Fidra's Sustainable Fire Safety Project

This evidence review forms part of Fidra's Sustainable Fire Safety project which investigates the role of effective chemical management within a circular economy, using CFR use in mattresses as a case study. The various health and environmental concerns connected with CFRs, coupled with the lack of chemical transparency along supply chains, highlights a significant challenge when considering resource circularity. With bulky waste items, such as mattresses, identified as targets for increased recycling incentives in the UK, this review looks to assess the impacts of CFRs on current mattress recycling practices and possible solutions.

Following the findings of this review, Fidra will continue to engage with relevant stakeholders in working towards solutions. For further information on the project and opportunities for input, please contact Fidra directly via info@fidra.org.uk.

## 2. Chemicals and the Circular Economy

It is now widely accepted that our current take, use and dispose approach to product manufacture is not sustainable. This linear method has led to widespread waste and pollution, including excessive $CO_2$ emissions and a normalised undervaluing of our finite resources. To achieve responsible production and ensure long-term environmental and economic security, we must evolve and embrace a circular economy.

### 2.1 What is a Circular Economy?

A circular economy is an approach in which products and services are designed to be in use for as long as possible, maximising their value and minimising waste. This can be achieved through intelligent design of products that are built to last, simplifying dismantle and repair processes, and retaining the highest value of raw materials ready for reuse or recycling.

A hierarchy for resource management (Figure 1) is commonly used to further demonstrate the principles of a circular economy by outlining five key considerations for a products lifespan in order of preference. First prioritising 'Reduction' of any unnecessary materials or energy to lower the overall footprint of the manufacturing process. Then, ensuring products are designed to be long lived, easily repaired and 'Reused' for as long as possible. If these first steps cannot be achieved in entirety, products should then be built to achieve maximum recycling rates whilst retaining the highest possible value of the product's raw materials. When sustainable material recycling cannot be achieved, 'Energy Recovery' allows usable energy in the form of electricity, heat, or fuel to be retrieved from the treatment and processing of waste products (1). 'Disposal' of products to landfill or incineration without energy recovery is the final and least preferable option.

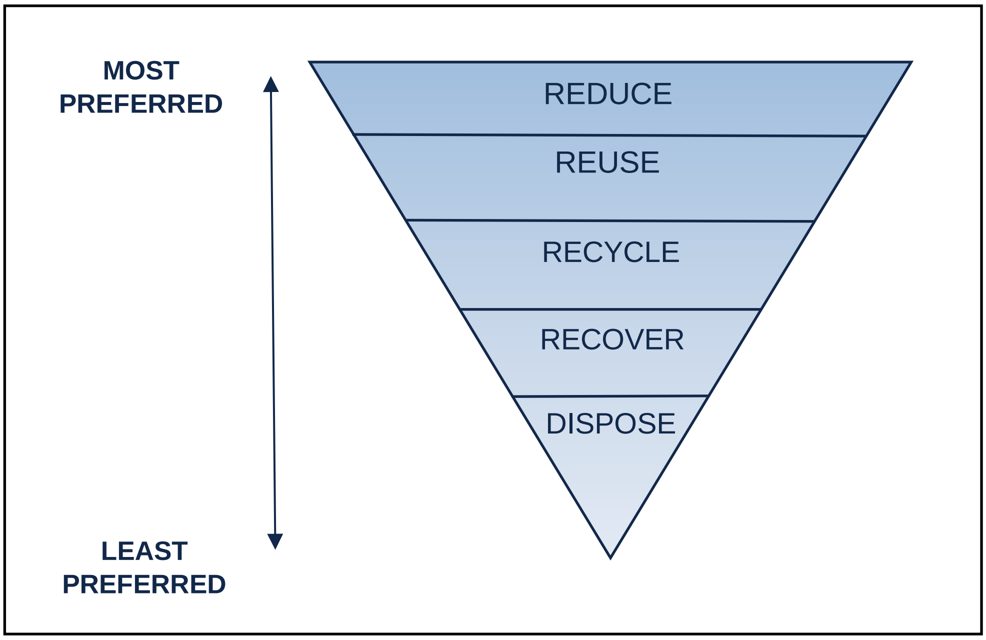


**Figure 1**: Resource Management Hierarchy. *Source: Fidra, 2023.*

## 2.2 A Circular Economy in the UK

### 2.2.1 Environmental Benefits

Climate Change

A growing body of research confirms that embracing a circular economy could offer major contributions towards achieving the UK's Net Zero targets, whilst still supporting a growing economy (2). In 2018, a Green Alliance report demonstrated that by improving resource efficiency in five key sectors (food and drink, electronics and appliances, clothing and textiles, vehicle manufacture, and construction), the UK could achieve its fourth carbon budget target and reduce an expected overshoot of its fifth target by up to 80% (3). This was echoed in a study conducted by the Ellen MacArthur Foundation that found emissions could be reduced by up to 40% in 2050 if a circular economy approach was applied to just four key materials: cement, steel, plastic, and aluminium (4).

Resource Management

Moving towards a circular economy also inherently works towards meeting the UK's resource management targets. The Resources and Waste Strategy for England (2018) for example, sets out to achieve zero avoidable waste and double resource efficiency by 2050 (5); both of which are outcomes of improved circularity. In their 2016 strategy, 'Making Things Last: A Circular Economy Strategy for Scotland', the Scottish Government similarly set targets to reduce waste by 2025, including a reduction in total generated waste by 15%, with 70% of remaining waste being recycled and no more than 5% being sent to landfill (6). In 2021, the Welsh Government published aims to reduce overall waste by 26%, with zero waste being sent to landfill by 2025 (7), and Northern Ireland is currently developing a new Waste Management Strategy to advance on its 2013 targets, due to be published in 2023 (8). At its core, the circular economy aims to design out waste and improve resource efficiency and so should be a key component for any future resource management strategy.

Biodiversity

Extraction of raw materials and pollution caused through goods manufacture, use and disposal intrinsically undermines the protection of our natural environment. In fact, it is estimated that up to 90% of global biodiversity loss and water stress can be attributed to resource extraction and processing (9). In addition to the targets set under its own 25 Year Environment Plan, the UK is also a signatory to the Convention on Biological Diversity (CBD) and must therefore continue to work towards the Aichi Biodiversity Targets and overall vision of ensuring "biodiversity is valued, conserved, restored and wisely used" by 2050 (10). By moving away from the linear economic model, the UK can begin to dissociate economic growth with resource extraction and consumption, and remove barriers currently obstructing the CBD vision.

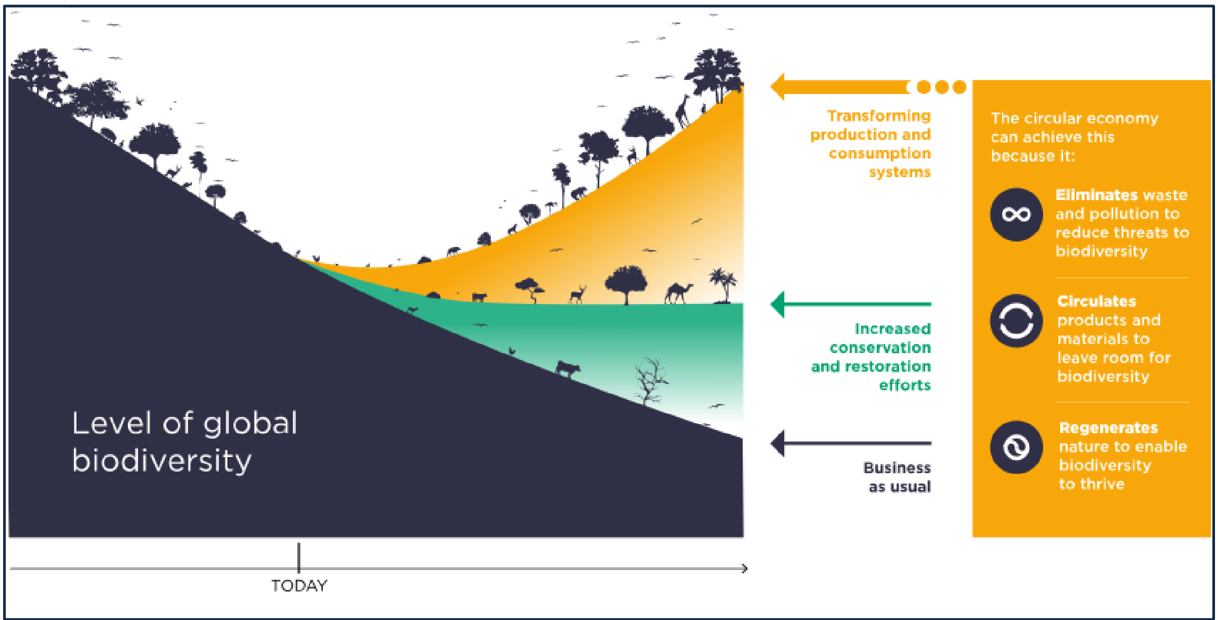


**Figure 2**: How the circular economy can play a fundamental role in halting and reversing biodiversity loss. *Source: Ellen MacArthur Foundation adaption of Secretariat of the Convention on Biological Diversity's report "Global Biodiversity Outlook 5" (2020) and the Nature article "Bending the curve of terrestrial biodiversity needs an integrated approach" (2020).*

### 2.2.2 Economic Benefits

Progress towards a circular economy can offer the UK increased economic security. As a net importer, the UK relies heavily on the stability of numerous complex supply chains that over the last decade, have become increasingly turbulent. By reusing existing resources to produce goods, the UK economy can decrease production costs and increase supply-chain resilience, all whilst encouraging businesses to evolve and diversify (11). This was supported by a recent study that predicted that the UK could achieve a net gain of £9.1 bn in Gross Value Added (GVA) by 2030 should it integrate resource conservation into its industrial strategy (12). The study highlighted the potential financial benefits of investing in recycling and re-use initiatives, as well as boosts to company profits through reduced use of raw materials. Waste prevention initiatives have also been predicted to unlock £3-4 bn for UK businesses by reducing waste management costs and generating additional revenue from secondary products and materials (13).

In the aftermath of a global pandemic, a circular economy could further support the UK's ambition of a 'Green Recovery'. Research from the London School of Economics found that a recovery package based on improved resource efficiency could result in a sustained economic recovery, with greater job creation and stabilised public debt (14). This was echoed in an earlier study that demonstrated how transitioning from a linear to a circular economy could significantly boost UK employment rates, creating up to 517,000 jobs (15). A circular economy could also offer many of the societal benefits needed for a successful recovery. For example, by shifting the focus from ownership to access, the cost of goods and services to the UK public could be significantly reduced; utilising modern technology to repurpose waste could help drive innovation and relieve pressure on public services; and improving resilience and stability could help future-proof the UK's economy and infrastructure under the growing uncertainty and economic risks associated with the climate crisis (11).

Increased circularity similarly supports the urgent need for change within global economies, as outlined by the 2021 Dasgupta Review (16). Through an analysis of the economics of biodiversity, the review warned that current practises have *"failed to manage our global portfolio of assets sustainably*". The review outlined a stark misalignment between economic growth and finite natural resources, concluding that current rates of consumerism would require 1.6 planet Earths to maintain. To avoid imminent risks to both global economies and human well-being, the review determined that there must be a shift towards "*sustainable economic growth and development*", ensuring that "*our demands on Nature do not exceed its supply*".

### 2.2.3 Current Circular Economy Initiatives

Each UK nation has developed strategies for achieving a circular economy. The Resource and Waste Strategy (RWS) for England outlines plans to preserve resources through waste reduction and increased efficiency as part of the UK's wider 25 Year Environment Plan (5). The Welsh Government's strategy, Beyond Recycling, sets out its aim of making a circular, low carbon economy in Wales and achieving zero-waste by 2050 (7). In May 2022, the Scottish Government released two public consultations setting out its plans to build on its previous circular economy strategy, Making Things Last, with a new Circular Economy Bill and Route Map to 2025 and beyond (6). Northern Ireland is similarly reviewing its plans, with a new Waste Management Strategy expected in 2023 (8).

Following this movement, new initiatives in the UK are beginning to take shape. Refill stations for example are soon to become commonplace as some of the UK's leading supermarkets, including Waitrose, Morrisons and M&S, plan to introduce refillable groceries as part of a Refill Coalition group (17). Scotland's Deposit Return Scheme is set to launch in August 2023 with the aim of significantly improving recycling rates for drink bottles and cans (18). A similar initiative for England, Wales and Northern Ireland is under review. The UK is also introducing an Extended Producer Responsibility scheme for packaging, meaning manufacturers will need to pay for the management and recycling of their packaging waste, with higher fees being incurred for materials more difficult to reuse or recycle (19).

The need to embrace a circular economy is now widely accepted, but actioning such will come at no small cost. A successful transition will require significant investments of time and resources to reconstruct the UK's commercial and waste infrastructures. It is therefore essential that a comprehensive and holistic approach be taken to ensure a safe and effective circular economy can be realised (4; 20).

## 2.3 Chemicals in a Circular Economy

There is a significant misalignment between the UK's current approach to chemical management and its ambitions for a successful circular economy. Shortcomings of present-day management strategies has meant that chemicals have often been brought to market with incomplete safety information, risking public and environmental exposure to potentially harmful substances. Research by the German Federal Institute for Risk Assessment determined that only one-third of registration dossiers for chemicals under EU REACH (Registration, Evaluation, Authorisation and restriction of Chemicals) were fully compliant with current information requirements (21). When considering a circular economy, such risks are amplified as chemicals are likely to remain in circulation for longer, increasing opportunities for exposure. Additional considerations are also required to assess potentially unintended fates of chemicals that may be recycled into secondary and tertiary products.

By some estimates, there is no data on the environmental impacts of up to 95-98% of chemicals currently on the global market (22). One study found that out of a sample of 95,000 industrial chemicals, only 2,200 were found to have acute aquatic toxicity data, 1,100 had bio-concentration factors, and 220 had biodegradation half-life data (Figure 3). Such findings demonstrate the focus of current management practises on a chemical's primary use and a significant knowledge gap on their fates beyond this point. Given the additional complexities of chemical movement within a circular economy, this highlights another important challenge in achieving effective chemical management.

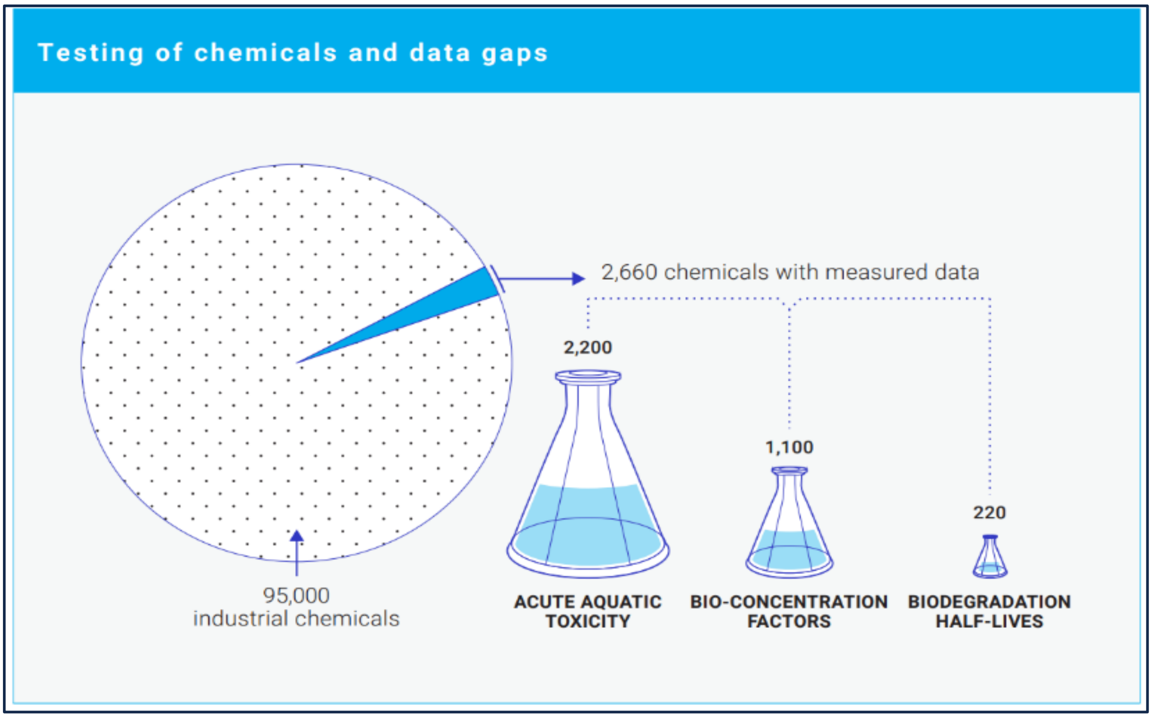


**Figure 3:** Testing of chemicals and data gaps. *Source: 'Screening for PBT Chemicals among the "Existing" and "New" Chemicals of the EU'. Strempel et al., 2012.*

Procedural complexities have also led to significant time delays between recognition of risk, and a chemical being removed from the market. Analysis conducted by the European Environmental Bureau found that EU officials could take anywhere between 3.5 and 12 years to identify and classify a hazardous substance, with the introduction of control measures, such as chemical restrictions, taking between 5.5 and 9.5 years on average (23). Listing of Substances of Very High Concern (SVHCs) in the EU Candidate List was noted to be a more efficient process. The SVHC list, now replicated under UK REACH, includes substances that have been identified as having serious health or environmental consequences, and requires suppliers to notify downstream users if they are supplying an article that contains a SVHC in concentrations above 0.1% weight by weight (w/w) (24). Whilst this offers some means of chemical transparency, it cannot prevent such chemicals already in circulation from entering waste streams, nor does it future proof against newly emerging chemicals of concern.

Lack of full chemical traceability and effective product recall in current management practises therefore means harmful chemicals may remain in use for the lifespan of a product and continue to resurface through recycled and reused materials. This was highlighted in findings from a recent study for the Office for Product Safety and Standards (OPSS) on chemical safety concerns in recycled materials, which determined chemical safety risks to be driven "*by the purposeful addition of functional additives to products*", quoting examples such as heavy metals, phthalates and flame retardants (25).

### 2.3.1 Case Studies - Bisphenols

Bisphenol-A (BPA) is a chemical commonly used in plastics, food can linings and thermal paper. It is classified as being toxic to reproduction by the European Chemicals Agency (ECHA) and is a recognised Endocrine Disrupting Chemical (EDC) (26). Following concerns of the potential impacts on human health and the environment, BPA was added to the SVHC candidate list in 2017 and banned from use in thermal paper in 2020 (26; 27).

Research has shown that the restriction of BPA in thermal paper has largely led to its replacement with another bisphenol, Bisphenol-S (BPS) (28). BPS is similarly suspected of being a reproductive toxicant and endocrine disruptor, and was banned from use in receipts in Switzerland amid public health concerns (29; 30). Bisphenol-B (BPB), another common BPA replacement, was also classified as an endocrine disruptor by the French authority, ANSES, in 2019 (31).

As a result of their continued and extensive use, bisphenols are now ubiquitous in our environment. They have been found in the air (32) and on beaches (33) across the world, and are spread directly onto land through sewage sludge used as agricultural fertilizer (34). Once in the environment, bisphenols have been shown to cause hormonal disruption and reduced reproductive success in numerous wildlife species (35; 36).

The bisphenols group are widely acknowledged as chemicals of concern, as demonstrated by their inclusion in the UK REACH Work Programme priority list for

2022-23 (37). This concern extends to their potential impact within a circular economy. Despite numerous restrictions, BPA has been found in many products made from recycled materials, such as napkins and toilet paper (38). Lack of full chemical traceability means contaminated items cannot be readily isolated and chemicals such as BPA may therefore become locked within products unintended for their use.

The bisphenols case study demonstrates how regrettable substitution (see Figure 4) of chemicals of concern can lead to contamination of recycling initiatives, weaving harmful chemicals into the circular economy without means of traceability or extraction. Chemicals of concern should therefore be considered within groups or sub-groups of those with similar chemical characteristics and potential for harm to avoid future cases of regrettable substitution. Chemical transparency and traceability would also ensure any problematic substances within recycling streams can be identified and managed appropriately, protecting the safety and longevity of material re-use.

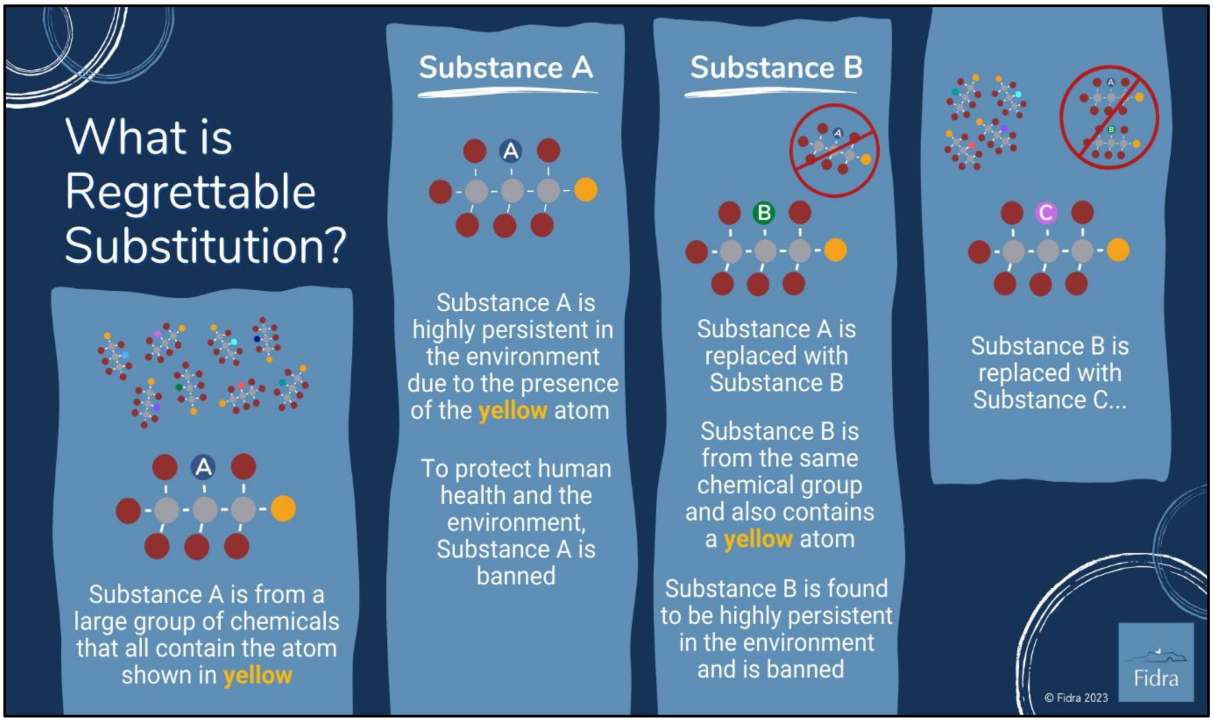


**Figure 4**: An infographic demonstrating the principle of 'Regrettable Substitution' where regulated harmful substances are replaced with similarly harmful unregulated substances. In this simplified example, a yellow atom that forms a strong chemical bond results in harmful environmentally persistence, a trait which is shared across the chemical group. *Source: Fidra, 2023.*

### 2.3.2 Case Studies – PFAS

Per- or poly-Fluorinated Alkyl Substances, known as PFAS, are a group of over 4,700 industrial chemicals used in a wide variety of everyday items, such as clothing, cosmetics, furniture and cookware. The characteristic carbon-fluorine bond found in these 'forever chemicals' means they are extremely persistent and can bioaccumulate along food chains to harmful concentration levels (39; 40). Numerous health impacts for both people and wildlife have been connected with PFAS exposure, including growth, learning, and behavioural conditions, multiple cancers, immune system disorders, fertility issues, kidney and liver damage, and obesity (41; 42; 43; 44; 45; 46; 47; 48).

Many PFAS-containing products can be reused or recycled at End of Life (EoL). PFAS use in paper and board food packaging for example is widespread across the UK. In a recent Fidra study, 89% of packaging samples taken from UK supermarkets and 100% of samples from takeaway outlets were found to contain significant levels of PFAS (49). Most of these items were identified as recyclable or compostable, demonstrating a direct route for PFAS contamination within a circular economy. The study also found evidence to suggest PFAS may already be circulating within recycling streams. One sample tested was made from 80% recycled material, but the PFAS origins (production process or contaminated recyclate) could not be determined (49).

Restrictions on PFAS are increasing across the globe, one of the most notable being the EU's recent proposal to limit more than 10,000 PFAS (50). Whilst restrictions can prevent additional sources of PFAS entering circulation, the wide array of existing sources remains a significant challenge to ensuring a safe circular economy. The PFAS case study highlights the potential harm of persistent chemicals within a circular economy, emphasising the need to adhere to the precautionary principle and consider the longer-term implications of chemical use in products. PFAS also demonstrate the possible benefits of chemical traceability should new guidance or restrictions be introduced.

### 2.3.3 Case Studies – Chemical Flame Retardants

Chemical flame retardants (CFRs), commonly used in furniture, vehicles, electronics and building materials, have been shown to interfere with the hormones of different wildlife species across the globe, including otters, penguins, dolphins, orcas, porpoise and salmon, impacting their behaviour, fertility and ability to survive (51; 52; 53; 54; 55; 56; 57). They have also been connected to severe adverse human health concerns, such as carcinogenicity, abnormalities in reproductive and neurological development, and endocrine disruption (58). In some cases, the degradation products of CFRs are known to cause similar or even more severe harm to human health and the environment, making them a particularly important consideration for waste management. Numerous studies have demonstrated the ability of otherwise safe CFRs to be transformed into more toxic or bioaccumulative substances (59; 60). Halogenated compounds, for example, can produce harmful dioxins during incineration or recycling processes (61); dioxins are listed under Annex C of the Stockholm Convention and are classified as possible human carcinogens (62; 63).

The long life of products that commonly contain CFRs also makes them more likely to contain newly restricted chemicals by the time they reach EoL. Without means of full chemical traceability, it is then challenging for such items to be identified and isolated to prevent contamination of waste and recycling streams. This has been demonstrated by the presence of brominated flame retardants (BFRs) in recycled plastic products. Under the EU Waste Electronic and Electrical Equipment (WEEE) Directive, plastics containing a variety of CFRs must be separated before entering waste and recycling streams (64). Without accessible chemical content data, this separation process is reliant on material chemical analysis which is highly specialised and costly (65). Numerous studies have now found BFRs in recycled plastic products such as kitchen utensils and children's toys, one of the most commonly detected BFRs in utensils being decabromodiphenyl ether (decaBDE), a chemical now listed as a Persistent Organic Pollutant (POP) and restricted under Annex A of the Stockholm Convention (66; 67; 68; 63). CFRs were also highlighted in the Human Biomonitoring for Europe's (HBM4EU) recent report, 'Chemicals in a circular economy', which outlines how a circular economy creates new pathways for exposure to hazardous chemicals (69). Within its five case studies, two demonstrate concerns around CFRs, quoting BFRs in children's toys, kitchen utensils, and polystyrene packaging as key examples impacting consumer exposure.

These findings highlight potential failings within the current waste management system and support the case for greater chemical transparency and traceability. As seen with PFAS and bisphenols, the fate of harmful chemicals within a circular economy requires greater consideration and a more precautionary approach to ensure safe and successful recycling and reuse initiatives.

# 3. Chemical Flame Retardants in Mattresses

## 3.1 Mattress Recycling

Mattresses are considered a problematic waste stream by local authorities. This is largely due to their size, making storage and disposal challenging, as well as the recoverable materials from mattresses being of relatively low value (70). Bulky waste, including mattresses, furniture and carpets, were therefore listed as priority items for Extended Producer Responsibility (EPR) schemes in England's 2018 waste strategy, 'Our Waste, Our Resource: A Strategy for England', which aims to review and consult on five priority waste streams by 2025 (5).

The National Bed Federation (NBF) have reported on EoL mattress data since 2014, monitoring progress towards their goal of diverting 75% of mattresses from landfill by 2028. In their latest report, it was estimated that 6.4 million mattresses were disposed of in the UK in 2020 (70). The report acknowledges that whilst recycling rates have increased, from an estimated 10% in 2012, to 24% in 2021, there is still much work needed if their 2028 target is to be realised. The report also recognizes that the figures quoted do not accurately reflect 'real' recycling rates; 24% referring to those *sent* for recycling, whilst a more modest 14% referring to those *actually recycled* after processing. Landfill was identified as still being the most common disposal route for the remaining 76% of EoL mattresses.

Collection methods and lack of incentives for local authorities to recycle mattresses were listed as key barriers to improving recycling rates; aside from the UK's municipal solid waste targets, there are no recycling targets assigned to Household Waste Recycling Centres (HWRCs). Smaller recyclers were also identified as being less likely to have the quantities of material required to obtain reliable trade. Larger recyclers were therefore shown to be at an advantage and more likely to secure trade of recycled materials, including metal, polyester, foam and mixed textiles, for secondary uses (53). The NBF report also highlights future EPR schemes and product design as key mechanisms for reaching the NBF's 75% target. EPR schemes were recognized to be essential in providing the resource and incentives necessary to develop an effective collection infrastructure. Innovative product design would then be needed to ensure mattresses can be dismantled with ease and produce the highest quality secondary materials possible. This introduces additional complexities when considering the overall environmental impact of materials. For example, despite being used to improve product sustainability, the tendency for damp natural fibres to decompose leads to poorer recycling rates. Recyclers therefore acknowledged foam mattresses to be preferrable over natural fibre mattresses when considering ways to maximise recycling efforts. Full life cycle analysis for all materials used was therefore recommended to ensure optimum sustainability.

Efforts to improve mattress recycling rates are also underway across the devolved nations. Zero Waste Scotland are working closely with the NBF to explore mattress EPR schemes in Scotland and the potential for an EPR roll out across the UK should it prove successful (71). Following the opening of Hamilton Waste and Recycling in 2018, Scotland has also significantly increased capacity for mattress recycling. This was reflected in local authority reporting of recycled and reused mattresses which jumped from 0 in 2017, to 722 in 2020 (70). Northern Ireland also showed improvement, increasing from 337 units in 2017, to 572 in 2020. Wales was the only nation not to report an increase across the same time period, however, Wales still maintains one of the highest rates of recycling and reuse per capita, second only to London.

## 3.2 Chemical Flame Retardant use in Mattresses

Effective management of bulky waste is an essential part in achieving the UK's circular economy ambitions. Whilst a number of significant challenges have been outlined in achieving this goal, chemical content is one that is often overlooked.

In England's 2018 Waste Strategy however, it was acknowledged that chemicals pose a distinct threat to safe reuse and recycling initiatives (5). The report outlined how this could be due to chemical use in long-lived items, such as mattresses, where new risk data is published after the products have entered circulation. This can then result in newly restricted chemicals remaining in use and contaminating waste streams at EoL. Other chemicals that may be benign can also add additional complexity to the sorting of recycled products and reduce the quality of secondary materials.

> ***"…for example soft furnishings that contain chemicals which were legal at time of manufacture but which have subsequently been banned."***
>
> **Source:** *Our Waste, Our Resources: A Strategy for England (2018), HM Government*

### 3.2.1 UK Furniture and Furnishings (Fire) (Safety) Regulations

The leading chemical group of concern within UK mattresses and other soft furnishings are flame retardants. CFRs fall into six broad categories: 1) brominated organic, 2) chlorinated organic, 3) organophosphorus, 4) halogenated organophosphorus, 5) nitrogen-based and 6) inorganic (72). Although the current UK Furniture and Furnishings (Fire) (Safety) Regulations (FFRs) (1988) do not mandate their use, CFRs have been identified as the most cost-effective way of passing stringent fire safety testing requirements (73). Table A1 in the Appendix provides examples of common CFRs currently and previously used in UK mattresses.

Current UK fire safety regulations require furniture and furnishings to pass a 'smouldering cigarette test' and a 'match flame test' (see Section 4.3 for further information). The match test is designed to replicate a match or small flame igniting the cover fabric on upholstered furniture, whereby the test material is placed tightly against a flammable test foam with a flame held against it for 20 seconds. After the flame is removed, any remaining fire must go out within two minutes (74; 75). To pass this test, many furniture manufacturers apply large volumes of CFRs to both foams and cover fabrics (73).

In the Environmental Audit Committee's (EAC) 2019 report, Toxic Chemicals in Everyday Life, the match test was criticized for its inaccurate representation of real-world scenarios, such as cover fabrics being tested over flammable foam, despite such materials no longer being allowed in furniture construction (73). Lack of consideration for modern furniture construction, such as 'barrier' materials, was also highlighted, resulting in a lack of clarity as to what stage a component or furniture piece must comply with the regulations and doubts over the legality of prosecution.

The EAC report also questioned the overall effectiveness of current UK fire safety regulations. It outlined how, whilst fatalities from UK house fires have undoubtedly decreased since the regulations were introduced, other countries with no or less prescriptive furniture fire safety requirements had similar fatality trends as the UK. New Zealand for example recorded a decline in fire fatalities mirroring that of the UK despite having no regulations on furniture flammability (Figure 5). Similar declines had also been reported in EU countries with less prescriptive fire safety regulations and greater caution around CFR use (Figure 6) (73). This was supported by a 2023 academic consensus paper on the role of CFRs in fire safety which concluded that there was "*significant uncertainty about whether and to what extent flame retardants contribute to fire safety*" (76).

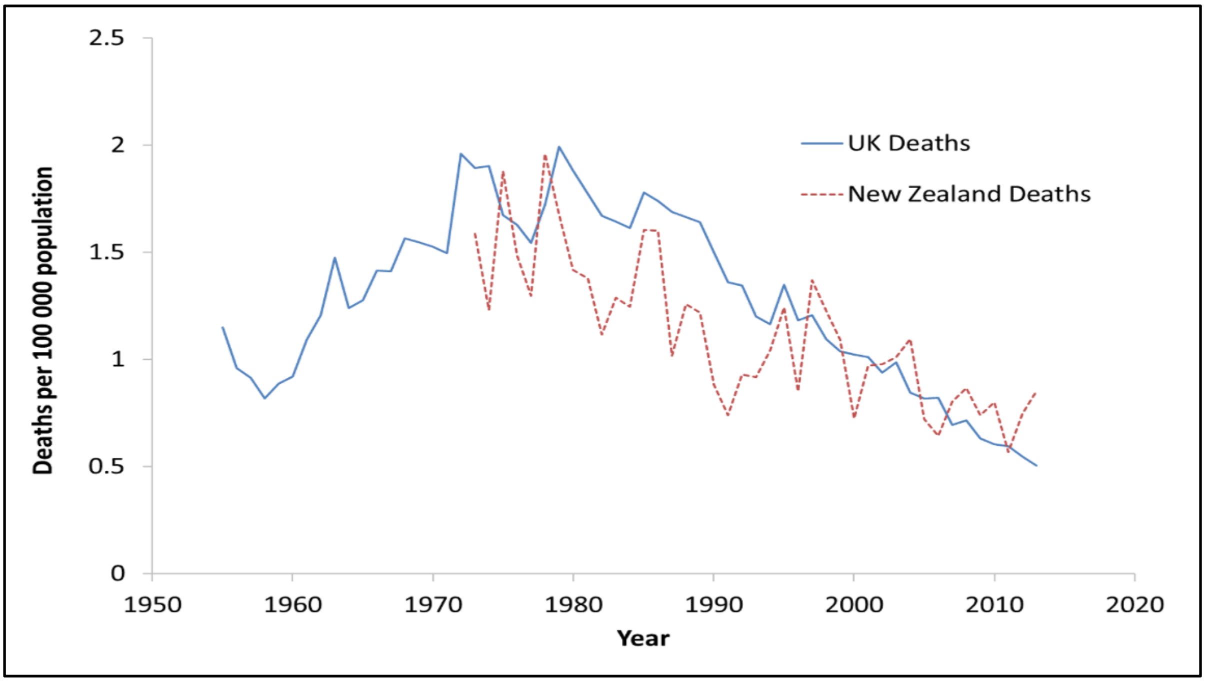


**Figure 5**: Fire deaths per 100 000 population in the UK and in New Zealand. *Source: Written evidence submitted by the Centre for Fire and Hazard Science, University of Central Lancashire. Accessed January 2023.*

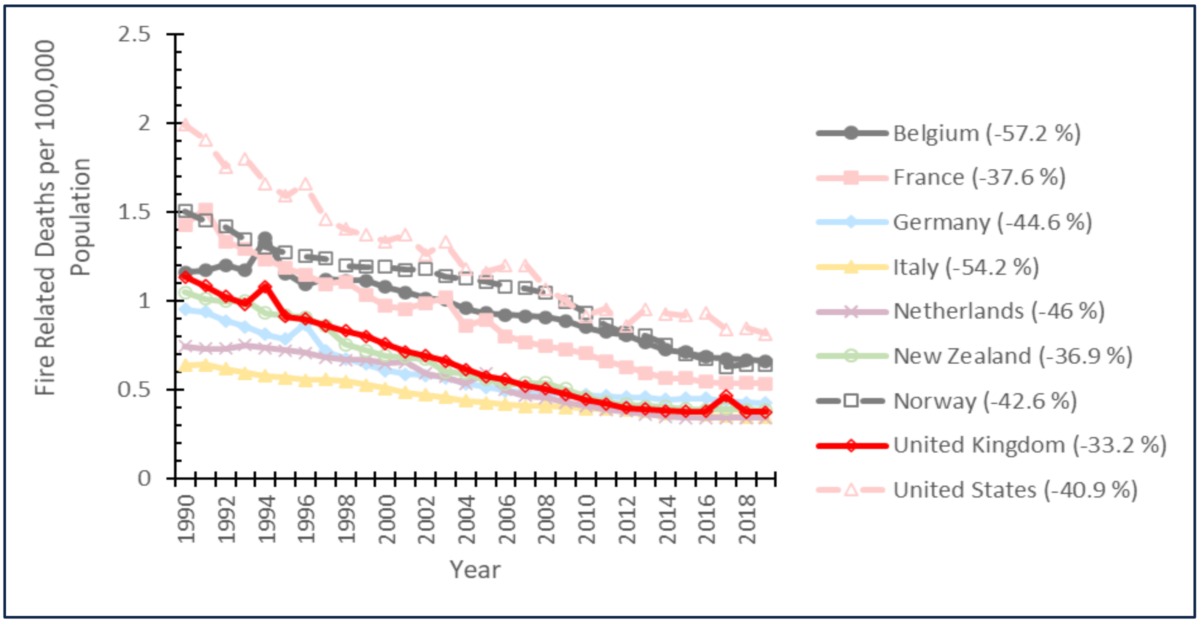


**Figure 6**: Fire related deaths per 100,000 population in the UK (with domestic furniture flammability regulations) and other developed countries (without domestic furniture flammability regulations) from 1990 to 2019. *Source: IHME: [https://vizhub.healthdata.org/gbd-results/](https://vizhub.healthdata.org/gbd-results/). Accessed February 2021.*

Alternative theories have therefore been proposed as to the UK's success in reducing fire fatalities over the last 30 years. For example, in 1988, when the regulations were implemented, smoke alarm ownership in England and Wales was 8%, by 2017 this increased to 90% (77). The rate of smoking over this time period has also almost halved (78); smoking materials are consistently recorded within the top three causes of accidental house fire across England (79). Since the 1990s, the majority of deaths and injuries from fires have been caused by the inhalation of toxic smoke, which is worsened by the presence of CFRs (80). Reports and reviews commissioned by the EU and individual member states have therefore concluded that there is not enough evidence to support the claim that flammability requirements, such as those in the UK, actually lead to fewer fire deaths (73; 81).

The effectiveness of the regulations was also analysed in two separate reports commissioned by the UK government, first in 2000 (82) and later in 2009 (83). In 2010, the regulations were recommended for update. Four years later, in 2014, the government's Department for Business, Innovation and Skills (BIS) published its first consultation, outlining changes to the regulations and stating, *"it is possible to demonstrate in full scale tests that the Regulations are ineffective"* (84). The consultation document concluded that the proposed changes would reduce CFR use by up to 50%, saving the industry up to £50 m per year, and citing growing evidence that CFRs are harmful to health and the environment. However, the process of updating the legislation was put on hold following on-going discussions with both the furniture and the chemical industries. In 2016, a further consultation, again proposing regulatory changes, was announced but results were not published until three years later following pressure from the EAC (85). Despite numerous recommendations for the regulations to be updated, the government's response, published in 2019, stated *'We have decided not to proceed with our proposal to revise the prescribed testing regime set out in the FFRs' and 'we will work… to develop… a further consultation … with a view to introducing legislation as soon as is practicable'* (86). A third review process is now underway.

There are no harmonised furniture fire safety standards at a European level and therefore, each EU Member State has the option to introduce its own standards. Following the UK's departure from the EU single market, the Irish Government Department for Enterprise, Trade and Employment announced that it would no longer recognise the UK FFRs as complying with its equivalent Irish (1995) regulations (87). UK regulations then faced fresh criticism regarding trade barriers between UK and Irish law; disputes between UK and Irish law over the use of CFRs in furniture have existed since 2002 following EU recognition of their potentially harmful environmental impacts (88). Currently, products sold into Ireland need to pass a different (composite base) testing regime to that in the UK, making trade of furniture goods more challenging (87).

### 3.2.2 Leading Concerns

Mattresses sold within the UK must comply with two pieces of legislation: the Furniture and Furnishings (Fire) (Safety) Regulations 1988 and General Product Safety Regulations 2005. These require mattress fillings and full mattress units to meet certain safety standards. These include flammability tests such as the smoulder test and match flame or open flame test, both designed to replicate potential ignition following contact with smoking materials (89).

Although it is possible to produce mattresses free from CFRs, many manufacturers still rely heavily on their use to meet current safety requirements, believing alternative methods to be too costly (73). However, increasing human and environmental health concerns have led to an overall agreement that CFR use must be reduced. This was outlined in the recently published scope for a new standard within the revised Furniture and Furnishings (Fire) (Safety) Regulations, which states, '*Consumers and the environment will benefit through the minimisation of fire retardants'* (90), and was supported within the conclusions of a recent academic consensus paper (76).

#### Chemical Flame Retardants & Human Health

CFRs are commonly used in electronics, electrical devices and construction materials, as well as furniture and furnishings. Human exposure to CFRs often occurs when they are released from household products into air and dust, which then collects on floors and other surfaces (76; 91). In general, exposure to CFRs is thought to be highest for young children as a result of breast milk intake and greater exposure to dust by putting their hands and objects in their mouth (mouthing behaviours) (76; 92).

There is increasing evidence that exposure to chemicals commonly used for flame retardancy can have severe and long-term human health effects (73; 76; 93; 94). Many of the organic flame retardants studied for example have been connected adverse health impacts, including abnormalities in neurological and reproductive development, and carcinogenic properties. Numerous BFRs have additionally been shown to exhibit endocrine disruption properties, meaning they can interfere with normal hormone functions. Discovery of such health concerns has led to the restriction of many widely used CFRs, such as several Polybrominated Diphenyl Ethers (PBDEs), linked to endocrine disruption, reproductive toxicity and neurotoxicity (73; 94). However, emerging evidence has demonstrated similar concerns for CFRs currently in use. For example, 2,2-bis(bromomethyl)-1,3-propanediol (BBMP), often used in polymers and construction materials, has been shown to cause cancer in rodents, and Tris(1,3-dichloroisopropyl) phosphate (TDCPP) and Tris(2-chloroethyl) phosphate (TCEP), used as CFRs in a wide range of applications, can both induce the formation of tumours (94). TCEP is also a suspected EDC, and early evidence has connected the BFRs 2-ethylhexyl tetrabromobenzoate (TBB) and Bis-(2-ethylhexyl) tetrabromophthalate (TBPH) with reproductive toxicity (94). See Appendix Table A1 for more information about CFRs used in mattresses.

A strong parallel has been demonstrated between furniture fire safety regulations and CFR exposure. The UK and US, recognised for holding some of world's most stringent fire safety requirements, have also recorded the highest levels of CFRs found in dust and human body fluids, including breast milk (94). The US state of California, found to have the greatest exposure rates to CFRs, until recently has had the most rigorous furniture fire safety standards (94). However, as a result of human health concerns, Californian regulations were changed to no longer require an open flame test. This allowed the remaining smoulder test to be more easily met without CFRs and without compromising on fire safety (95; 96).

## Chemical Flame Retardants & the Environment

Flame retardant chemicals are readily lost to the environment through production, use and disposal of everyday products. They have now been recorded in air, water, and soil, where they are known to persist and bioaccumulate (73). Bioaccumulation of BFRs within food chains is well documented, with dose and consequently risk of harm highest for top predators (97). Recent studies have also detected BFRs in some of the world's deepest oceans, including the hadal trenches (98).

CFRs also have the potential for long-range transboundary transport; the ability to travel far from known sources using oceanic currents or airwaves (99). This has resulted in their detection in wildlife species across the globe, including UK gannet and otter populations, seals in the Baltic Sea, Antarctic penguins, Arctic gulls and polar bears, flies in Japan, dolphins, orcas, porpoises and salmon populations, with documented adverse effects to behaviour, fertility and survival rates (51; 52; 53; 54; 55; 56; 57). The long-range transport of PBDEs has long been recognised in scientific literature, contributing towards the consensus for their restriction (99). However, there is now evidence of replacement CFRs, such as organophosphate esters (OPEs), in oceanic sediments ranging from the North Pacific to the Arctic Ocean, indicating a similar risk of environmental contamination (100).

CFRs are a contributor to global chemical pollution, a major influence in current environmental crises. The United Nations now list pollution as one of the five main drivers for biodiversity loss (101), and in 2022, new research warned that Earth's planetary boundary for chemical pollution had been crossed, beyond such point there is high risk of the planet no longer being able to support life (102).

Chemical Flame Retardants & the Circular Economy

Recent developments regarding the management of waste domestic seating have demonstrated why it is essential to consider the impact of other bulky waste items, such as mattresses, within a circular economy. In May 2021, a report commissioned by the Environment Agency (EA), conducted by the Water Research Centre Limited (WRc), looked to assess whether BFRs that were now classified as Persistent Organic Pollutants (POPs) were present in waste domestic seating (103). The research was hoped to inform appropriate waste management and *"reduce the likelihood that these chemicals would enter the wider environment"*. Following an investigation into 282 samples from across England, the report concluded that a *"significant number of samples were found to contain decaBDE"*, a member of the PBDE family now listed as a POP under Annex A of the Stockholm Convention (see Section 1.3.3). Based on the results of the study, it was estimated that there is between 364 and 476 tonnes of POPs classified BFRs per 100,000 tonnes of waste domestic seating, the majority of which thought to be decaBDE. As a result of these findings, the report recommended that *"some items of waste domestic seating should be classified as POPs"* and must therefore be subject to *"suitable end of life waste management"*.

In August 2022, the Waste Industry Regulatory Management department of the EA informed local authorities that waste upholstered domestic seating must be incinerated or processed in cement kilns following the findings of the 2021 investigation (103; 104). The letter outlined that items that may contain POPs, such as sofas and office chairs, must not be landfilled, mixed with other non-contaminated waste items, reused or recycled. Despite the 2021 report estimating that around 30% of upholstered domestic seating would be affected by POPs, the changes must be assumed to be applicable to all relevant items, unless it can be proven otherwise. Local authorities have since been provided with further guidance and asked to prepare for a formal compliance campaign, due to launch in 2023 (105; 106).

In response, waste recycling centres and local authorities have expressed significant concern over limited resources available to honour such changes (106; 107). The Environmental Services Association (ESA) referred to the limited availability of Energy from Waste (EfW) facilities that are equipped with current dust abatement techniques specified within the guidance, as well as the lack of capacity and infrastructure to meet the additional logistical challenges.

Before it's restriction, decaBDE was widely used amongst mattresses and other upholstered furniture items (73; 108). This has been acknowledged by Scottish

Environment Protection Agency (SEPA) who are considering the EA guidance and who have noted that they may extend the scope to include other items, such as mattresses, carpets and curtains (109). Similarly, the EAC's report on Toxic Chemicals in Everyday life, specifies how decaBDE poses 'waste disposal challenges' following its use in mattresses (73). The report also highlights the risk of on-going challenges following the regrettable substitution of decaBDE with alternative CFRs, such as Tris (2-chloroethyl) phosphate (TCEP), Tris chloropropyl phosphate (TCPP) and Tris dichloropropyl phosphate (TDCPP), all now facing restrictions (73). This is echoed by a 2023 study which found significant levels of TCEP, TCPP and TDCPP in waste synthetic foam and fabric items collected in Ireland between 2019 and 2020. Should these chemicals face similar waste concentrations limits as current EU limits for harmful PBDEs and hexabromocyclododecane (HBCDD), the study estimates that up to 7200 t/year of such waste (24 % of the total) would be deemed unrecyclable (110).

The UK currently has a limited capacity for incineration, with 25 incinerators capable of energy recovery in operation (111). Incinerators that can combust hazardous waste containing POPs at temperatures > 850 °C require specialist technologies such as rotary kiln incineration that controls the air/fuel ratio (111; 112). Gate fees are also particularly high for hazardous waste, quoted as approximately £100/tonne in 2022-23 (111; 113). Limited infrastructure, high operational costs, loss of materials and increased air emissions makes hazardous waste incineration both highly burdensome to local authorities and a significant barrier to achieving the UK's broader environmental and waste management targets (5; 6; 7; 8).

It is clear from the available evidence that continuing with current practises risks undermining a successful circular economy. Without means of traceability, chemicals of concern may continue to contaminate waste and recycling streams, and place huge pressures on local authorities and recycling centres. Affected waste streams risk compromising the safety and quality of secondary materials, impacting potential trade and weakening public confidence in recycled products.

### 3.2.3 Need for Change

In its Resource and Waste Strategy, the Government committed to reviewing EPR schemes for bulky waste items, including mattresses, furniture and carpets by 2025 (5). Action is already taking place to manage high risk items, as seen with the domestic seating case study, and numerous sources indicate mattresses may also fall into this category (5; 73; 109). CFRs have also been listed under the UK REACH priority list and are to be reviewed as part of the 2022-23 work programme (37; 114).

The need for change is evident. A safe circular economy can only be achieved through effective chemical management and ending unnecessary use of harmful substances wherever possible. Options such as EPR schemes, increased chemical transparency, and changes to the current UK Furniture and Furnishings (Fire) (Safety) Regulations (FFRs), may all provide viable solutions that could be effectively demonstrated through a mattress case study.

## 4. Solutions

### 4.1 Chemical Transparency and Traceability

Chemical transparency and traceability could help realise a profitable circular economy with health and environmental protection at its heart. Accessibility of full chemical content data along supply chains would allow appropriate reuse, recycling and disposal of products, and prevent newly regulated or restricted chemicals from undermining material safety. Providing information to all parties along supply chains could further empower retailers and manufacturers wishing to take greater ownership of the chemical substances used in their products, as well as stimulating prospects for trade of recycled materials.

Demand for chemical transparency is growing globally. In a recent announcement, the Government of Canada confirmed their intention to improve product labelling of toxic chemicals, including CFRs used in upholstered furniture, as part of a broader strategy to improve supply chain transparency due to be published in 2023 (115; 116). In the EU, a letter was sent by 23 investors, representing €4.1 trillion, to 50 leading chemical producers calling for greater transparency (117). This was followed by another letter in 2022 written by the International Chemical Secretariat, ChemSec, and seven major companies that was sent to the European Commission highlighting the importance of chemical transparency for companies wishing to meet their sustainability commitments and future-proof against potential upcoming restrictions (118). It read, "…*we want to emphasise that there is one outstanding issue where your support could make the most difference in our strive towards proactive chemicals management… This is to raise the legal obligations for transparency when it comes to information on chemical content...*". Also in 2022, HEJSupport, the Swedish Society for Nature Conservation and groundwork South Africa, in partnership with the Organization for Economic Development (OECD), ECHA and the Ministry of Environment, Waters and Forests of Romania, hosted an event to launch a concept known as the Global Minimum Transparency Standard (GMTS) for hazardous chemicals. The tool aims to improve disclosure of hazard chemicals used in products, allowing equal access to information for all stakeholders along supply chains across the world, and ensuring effective protection for public health and the environment (119). In research conducted by Fidra, UK retailers also consistently highlighted greater transparency of chemical content as an important factor in simplifying their own chemical management (120), and in a 2023 academic consensus paper, developing a "*labelling system for tracking the use of chemicals in products, including flame retardants*" was one of the key recommendations for the UK government to protect the circular economy from "*undesirable substances*" (76).

Voluntary data sharing could provide a first step towards greater chemical transparency along supply chains, whether this be through increased demand from downstream users, or evolving standards of best practises within industry. Mandatory data sharing could further improve transparency but would first require data availability amongst UK regulators. Since leaving the EU, the UK no longer has access to chemical registration data held by the European Chemicals Agency, ECHA. This undermines the 'no data, no market' principle, limits regulatory decision making, and inhibits progress towards improved supply chain transparency. To ensure informed chemical management, the UK must either align with EU REACH, and thus utilise data held by ECHA, or introduce requirements for full chemical data sets under UK REACH. Requirements for full supply chain transparency should then also be legislated. This should include improved data requirements which provide further evidence of health and environmental safety, including shared characteristics of concern across chemical groups, and potential exposure routes within a circular economy.

Use of smart labelling or product passports could ensure that chemical data is dynamic and therefore reactive to new research and updated guidelines or restrictions. Developments in technologies such as Radio-Frequency Identification (RFID) and blockchain have already demonstrated great potential for improving waste management across the electronic, textile, and building industries, allowing large quantities of product data to be accessible along supply chains whilst retaining discretion of competitively sensitive information (121; 122; 123). Digital labelling was also acknowledged as a promising way forward in Canada's recent plans to improve supply chain transparency, being described as being able to "*modernise and simplify regulatory interactions*" (115). As such, smart labelling could offer an opportunity to improve waste sorting processes and increase recycling rates, as well as providing greater transparency for all members of the value chain and incentivising higher standards of sustainability.

## 4.2 Extended Producer Responsibility Schemes

Extended Producer Responsibility schemes (EPRs) are a form of environmental policy that shift responsibility for the management of waste products back on to producers. This aims to incentivise sustainable product design and encourage producers to consider EoL management for their products, promoting products that are easier to reuse and recycle (124). This in turn encourages greater sorting, collection, and recycling rates, as well as reducing littering and fly tipping activities and relieving pressure on local authorities (124; 125; 126).

The UK Government and devolved administrations are set to introduce an EPR scheme for packaging as of 2023, aimed to financially incentivise increased use of recyclable and recycled packaging materials (127). As part of England's 2018 waste strategy, mattresses, furniture, and carpets were prioritised as potential subsequent schemes (5). In their 2022 report, the NBF echoed the call for EPR schemes, deeming them essential if the mattress industry is to meet current waste management targets, and highlighting the need for innovative product design to improve recycling rates and produce high quality secondary materials (70).

Numerous efforts towards increased recycling rates and EPR schemes for mattresses are already underway across the EU. For example, the Dutch company RetourMatras has introduced a fully automated mattress treatment plant capable of processing 190,000 mattresses per year (128). The Netherlands is also set to introduce an EPR scheme that aims to reach 75% mattress recycling by 2028 (128), the same as the UK's NBF target (see Section 3.1). France has introduced the first chemical recycling plant capable of processing foams from EoL mattresses and other plants are planned or already under construction in The Netherlands, Spain, Germany and Belgium (128).

As shown throughout Section 3, the UK's current reliance on CFRs in mattresses presents a significant barrier to progression but EPR schemes may form part of a solution. With incentives in place to ensure products are made sustainable by design, producers could be encouraged to consider chemical content, as well as product materials and construction. This in turn would heighten the call for improved chemical transparency and traceability (Section 4.1). Combined, producers could be given more control over the products they make and sell, and a greater ability to meet self-assigned or Government-led sustainability targets.

EPR schemes could also reward those with existing commitments towards chemical sustainability and stimulate further product innovation. Numerous mattress producers, including Silentnight, IKEA® and Cottonsafe®, have already demonstrated design initiatives to reduce chemical use and improve recycling rates, such as using inherently flame retardant materials, e.g., wool or polyester, to remove or reduce the need for CFRs, as well as avoiding adhesives and solvents to allow easier deconstruction and cleaner end materials (129; 130; 131; 132).

Given current concern around CFR use in bulky waste items (Section 3.2), and existing momentum from UK Government and NBF targets, mattress EPR schemes may provide a prime opportunity for ensuring effective chemical management strategies within a circular economy.

### 4.3 Amendments to UK Furniture and Furnishings (Fire) (Safety) Regulations 1988

Effectiveness of the current UK FFRs has been repeatedly challenged, leading to a series of reviews (see Section 3.2.1). It is now widely acknowledged that amendments to the FFRs must reflect modern furniture construction and fire risks, whilst reducing reliance on CFRs (73; 76; 133)

As outlined in Section 3.2.1, amendments should review current test methods which still require use of flammable foam materials no longer allowed in UK furniture construction. Tests should also reflect modern product designs which support fire safety, such as protective barrier materials used underneath cover fabrics. Removing the match flame test completely and using only the smouldering cigarette test, as adopted in the US, also offers an effective solution for allowing fire safety requirements to be met without use of CFRs, whilst maintaining fire safety (73; 134).

Furniture fire safety laws in California were changed in 2013 to no longer require flame retardant chemicals in Californian sourced furniture (see Section 3.2.2). The Californian standard now relies only on a smoulder test for assemblies of furniture fabric, foam and optional inter-liner (protective materials underneath the cover) materials and does not require an open flame test (135; 136). There is also a companion Californian law that requires upholstered furniture labels to state whether a product contains CFRs (135; 136). Many European countries such as France and Germany also typically use significantly less CFRs in domestic upholstered furniture to meet fire safety standards, following less stringent testing requirements than those currently used in the UK, whilst maintaining similar levels of fire mortality (73; 137).

Modern research and working case studies from around the world demonstrate that effective fire safety without unnecessary use of flame retardant chemicals can be achieved. Amendments to current FFRs in line with modern furniture construction and fire risks could therefore reduce the burden of chemical exposure on people, the environment, and the circular economy, whilst simultaneously stimulating product innovation and competitive growth for industry (73; 136).

## 5. Recommendations

From the evidence reviewed throughout this report, it is clear that current chemical management practises present a significant barrier to achieving a safe and successful circular economy (Box 1). Continued use of chemicals of concern, such as CFRs, PFAS, and bisphenols, have shown how regrettable substitution can allow harmful substances to become locked within material recycling, without effective means of traceability or extraction. These findings highlight an urgent need to modernise current practises, including reducing reliance on chemicals of concern (Box 2).

The example of CFR use in mattresses under the UK Furniture and Furnishings (Fire) (Safety) Regulations 1988, provides a working case study of the potential impacts of chemicals of concern within recycling initiatives, as well as an opportunity to demonstrate workable solutions. Options such as Extended Producer Responsibility schemes, increased chemical transparency and traceability, and changes to the current furniture fire safety regulations could help reduce reliance on CFRs, incentivise innovative and sustainable product design, and support successful long-term recycling initiatives (Box 2).

**Box 1. Barriers presented by existing chemical management practises.**

- Focus on a chemical's primary use results in minimal to no consideration for the extended life of chemicals within a circular economy.
- Time delays between risk recognition and removal of chemicals from the market results in long-lived items being particularly vulnerable to containing newly restricted substances.
- A substance-by-substance approach to chemical regulation allows for repeated cases of regrettable substitution.
- Lack of chemical transparency and traceability means manufacturers and retailers have limited abilities to future-proof against future restrictions and make informed decisions about the chemicals used in their products.
- Lack of chemical transparency and traceability allows chemicals to be recycled into products unintended for their use, without means of identification or extraction.

**Box 2. Recommendations for future chemical management practises.**

- Update the current Furniture and Furnishing (Fire) (Safety) Regulations 1988 in line with latest evidence on effective fire safety and the established need to reduce public and environmental exposure to harmful chemicals.
- Incentivise development of products made sustainable by design to minimise the use of harmful chemicals and maximise reuse and recycling rates.
- Adopt full chemical transparency and traceability to ensure products are reused, recycled, or disposed of appropriately and without unintended adverse effects on human health, the environment or recycled material safety.
- Adopt full chemical transparency and traceability to allow manufacturers, retailers, and consumers to make informed decisions on the products they make, sell and purchase.
- Factor potential unintended uses of chemicals within a circular economy into chemical risk assessments and decision making.
- Adopt a group-based approach to chemical management to reduce cases of regrettable substitution.

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# 8. Appendix

**Table A1:** Examples of common CFRs used or previously used in UK mattresses including chemical information, status and EU market tonnage where appropriate.

*Source: Cancer Prevention and Education Society, Fidra, Environment Agency 2003* (72) *and ECHA database (available here: https://echa.europa.eu/cs/information-on-chemicals/registered-substances).*

| Group | Chemical name | Abbrev. | Trade name | Chemical Abstracts Service (CAS) number | Status[1] (EU market tonnage (tonnes per annum), if in use) |
|---|---|---|---|---|---|
| Brominated organic | decabromodiphenyl ether | decaBDE | - | 1163-19-5 | Listed as persistent organic pollutants under the Stockholm Convention |
| | pentabromodiphenyl ether | pentaBDE | - | 32534-81-9 | |
| | tetrabromodiphenyl ether | tetraBDE | - | 446254-32-6 | |
| | hexabromocyclododecane | HBCDD | - | 25713-60-4, 3194-55-6 and others | |
| | decabromodiphenylethane | DBDPE | - | 84852-53-9 | Currently used[2] (10,000-100,000) |
| | tetrabromobisphenol A or 4,4′-(propane-2,2-diyl)bis(2,6-dibromophenol) [and its derivatives e.g. Tetrabromobisphenol A Bis(2,3-dibromopropyl) ether] | TBBPA<br><br>[TBBPA-BDBPE] | - | 79-94-7<br><br>[21850-44-2] | Currently used[2,3] (10,000-100,000)<br><br>[Currently used[2] (1,000-10,000)] |
| | 2,2-Bis[3,5-dibromo-4-(2,3-dibromo-2-methylpropoxy)propane] | - | Pyroguard SR-130 | 97416-84-7 | Currently used[2] (1000-10,000) |
| | Bis-(2-ethylhexyl) tetrabromophthalate | TBPH | Firemaster® 550 | 26040-51-7 | Currently used[2] (100-1000) |
| | 2-ethylhexyl-2,3,4,5-tetrabromobenzoate | TBB | Firemaster® 550 | 183658-27-7 | *Low tonnage so not in REACH but component alongside TBPH in currently used product* |
| | Brominated aliphatic polyether triol | - | IXOL® B251 | 78-40-0 | Currently used[3] (1000-10,000) |

| | | | | | |
|---|---|---|---|---|---|
| | | | *similar to IXOL® B350* | | |
| Organophosphorus (halogenated and non-halogenated) | Tris dichloropropyl phosphate | TDCPP | - | 13674-87-8 | Currently used[2] (1,000-10,000) |
| | Tris chloropropyl phosphate or Reaction products of phosphoryl trichloride and 2-methyloxirane | TCPP | - | 6145-73-9, 13674-84-5 | Currently used[2] (10,000-100,000) |
| | Tris (2-chloroethyl) phosphate | TCEP | - | 115-96-8 | Restricted[3] |
| | Triphenyl phosphate | TPT (or TPhP) | - | 115-86-6 | Currently used[2] (1,000-10,000) |
| | Triethyl phosphate | TEP | - | 78-40-0 | Currently used (10,000-100,000) |
| | Tris (2-butoxyethyl) phosphate | TBEP | - | 78-51-3 | Currently used[4] (1,000-10,000) |
| | Tris(2-ethylhexyl) phosphate | TEHP | - | 78-42-2 | Currently used (1,000-10,000) |
| | Tris(methylphenyl) phosphate | TMPP | - | 1330-78-5 | Currently used[2] (1,000-10,000) |
| | Trixylyl phosphate | TXP | - | 25155-23-1 | Currently used[2,3] (1,000-10,000) |
| | Bisphenol A bis(diphenyl phosphate) | BPA-BDPP | - | 5945-33-5 | Currently used (1,000-10,000) |
| | Cresyl diphenyl phosphate | CDP | - | 26444-49-5 and others | Currently used (1,000-10,000) |
| | Resorcinol bis(diphenyl phosphate) | RBDPP | - | 57583-54-7 | Currently used[2] (1,000-10,000) |
| | 2-ethylhexyl diphenyl phosphate | EHDPP | - | 1241-94-7 | Currently used (1,000-10,000) |
| | 2-Butyne-1,4-diol, polymer with 2-(chloromethyl)oxirane | - | IXOL® B350 | 68441-62-3 | Currently used[4] (1000-10,000) |
| Chlorinated organic | Short-chain chlorinated paraffins | SCCP | - | 85535-84-8 | Listed as persistent organic pollutant under the Stockholm Convention[3] |

| | | | | | |
|---|---|---|---|---|---|
| | Medium-chain chlorinated paraffins | MCCP | - | 85535-85-9 | Currently used[2] (10,000-100,000) |
| Nitrogen-based | Melamine or 1,3,5-triazine-2,4,6-triamine | - | - | 108-78-1 | Currently used[3] (100,000-1,000,000) |
| | Melamine phosphate or 1,3,5-triazine-2,4,6-triamine phosphate | MP | Melagard® | 255-449-7, 41583-09-9 | Currently used[6] (1000-10,000) |
| | Melamine polyphosphate or 1,3,5-triazine-2,4,6-triamine polyphosphate | MPP | Melapur®200 | 218768-84-4, 20208-95-1 | Currently used[6] (*unknown*) |
| | Melamine cyanurate or 1,3,5-triazinane-2,4,6-trione | MC | Melaguard® MC | 37640-57-6 | Currently used[6] (10,000-100,000) |
| Inorganic | Antimony trioxide (or diantimony trioxide) | - | - | 1309-64-4 | Currently used[2] (≥ 10,000) (*co-synergist used with halogenated flame retardants*) |
| | Graphite | - | - | 7782-42-5 | Currently used (100,000-1,000,000) |
| | Ammonium polyphosphate | APP | - | 68333-79-9 | Currently used (10,000-100,000) |
| | Diammonium phosphate | DAP | - | 7783-28-0 | Currently used (1,000,000-10,000,000) |
| | Aluminium hydroxide | - | - | 21645-51-2 | |
| | Magnesium hydroxide | - | - | 1309-42-8 | Currently used (100,000-1,000,000) |

1. All chemicals currently manufactured or imported (> 1 tonne per annum) must be registered under UK and EU Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).
2. Being evaluated under European Chemical Agency (ECHA) Community rolling action plan (CoRAP).
3. Added to ECHA Substances of Very High Concern (SVHC) list and listed as or on candidate list requiring authorisation before use.
4. In public activities coordination tool (Pact) list under REACH regulation.
5. ECHA Substances of Very High Concern (SVHC) requiring authorisation before use.
6. Pre-registered under REACH.

Fidra