Fidra is an environmental charity working to reduce plastic waste and eliminate the burden of chemical pollution on the environment. Fidra works with the public, industry and governments to deliver solutions which support sustainable societies and healthy ecosystems. We use the best available science to identify and understand environmental issues, developing pragmatic solutions through inclusive dialogue. www.fidra.org.uk

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Chemicals and waste in a circular economy

There currently exists a significant and detrimental misalignment between both UK and EU chemicals legislation and the goals of developing circular economy policies. Current chemical legislation has been designed around a linear model of use and disposal. Regulations do not adequately implement the precautionary principle, nor employ a group-based approach to restrictions. As a result, chemicals are brought to market with non-existent or incomplete safety information.

Procedural complexity leads to significant time delays between recognition of risk and toxicity and eventual removal of that chemical from market. Without product recall, the chemical remains in the user's environment for the lifespan of the product and then traditionally enters the waste stream. However, the intention to promote extended use, reuse and recycling under a circular economy, inevitably increases this time period between recognition of risk and the cessation of public exposure. **The lack of effective regulation on harmful chemicals risks locking contaminants into a circular economy.**

Additionally, the current lack of transparency and traceability in product chemical content, alongside inadequate enforcement of chemical waste restrictions in recycling, has led to **significant uncertainty in the chemical safety of secondary materials**. One important example of this is the presence of harmful flame retardants in food contact articles, and in plastic food packaging found in marine litter, linked to inappropriately recycled electronics [1-3]. See below for further information on flame retardants in recycling.

Harmful chemicals in products can originate from both intentional and unintentional sources. For example, virgin plastics contain additives for function as well as non-intentionally added substances, including heavy metals from the fossil fuel starting material[4]. Another example is the per or poly-fluorinated alkyl substances (PFAS) found in cosmetic products, these originate as desired ingredients, unintentional degradation products or impurities linked to industrial lubricants in production processes[5]. To ensure full chemical content is considered in a circular economy, **transparency and traceability needs to account for both intentionally added content as well as unintentional biproducts from manufacturing processes**.

Fidra believes that sound chemical management, essential to meeting the goals of a functioning circular economy, needs to be based on the principles outlined below:

- **Ending unnecessary use of chemicals:** All producers, manufacturers, retailers and consumers need to identify and undertake measures to reduce non-essential chemical usage. Voluntary efforts must, in turn, be supported by underlying regulatory principles that **prevent the use of chemicals of environmental concern for all non-essential functions**.
- **Proceed with precaution:** The **precautionary principle** must be applied when considering the use and restriction of chemicals. To implement the precautionary principle, we advocate a

chemical **class-based approach**. Restrictions limiting the use of known chemical hazards or chemicals of emerging concern should extend to include similar compounds within the relevant chemical class, unless the safety of these chemical analogues can be demonstrated.

- **Supply chain transparency: Full materials disclosures** are essential to enable the identification of known hazards at all levels within the value chain and will allow supply chains to react efficiently to newly identified hazards, substances of concern and legislative changes.
- **Access to information: Transparency and accessibility of data for all users** will ensure safe use, reuse and recycling within a circular economy and enable informed decision-making at all levels from primary sale to end-of-life disposal.
- **Assess and reassess regularly:** Thorough and regular assessment of the emerging evidence base is needed to ensure consumer and environmental safety is maintained.
- **Enforcement:** Strict enforcement with regular checks and prohibitive penalties for non-compliance, should be applied across all stages of the supply chain.
- **Chemical justice**: Those impacted by chemical pollution must be considered and represented in chemicals governance and decision making. **Routes to influence** must be established for those impacted by chemicals pollution, informing legislation and industry practices.
- **Who pays**: In line with the polluter pays principle, the economic model should be such that the full financial burden of disposal, management and clean-up is borne by the producers and suppliers of chemicals and products containing chemicals, not the public.
- **Strong evidence base:** Research and long-term monitoring are essential in providing policy, industry and society with the knowledge, predictive understanding and tools necessary to ensure safe use of existing chemicals and the early identification of emerging contaminants.

Wastewater

Protecting our environment and health from harmful chemicals requires a holistic approach, encompassing effective wastewater treatment, product design and restrictions on non-essential chemicals. Wastewater treatment plants are a major source of contaminants of emerging concern across Europe [6], with potentially harmful chemicals originating from personal care products, pharmaceuticals and textiles [6]. Unnecessary contaminants must be addressed in high level chemical policy, with chemical safety incorporated into product design, moving away from the current ineffective emphasis on wastewater treatment. Where potentially hazardous chemicals cannot be eliminated and their presence in wastewater is inevitable, for example in pharmaceuticals [7,8], **stringent legislation, monitoring and enforcement is required to ensure effective removal to protect the wider environment**.

Flame retardants

The presence of flame retardants makes responsible recycling of goods more difficult and expensive [9]. Many of the organic flame retardants studied have shown serious adverse health effects, including abnormalities in neurological and reproductive development, or carcinogenic properties [10,11]. Many Brominated Flame Retardants (BFRs) have additionally been shown to exhibit endocrine disruption properties, i.e. they have adverse effects on the body's hormone system. For many flame retardants, the potential for harm continues even after the chemical begins to degrade, and in some cases the degradation products are themselves the primary concern, making them extremely relevant to waste processers. Multiple studies have highlighted the potential for otherwise safe flame retardants to be converted under incineration to more toxic or bioaccumulative compounds [12,13]. Halogenated compounds have been shown to produce toxic dioxins and furans when heated [14] e.g. during recycling, incineration, or if left exposed to sunlight upon improper disposal. Dioxins, listed under Annex C of the Stockholm Convention, have been associated with immune and enzyme disorders, chloracne, and classified as possible human carcinogens; studies on lab animals have also shown a link between dioxin exposure and increased birth defects and stillbirths [15]. This leads to increased exposure risk to employees and communities near recycling plants, and potential widespread environmental harm when incinerators are run below optimal operating conditions or landfills have sub-standard leachate collection technologies. A 1994 health assessment carried out by the US Environmental Protection Agency concluded there was no safe level of dioxin exposure for humans [16].

Despite the adverse effects evidence, the UK remains a lead consumer of flame-retardant chemicals. Outdated UK legislation, such as the **Furniture and Furnishings (Fire Safety) Regulations 1988**, not only encourages the use of flame retardants on the UK market, but prevents the use of innovative, non-chemical fire safety measures, which have been employed in other countries with no detriment to fire safety [17].

Several BFRs are known to degrade the mechanical properties of recycled engineering plastics [18], promoting downcycling rather than recycling. Separation of plastics containing a variety of flame retardants (as required for BFR under Annex II of the EU WEEE Directive) is also difficult and costly under the current system, which is reliant on material analysis within the recycling system rather than accessible and transparent full materials disclosure throughout the products life. **True recycling to equivalent function is essential to realise the benefits of a 'closed loop system' and reducing demand for resource inefficient virgin materials.**

The mixed chemical content of the plastics in electrical products leads to significant challenges in recycling. As described above, the separation of plastics based on the profile of flame retardants they contain is difficult and expensive to achieve, reducing the value of the secondary material. EU Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) includes requirements that the public be informed about the potential effects of hazardous substances in electrical items and that manufacturers and importers make relevant information on the presence and location of hazardous substances in their products available to recyclers. However, with no stipulated method for transparency and traceability, insufficient enforcement and the low-level requirements for compliance, the **current legislation is ineffective** for the vast majority of chemicals.

With little information on chemical content made available to recyclers, identifying specific flame retardants becomes extremely difficult with available technology, e.g. x-ray fluorescence (XRF) techniques can be used to detect elemental phosphorous in non-BFR plastics, but cannot differentiate between different phosphorous compounds. Different phosphorous compounds exhibit different chemical behaviours and produce different by-products [9]. This makes safely managing the recycling process, from unwanted emissions to occupational exposure hazards and confidence in the composition of the secondary material, almost impossible. **Reducing the chemical content and eliminating chemicals of high concern from primary products, should form the foundation of any policy aimed at achieving a safe and functioning circular economy.** Where chemicals are required, these should be documented and controlled, with full chemical history passed from manufacture to disposal. **Full chemical disclosure, traceability, transparency and availability of data** are key to ensuring recycling is done safely and recycled materials are used appropriately. This should be easily achievable utilising current technologies (e.g. radio-frequency identification) linked to accessible databases, where full product histories and chemical content can be recorded.

Bisphenols

Bisphenols are a group of industrial chemicals, widely used in plastic and thermal papers such as receipts and transport tickets. Bisphenol A (BPA) is one of the highest production volume chemicals in the world, with around 8 million tonnes produced annually [19], and is recognised as a known endocrine disruptor. The use of bisphenols and bisphenol contaminated waste impacts manufacture, retail, sewerage, waste management and agriculture sectors. Bisphenols are lost to the environment during manufacture (e.g. paper mill sites), use and landfill, and can contaminate recycled products such as toilet paper and paper and board food contact materials. As a direct result of this, bisphenols are widespread in our environment and in our bodies. A recent study in the UK found BPA in 86% of participants [20]. Bisphenols enter our bodies from dietary sources (plastic bottles and canned food being notable sources) and due to skin contact with thermal paper.

Many countries have banned the use of BPA in baby's bottles to protect young children from potential hormone-disrupting effects. The use of BPA in receipts will also be banned across the EU, in 2020. These efforts were designed to limit exposure for those most at risk, however restrictions apply specifically to BPA, ignoring chemically and functionally similar bisphenols despite mounting evidence of similar risk, and are product specific rather than addressing the greater issue of widespread use.

Bisphenol A (BPA) is regulated in EU food contact materials such as plastic, varnishes and coatings under the EU Food Contact Materials legislation 1935/2004. However, these regulations do not cover paper and board food contact materials, also likely to contain BPA, originating from contaminated recycled paper [21]. Fidra submitted evidence to the recent EU Evaluation of Food Contact Materials Legislation, calling for stringent harmonised regulation that would restrict the use of *all* bisphenols, including BPA, across *all* food contact materials. However, accomplishing this goal without prohibiting the use of recycled materials, requires consideration of the waste legislation that allows, or does not effectively omit, bisphenols from recyclate.

Continual human exposure to BPA and other bisphenols through food and food contact materials, combined with ineffective removal of bisphenols by common wastewater treatment processes, has led to sewage sludge becoming a major source of bisphenol contamination to the environment. The Sewage Sludge Directive 86/278/EEC does not restrict the application of sludge containing BPA, leading to BPA concentrations in agricultural soil at levels that may present a risk to terrestrial ecosystems [22]. An additional source of bisphenols to the environment is through industrial discharge to municipal waterways. UK discharge permits restrict legislated pollutants such as metals, but make no inclusion for bisphenols, despite their known toxicological risk.

Inconsistencies across legislative areas does not offer sufficient protection to the public or the environment from bisphenols. A top down approach, eliminating bisphenol use at source, by group-based restriction, will be the most effective method of reducing public exposure and environmental risk, whilst also preventing contamination of recycled material as we move towards a circular economy.

PFAS

Per or poly-fluorinated alkyl substances (PFAS) are a group of approximately 4500 different highly fluorinated synthetic chemicals. Whilst restrictions apply to some chemicals within this group due to their persistence and toxicity, **less than 2% of PFAS available on the global chemicals market, are registered under REACH** [23]. Their unique and versatile functions have led to widespread use in many consumer goods and chemical products. Uses include, but are not limited to, paints, industrial cleaning products, fire-fighting foams and water and oil repellent finishes on textiles, furnishings and paper and board food contact materials.

PFASs are found in marine animals, seabirds and predators in all parts of the world including polar bears in the remote arctic [24]. **They are now ubiquitous in the environment and the human population** [25]. Contamination of ground water is a major source of drinking water contamination, recognised as a nationally significant challenge in countries including the US and Sweden [26,27].

Whilst the effects on humans are not well understood, studies have suggested **links to possible growth, learning, or behavioural problems, cancer, immune system disorders, fertility problems and obesity** [28-31]. The most commonly studied chemicals within the group, and the focus of regulatory actions across the EU and elsewhere, are PFOS and PFOA. Official classifications include 'carcinogenic' (Cat2, suspected human carcinogens), 'reprotoxic' (Cat 1B, presumed human reproductive toxicants), 'Lact' (may cause harm to breast-fed children), and 'toxic to specific organs' (liver) [32]. The toxicity of lesser studied forms of PFAS, increasingly used as alternatives to the restricted substances, are still uncertain. Whilst many forms of PFAS are considered safe, their production, use and disposal can indirectly lead to environmental inputs of harmful PFASs as precursors or deposition products.

Legislation is currently incomplete and piecemeal. Restrictions target individual chemicals, despite functional similarities and emerging evidence of risk across the chemical group. Country specific regulations, such as those recently announced by Denmark banning PFAS in food contact materials, or the Swedish limits on PFAS in drinking water, create divisions in public safety and **highlight current deficiencies in EU regulations**. Directive 2008/105/EC, which describes environmental quality standards in the field of water policy, currently only restricts PFOS with a value of 0.00065 $\mu g\ L^{-1}$. However, the Commission recently proposed an amendment to regulate PFAS as a group [33] (as defined by the OECD [34]), suggesting a limit on total PFAS, not exceeding 0.5 $\mu g\ L^{-1}$. To meet these 'total PFAS' standards across the EU, a **greater emphasis on group-based legislation is required from manufacturing and product chemical content, through to waste regulation, with a harmonised approach to implementation that ensures compliance in water bodies across national borders**.

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