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The new European database for chemicals of concern: How useful is SCIP for waste management?

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ABSTRACT

The interface between chemicals and waste legislation is a major problem for the envisaged circular economy. To re-use or recycle more waste, information on its composition is needed. The EU Waste Framework Directive obliges producers to document the presence of substances of very high concern in a new database (SCIP), which went online in January 2021. We studied some products of varying complexity and with different pollutant problems from a number of industries. Our investigation indicates that the new database is of limited use for recycling companies. Further requirements focusing on the intended recycling of used products are discussed.

1. Introduction

With its 7th Environmental Action Programm[e] (EAP), the European Commission had already set itself two particularly important goals, which were to be achieved in parallel by 2020 (Decision No 1386/2013/Eu, 2013). One priority objective is to protect EU citizens from environment-related burdens and risks to health and wellbeing, among others by reducing hazardous substances in the environment. The Commission's recently published "strategy for a non-toxic environment" (The European Council et al., 2019) aims at "the minimisation of exposure to chemicals in products, including, inter alia, imported products, with a view to promoting non-toxic material cycles and reducing indoor exposure to harmful substances". The reference to "non-toxic material cycles" refers to the Commission's second important objective, which the new Waste Framework Directive (WFD) aims to achieve. A priority objective is to turn the Union into a resource-efficient, green and competitive low-carbon economy, among others by significantly higher recycling rates, but with pollutant-free material cycles ("promoting non-toxic material cycles, so that recycled waste can be used as a major, reliable source of raw material for the Union" (European Parliament, 2018)). In the 7th EAP, it was emphasised that a residual waste volume "close to zero" should be aimed for. In the "European Green Deal" (European Parliament et al., 2020), both targets are again underlined.

The two goals cannot be achieved concurrently (Friege et al., 2019). The consultation on the interface between chemical, product and waste legislation (The European Parliament, 2018; Summary Report of the Public, 2018) indicates that the Commission has recognised this problem. In October 2020, the Commission presented its new chemicals strategy with the aim of issuing concrete targets for a "Toxic-Free Environment" (The European Council et al., 2019): "In a clean circular economy it is essential to boost the production and uptake of secondary

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raw materials and ensure that both primary and secondary materials and products are always safe. … However, the creation of a well-functioning market for secondary raw materials and the transition to safer materials and products is being slowed down by a number of issues, in particular the lack of adequate information on the chemical content of products." (Section 2.1.2).

- With respect to the so-called non-toxic material cycles, the Commission intends to "minimise the presence of substances of concern in products by introducing requirements, also as part of the Sustainable Product Policy Initiative, giving priority to those product categories that affect vulnerable populations as well as those with the highest potential for circularity, such as textiles, packaging including food packaging, furniture, electronics and ICT (information and communication technology), construction and buildings;
- ensure availability of information on chemical content and safe use, by introducing information requirements in the context of the Sustainable Product Policy Initiative and tracking the presence of substances of concern through the life cycle of materials and products[1];
- ensure that authorisations and derogations from restrictions for recycled materials under REACH (authors' note: Registration, Evaluation, Authorisation and Restriction of Chemicals) are exceptional and justified;
- support investments in sustainable innovations[2] that can decontaminate waste streams, increase safe recycling and reduce the export of waste, in particular plastics and textiles; develop methodologies for chemical risk assessment that take into account the whole life cycle of substances, materials and products."

In this paper, we will examine the problems that arise in practice when recovering resources from contaminated products.

2. Problems of the interfaces between chemicals, product and waste legislation

If waste management stakeholders want (or need) to remove problematic substances from waste, they first need to know which substances are actually present in the waste. The WFD (Directive (EU) 2018/851, 2018) has therefore been supplemented by an obligation for manufacturers to provide information on hazardous substances (SVHC – substances of very high concern) in products.

Chemicals and waste legislation is regulated within a European framework; the REACH and CLP (Classification, Labelling and Packaging (of chemicals)) Regulations are applicable in all Member States. Of course, the WFD also aims to ensure that recycling of waste is as environmentally friendly as possible and that pollutants are removed from the material cycle. However, practice shows that.

- especially in the case of waste from used products (so-called "post-consumer waste" in contrast to waste from industrial processes), knowledge about its composition is incomplete and,
- above all, there is usually no indication of the pollutants contained.
- Even if the composition is known, the removal of pollutants often encounters considerable technical difficulties and sometimes physical limits.

In addition, the two regulatory areas differ in their respective framework: Chemicals legislation refers to substances and defines the need for regulation in terms of substance-inherent hazards[3] without considering the application context. Waste legislation, on the other hand, deals with usually poorly defined mixtures of substances or products and certainly contains risk[4] considerations. The difference between "hazard" and "risk" depends on the exposure pathway. A risk exists when exposure to a "hazard" occurs.

Substances and mixtures are classified in accordance with the EU CLP Regulation; the criteria are clearly defined. The classification of waste as hazardous (or non-hazardous) is regulated by the European Waste Catalogue (EWC). There, reference is made to Annex III of the WFD, which lists hazardous properties ("HP properties"). Whether a hazard-relevant property (e.g. toxic, flammable, carcinogenic) can be assigned to a waste depends, except for HP 9 "infectious", on the presence of substances according to Annex VI of the CLP Regulation, namely the hazard codes (H codes) assigned to them there and the concentration of these substances in the waste. In the case of waste containing persistent organic pollutants (POPs), the concentration limits from the EU POPs Regulation are used for classification with few exceptions. Waste in the sense of the WFD is not in the scope of the CLP Regulation. This means that waste is not considered as a substance, mixture or article, and operators of waste treatment facilities are therefore not considered as downstream users according to REACH. In contrast, substances or mixtures recovered from waste must be classified and labelled according to CLP. Today, this often leads to misjudgements on the part of the companies involved.

In addition to the POPs Regulation, REACH, the Packaging Act, the Food, Commodities and Feed Code, the Waste Electrical and Electronic Equipment Directive (WEEE) and the corresponding Restriction of Hazardous Substances Directive (RoHS 2), the End-of-Life Vehicles Regulation (ELV) or the Toys Directive must also be considered, all of which place requirements on recycling processes or recycled material for the manufacture of new products. To bridge the gap between the recovery of materials from waste products and the obligations from REACH, Art. 9 para 1 of the WFD urges producers to provide data on SVHC which are accessible to the recycling industry. Manufacturers of articles will have to identify substances of concern in their products and enter them into a database called "SCIP" (**S**ubstances of **C**oncern **I**n articles as such or in complex objects (**P**roducts)).

The players in the waste management industry do not consider the current proposals of the EU and European Chemicals Agency (ECHA) to be practicable (EURIC, 2018): The European Recycling Industry Confederation (EuRIC) "alongside with other players of the waste management and recycling industry have been pressing for years for an improvement of the information available to waste treatment operators and more importantly for substitution whenever technically feasible of SVHC as well as a better enforcement of existing legislation. Unfortunately, the recycling industry does not consider the current SCIP Database to be practicable. Given the sheer complexity of the database, the amount of entries to look up individually by operators is likely to be overwhelming, hence making it difficult to use it at operational level."

Against this background, we want to investigate.

- what data are needed to make a decision on the recoverability of contaminated waste,
- and which data can be expected from SCIP.

For this purpose, it is necessary to consider examples from different industries or products of varying complexity and with different pollutant

[1] Notably, building on ECHA's SCIP database, ongoing work on REACH review (action 3), COM (2018)0116, and the development of product passports.

[2] Taking into account the relevant state aid rules.

[3] Hazard = Inherent property of an agent or situation having the potential to cause adverse effects when an organism, system, or (sub)population is exposed to that agent (World Health Organization, 2014, p. 12).

[4] Risk = The probability of an adverse effect in an organism, system, or (sub) population caused under specified circumstances by exposure to an agent (World Health Organization, 2014, p. 13).

problems (see Table 1). The examples include, as far as possible, representative old products or wastes from consumers or relevant economic sectors. Data and facts for these examples were taken from literature. To answer the questions of which data are needed for recycling purposes and which data can be expected from SCIP, we analysed these examples in the context of established recycling processes. We then discuss how the information deficits can be eliminated and which requirements for transparency have to be met.

3. Case studies

3.1. Materials from construction and housing

3.1.1. Insulation materials containing HBCD

Insulation materials containing HBCD have been used for many decades. Following UNEP (UNEP, 2019), it "has been on the world market since the late 1960s and may still be produced for use in EPS and XPS in buildings, possible under the specific exemption in the Stockholm Convention Annex A". Polystyrene is pressed into boards and the most used material for the insulation of buildings. The basic material – expanded (EPS) or extruded polystyrene (XPS) – is combustible. Therefore, in the past, hexabromocyclododecane (HBCDD resp. HBCD) was added to EPS/XPS as a flame retardant. According to information from the ECHA (ECHA, 2009), the annual HBCD consumption in Europe for EPS/XPS was about 11,200 Mg in 2006, and its mean concentration in EPS and XPS applications was around 7000 mg/kg (0.7 wt%). The HBCD content in EPS is about 5000–10,000 mg/kg (0.5–1 wt%) and in XPS 8000–25,000 (0.8–2.5 wt%) (see Table 2).

In October 2008, HBCD was added to the candidate list for possible inclusion in the REACH authorisation list (ANNEX XIV) of substances of very high concern (SVHC) because of its hazardous properties. The European Commission's decision to include HBCD in the amended Annex XIV of substances for authorisation under REACH was published in February 2011. In May 2013, HBCD was added to the Stockholm Convention on Persistent Organic Pollutants (POPs Regulation). Since March 22, 2016, products (substances, mixtures and articles) containing more than 100 mg/kg HBCD (= 0.01 wt%) may no longer be manufactured or marketed in the EU.

Table 1
Examples of substances of very high concern in different substance streams.

Examples	Containing substances of very high concern	Need to improve the flow of information
Insulation materials containing HBCD	Hexabromocyclododecane (HBCD)	Uncertainty about the type and quantity of flame retardant
PVC floor coverings	Phthalates; possibly lead, organotin, short-chain chlorinated paraffins (SCCP)	Ingredients unknown (possibly long use, no documentation)
Waste wood	Chlorinated aromatic compounds, polycyclic aromatic hydrocarbons (PAH), other POPs	Concentration of substances unknown
Recycled (RC) construction materials	Asbestos fibres (cross-contamination)	No definition of the terms "containing asbestos" and "asbestos-free"; different legal requirements
Plastics from WEEE containing flame-retardant substances	Polybrominated diphenyl ethers (PBDE), polybrominated biphenyls (PBB); further POPs, if applicable	Missing labelling of additives in the product
Lithium (Li) batteries in electrical and electronic equipment and e-cars		Lack of information on battery cell system
Plastics from end-of-life vehicles (ELV)	POPs (various, e.g. brominated flame retardants)	Transfer of information from automotive industry databases?
End-of-life (EoL) tyres (ELT)	PAH	Lack of information on hazardous substances
End-of-life (EoL) footwear	Phthalates, PAH, organotin, SCCP, chromium-VI	Lack of information on hazardous substances

Table 2
Typical concentrations of HBCD in different materials (UNEP, 2019).

Flame-retardant materials	HBCD content (mg/kg)
Expanded polystyrene (EPS)	5000–10,000
Extruded polystyrene (XPS)	8000–25,000
High-impact polystyrene (HIPS)	10,000–70,000

In earlier decades, however, millions of insulation boards containing HBCD were installed. In the course of the turnaround in energy policy, more and more buildings are now being renovated and old insulation boards removed. According to a recent study (Conversio, 2017), about 7.2 million Mg of HBCD-containing EPS/XPS insulation materials are currently still installed in construction applications in Germany, corresponding to around 60,000 Mg of HBCD.

When dismantling HBCD insulation materials, the necessary information about the POP content or whether the limit value for the SVHC substance is exceeded is usually missing. Insulation materials, when they are disposed of, are not subject to the requirements of Art. 31 and 32 of the REACH Regulation (safety data sheets/general material information) because they are products, meaning that no safety data sheets are available and these products are not labelled. However, the information according to Art. 33 must be kept available in the supply chain for SVHC above 0.1 wt%, but this information is usually lost in the consumption or disposal phase. With regard to possible recycling, the limits are tight, as the POPs Regulation is the applicable law and does not allow any exceptions.

In summary, it is expected that no information will be available in the SCIP database because such products are no longer allowed to be placed on the market. Only for the period during which HBCD was listed as SVHC but the placing on the market of products containing more than 100 mg/kg HBCD was not yet prohibited does Art. 33 REACH apply: Accordingly, the manufacturer is obliged to keep relevant information available for the other actors in the supply chain. HBCD-contaminated waste will continue to accumulate for decades. Since the usual contents in EPS are around 0.5–1% (w/w) and in XPS 0.8–2.5% (w/w) (UNEP, 2019), such a product can only be recycled after separation of the HBCD; an exception, however justified, is not possible due to the POPs Regulation. Thus, in most cases, it will be necessary to provide analytical evidence.

3.1.2. PVC floor coverings

PVC floor coverings have been used extensively in apartments, offices, and industrial and administrative buildings since the 1960s. According to ECHA (ECHA, 2017), in 2014 around 6% of PVC in Europe was used in the flooring sector. With a volume of around 6 million Mg of PVC products (including additives), this corresponds to around 360,000 Mg of PVC flooring. A considerable part of this volume is imported: In 2014, for example, about 220,000 Mg of floor, wall and corner coverings (in rolls or tiles) were imported into the EU, mainly from Asia (ECHA, 2017). Soft PVC products – which also include elastic floor coverings – contain on average around 50% additives, plasticisers and fillers (ECHA, 2017). The PVC content is about 33% (w/w) in calendered coverings, about 50% (w/w) in foamed coverings and about 60% (w/w) in coated coverings. Further components are plasticisers (e.g. bis(2-ethylhexyl) phthalate (DEHP)) and mineral fillers (chalk). Organotin compounds are used as stabilisers; the use of lead-containing compounds cannot be excluded for imported products (ECHA, 2017).

In the EU, the low-molecular-weight phthalate plasticisers DEHP, dibutylphtalate (DBP), butyl benzyl phthalate (BBP) and diisobutyl phthalate (DIBP) may only be marketed and used with approval since

February 2015. Their use has only recently been restricted to 0.1 wt% of the plasticised material (DEHP, DBP, BBP and DIBP in total). However, the restriction on the use of phthalates in products not explicitly mentioned above only applies to products that were placed on the market after July 7, 2020 (ECHA, 2018). However, the authorisation requirement or the ban on the use of substances listed in Annex XIV does not apply to imported articles. The importer is only obliged to inform the ECHA about the use of SVHC in this article. The use of phthalate plasticisers or stabilisers containing lead is not regulated in the countries exporting elastic floor coverings, such as China, Thailand or the Philippines.

Due to concentrations up to 13% DEHP and up to 36% other phthalates (Stiftung Warentest, 2003), the use of this secondary material would far exceed the DEHP limits of 0.1%. The threshold limit might only be met by mixing the secondary raw material with primary material. The separation of DEHP from flooring is the subject of an ongoing research project as reported by AgPR (German Arbeitsgemeinschaft PVC-Bodenbelag Recycling) (AGPR, 2020). AgPR operates a plant in Troisdorf, Germany, for closed-loop recycling in particular of PVC flooring. The recyclate produced there contains PVC, plasticisers and fillers and is used for the manufacturing of outdoor construction products. According to AgPR, floorings with DEHP are used for products which are not installed inside buildings. The ReVinylFloor association names this plant as an example of how to recycle PVC flooring (REVINYLFLOOR, 2021).

In summary, it is expected that no information will be available in the SCIP database on phthalates and other legacy substances in old PVC floor coverings. The service life of plastic coverings is between eight and 15 years for residential buildings, depending on intensity of use (Anon, 2020). In addition to phthalate plasticisers, floor coverings now awaiting disposal are likely to contain other harmful substances (lead, organotin compounds, short-chain chlorinated paraffins).

- For the substances and mixtures used to manufacture floor coverings, the requirements of REACH apply, including the preparation of a safety data sheet (SDS). Polymers, on the other hand, are not subject to REACH registration (except in the case of monomer content > 2 wt %).
- Information on SVHC and other harmful substances is collected from the flooring manufacturer. Durable floor coverings are articles; they are not subject to the legal requirements valid for chemicals as mixtures, i.e. SDS is required.
- For construction products, however, according to the EU Construction Products Regulation (Art. 6, para 5), the SDS and the information on SVHC substances (Art. 31, 32 and 33 REACH Regulation) must be provided together with the declaration of performance.

The collection of old floor coverings is carried out either via bulky waste collection or – especially in the case of renovations or in the commercial sector – with separate containers,[5] i.e. mostly mixed with other waste. This makes it extremely difficult to identify the producer. At present, it is therefore reasonable to assume the presence of phthalates in old PVC floor coverings. The SCIP database will therefore not provide any additional information for recyclers in the foreseeable future.

3.1.3. Waste wood

Wood products either as load-carrying components (e.g. timber ceilings) or parts of the façade (wooden planks) have a long life and can last as long as the building. Especially parts exposed to the weather are protected with special chemicals, whereby protective coatings are renewed several times. In the course of time, different chemicals might be used. Moreover, additives are used against biological damage, e.g. insecticides. Wooden floorboards are mostly made of oriented strand boards (OSB), which are glued together with a large amount of adhesive to form multiple layers. They are sometimes replaced during the service life of a house. Chipboard (particle board) is made from wood chips with phenol, urea or melamine formaldehyde resins. Besides furniture, chipboard is used for partition walls inside the building. Apart from these resins, polyurethane, polyester, polyvinyl acetate and epoxy resins, among other chemical compounds, serve as adhesives. Many wood products are laminated with plastic, e.g. PVC (an overview of chemicals added to wood is described by Sandberg (Sandberg et al., 2016)). Large quantities of composites made of wood and plastic have entered the construction market in the last decades.

Waste wood, i.e. from construction and furnishings, can be used as a raw material for chipboard production. In Germany, the use of waste wood is regulated by the Waste Wood Ordinance (Deutsche Bundesregierung, 2002), which was amended in June 2020 to place greater emphasis on cascade utilisation in order to reduce the rate of incineration of used wood products as "biofuel". A material use for particle board can usually be reconciled with waste wood categories I and II, while categories III and IV are also suitable for charcoal production. In the case of wood from demolition or dismantling of buildings, it should be noted that 35–42% of all residential buildings in Europe were built before 1960; the life span of residential buildings is assumed to be seventy to one hundred years (European Parliament, 2016). Wooden parts normally remain in buildings for decades. Since recyclers do not know the origin of beams and boards and the protectants used (either before construction of the building or during renovation work), the German ordinance urges the recycling company to allocate "common waste wood assortments" to a category according to the regulation in the sense of a "presumption of conformity". SCIP will not provide any reliable figures on long-living beams and boards. While large quantities, e.g. from the construction sector, can also be analysed for pollutants, quantities from bulky waste collection can only be assigned to a category by means of a visual response (see also (Flamme et al., 2020)). This raises the question of which additional information, to be made as easily available as possible, can be used to improve sorting.

3.1.4. Summary on materials from construction and housing

The search for information on contamination of construction and housing materials with SVHC or other legacy substances at the end of a service life of many years or decades is a challenge for recyclers. This search will be guided by two available facts: the year in which the building was constructed and the building components in which hazardous materials were often used at that time. In the case of asbestos, for example, these are fire-retardant ceiling constructions normally installed before the 1980s, which must then be examined in detail before dismantling or deconstruction.

According to the EU Construction Products Regulation, (Art. 6, para 5 of (Regulation (EU) No 305/2011, 2011)), SDSs and information on SVHC used must be made available to the investor or owner of the building together with the declaration of performance. The extent to which this information from the construction phase or conversion phases remains available for decades, e.g. in the SCIP database, depends on the consciousness of the architects, investors and owners. However, this is not a solution to the information needs of recyclers today.

3.2. Plastics in waste electrical and electronic equipment (WEEE) containing flame retardants

The proportion of plastics in electrical and electronic equipment (EEE) averages around 20 to 35 wt%. As a result of technical innovations, the proportion of plastics is growing, e.g. in display screen equipment. ABS (acrylonitrile butadiene styrene), HIPS (high-impact polystyrene), PPE/PS (polyphenyl ether/polystyrene) and PS (polystyrene) are particularly relevant in terms of volume. Only 5–10% of these plastics contain flame-retardant substances, although these are

[5] The separate collection of plastic waste is anchored in German law (GewerbeabfallVO).

then present in high concentrations. As a rule, the proportion of flame retardants in plastics used in information technology (IT), telecommunications, TVs and tools is much higher than in household appliances. In the past, in particular polybrominated diphenyl ethers (PBDE) were used as flame retardants in this product segment. Analyses showed PBDE concentrations above the RoHS 2 Directive limit (0.1 wt%) and of more than 0.1 wt% of tetrabromobisphenol A (TBBPA), among others, in plastics from (old) electrical and electronic equipment (Wolf et al., 2017).

Many instrument casings are made of ABS or PS and are well suited for recycling as mono-batches, provided that parts with high concentrations of regulated flame retardants have been removed beforehand. Usually, information on the flame retardants contained in products is lacking. This is a challenge for sorting, especially since the above-mentioned devices have to a large extent been imported to Europe over many years. In addition, the different definitions of an "article" and a "product" (complete product or relevant parts) in the REACH and RoHS 2 regulations affect the respective limit values. As secondary plastics obtained from electrical and electronic equipment should be useable for universal applications, this is another obstacle.

WEEE is usually collected by local authorities, charity institutions or private waste management companies. As a rule, WEEE is made available for recycling according to the respective collection categories. IT equipment is pre-treated manually by dismantling companies, whereby the separation of parts with hazardous substances should also take place. As a rule, the plastic fractions are separated – as long as it is economically and technically feasible. These fractions are not labelled. It is thus not apparent to the dismantling company whether plastics are contaminated with flame retardants and, if so, with which ones. It cannot therefore be excluded that plastics contaminated with hazardous flame retardants classified according to CLP are present. Here, the question arises of how to implement labelling and whether other information sources, such as SCIP, can contribute to improving the identification of SVHC or POPs.

According to Art. 15 of the WEEE Directive (since 2015), companies that repair equipment, prepare it for re-use or dismantle and recycle it should be able to access information on "the different EEE components and materials, as well as the location of hazardous substances and mixtures in EEE". For many types of equipment, such data are available on the Information for Recyclers Platform (I4R) (WEEE Forum, 2020), which allows recyclers to access information on the exact location of materials and components in EEE that require separate treatment (The WEEE Forum runs the platform.[6]). However, SCIP goes far beyond Art. 15 WEEE in its requirements, although it is questionable whether the level of detail of SCIP will provide added value for recyclers.[7]

How is the connection between the devices treated at the facility and the SCIP or I4R database established? This is only possible if the equipment is identified by type, manufacturer and product number. In the case of repair and re-use, the devices in question are mostly separated before the waste phase, e.g. handed in to a repair shop. In such cases, the device is identifiable and repair instructions are available in accordance with the WEEE Directive. In the case of recycling, sufficient information is mostly available when replacing electronic equipment, e.g. IT hardware in the commercial sector. In the case of WEEE from municipal collection, this is much more difficult because here IT hardware of very different ages and from different manufacturers has to be processed, and WEEE product labels are often no longer visible after several years of use.

In the case of electrical appliances produced from 2021 onwards and which will be subject to disposal in the future, information from the SCIP database may be available during initial treatment, i.e. the removal of components with hazardous chemicals. The average service life of electrical and electronic equipment depends on both type and quality: A consumer survey determined an average of four years for laptops, ten years for washing machines, nine years for refrigerators, four years for kettles and over seven years for kitchen mixers (Hennies and Stamminger, 2016). This service life of electrical appliances measured in reality far exceeds the three years specified in the WEEE Directive for calculating the quantity to be collected. The information from SCIP will be available to WEEE processing companies in the next years, depending on the date of manufacture of the appliance.

3.3. Used batteries, electrical and electronic appliances

A rapidly increasing number of electrical and electronic appliances are powered by accumulators (Ni-metal hydride, lead, Ni/Cd, lithium-ion …). Li-ion accumulators are most important in the market for portable batteries (for detailed statistics and further literature see (Huisman et al., 2020)). Ni/Cd batteries are now only approved for industrial applications. In approximately 66% of all battery-powered WEEE, the batteries or accumulators are not removed before the old appliance is returned (Mählitz et al., 2020). This is especially true in the case of household equipment (Friege et al., 2016). In addition, the number of appliances in which batteries are permanently installed and cannot be removed by the user is increasing (Nigl et al., 2018). Damaged lithium-ion batteries are inclined to short circuit, leading first to the production of flammable and toxic gas and mostly followed by self-ignition and spontaneous combustion (Chanson, 2018; Kong et al., 2018). These properties have caused numerous fires in recycling plants and scrap yards (EERA, 2020; Ollion et al., 2020). For many electrical and electronic appliances, the type of battery inside is not indicated on the product.

While batteries based on nickel compounds – at least new ones – would have to be included in the SCIP list due to the classification of "Nickel and its compounds" (ECHA, 1807), this is unlikely to be the case for important components of Li-ion batteries: Only lithium chloride is classified as SVHC; this salt is not part of the batteries.

This means that SCIP does not support the identification of flammable batteries. An appropriate labelling of electrical appliances equipped with accumulators, already visible to the user, is therefore necessary in order to reduce the risks posed by them and to facilitate recycling. Batteries which cannot be easily removed from electric and electronic devices are a threat for recycling and should therefore be avoided in future.

3.4. Plastics from end-of-life vehicles (ELV)

According to the European ELV Directive 2000/53/EC, since January 1, 2015 vehicle and equipment manufacturers must ensure that new vehicles are reusable and/or recoverable to a minimum of 95 wt% and are reusable and/or recyclable to a minimum of 85 wt% per vehicle. In addition, new vehicles must be manufactured without hazardous substances (in particular lead, mercury, cadmium and hexavalent chromium). The exemptions listed in Annex II are subject to regular reviews in line with technical and scientific progress. With an average

[6] In 2005, CECED (Conseil Européen de la Construction d'appareils Domestiques) and DIGITALEUROPE, the association of household appliance manufacturers in Europe, agreed on the format of this information for manufacturers of household appliances and ICT/consumer electronics and the electronics recyclers of EERA (European Electronics Recyclers Association). Since then, manufacturers have collected the information in a harmonised reporting format for each product on their website.

[7] Moreover, it is unclear whether all data can be inserted in SCIP that are requested from manufacturers based on the definition of a "product". The trade associations point out that "in the case of assembled printed circuit boards, it is not possible <is> to locate the electronic component to which the information entered in SCIP belongs, because such a component usually has no identification features at all that enable it to be distinguished from others. A very high level of detail regarding the specification of SVHC in electronic components therefore does not lead to any further added value of information for the typical components" (ZVEIbitkomVDMA, 2020).

service life of 15–20 years, most of these vehicles will therefore likely be disposed of between 2030 and 2035.

In 2017, the volume of end-of-life (EoL) vehicles in EU-28was – according to registration figures – around 5.3 million, equivalent to a waste mass of 5.7 million Mg (EUROSTAT, 2020a). The share of plastic in cars has risen continually over the last decades. Within the last decade, the amount of plastic built into the typical car increased from about 100 kg to nearly 120 kg per vehicle. Including composite materials and reinforced plastics, the weight of synthetic materials is nearly twice as high (Freudenberg, 2019). For the 5.3 million end-of-life vehicles in EU-28in 2017 mentioned above, this corresponds to about 0.5–1 million Mg of used plastics from the ELV sector.[8] For Germany, this amounts to 50,000 to 100,000 Mg of ELV plastics. The volume of secondary plastics used in the automobile industry is rather low: In 2017, only 4% of 1.76 million Mg of secondary plastic in Germany (corresponding to about 70,400 Mg) was used in the automobile industry (Vogel et al., 2020). In contrast, the production of about 5.6 million new vehicles in 2017 (IOCA, 2017) equates to a plastic consumption of about 680,000 to 1.4 million Mg. According to the vehicle manufacturers, the low availability of used plastics of a suitable quality is the reason for the small volume of secondary material in new vehicles. Another problem is the large number of plastic types (thermoplastics, thermosets, elastomers) and formulations, which may differ from manufacturer to manufacturer, even if the functional components are the same.

These problems are reflected in the data on ELV dismantling companies in Germany: ELV recyclers accepted about 565,000 ELV in 2018. 1702 Mg of large plastic components were removed from these, which corresponds to 3 kg/ELV. Of the 1702 Mg, 86% were recycled and 9% reused. However, a large proportion of the plastics remains in the ELV and ends up in the shredder. In 2018, 81,723 Mg of shredder light fraction (including other non-metallic shredder light fractions) (SLF), but only 545 Mg of separated plastic fractions were produced in the German shredder plants (BMU, 2020). The high energy content of the SLF is either used in EoW plants or as solid recovered fuel, e.g. in cement kilns.

The minimum technical requirements for treatment in support of recycling include the "removal of tyres and large plastic components (bumpers, dashboard, fluid containers, etc.), if these materials are not segregated in the shredding process in such a way that they can be effectively recycled as materials" (Annex I). Plastic products in motor vehicles have so far contained only few secondary plastics. Instead, primary materials are still mostly used because of the usually high technical requirements on the functionality of the products (Vogel et al., 2020). This makes the separation of defined, uniform fractions all the more important. This is easier when dismantling takes place before the shredder. After the shredder, a mixture of polymers and other components is obtained, which is very difficult to separate. Identification of the flame retardants in individual particles, for example, would be extremely time-consuming. Information on SVHC in plastic parts from dismantling can be obtained via SCIP if.

- these substances in single articles are included in the database, which should be the case for end-of-life vehicles from January 2021, and
- the parts can be identified by the dismantling company.

Besides SCIP, the International Material Data System (IMDS) (DXC.technology, 2017) of the automotive industry can also be used. In the IMDS,[9] all materials used in the production of vehicles are collected, maintained, analysed and archived. Through the IMDS, the obligations imposed on automobile manufacturers and their suppliers by national and international standards, laws and regulations can be fulfilled. Within the IMDS, the critical substances newly included in the SVHC list are listed, and the manufacturers of corresponding products must then update their SDSs accordingly. These are also largely adopted in the Global Automotive Declarable Substance List (GADSL) (DXC.technology, 2017). In contrast to the GADSL, the IMDS does not contain all active substances in clear terms but partly encoded. If the GADSL includes all new SVHC, the use of this database for the treatment of end-of-life vehicles is at least as feasible as the use of SCIP.

3.5. End-of-life tyres (ELT)

In 2019, the volume of scrap tyres for further use and recycling in Germany amounted to 571,000 Mg (including the scrap tyres from the recycling of ELV and imported used tyres). These were processed and produced about 251,000 Mg of granulates and rubber powder; 175,000 Mg were used in the cement industry and another 6000 Mg were exported for energy recovery. The remainder (carcasses or entire tyres) was retreaded or re-used in Germany (36,000 Mg) or exported for these purposes or for further use (109,000 Mg). Material recycling of used tyres has continued to increase (+6% in 2019), while thermal recycling is still declining (Wirtschaftsverband).

Thermal recycling of used tyres is of great importance in the cement industry. About three quarters of used tyres consist of a combustible fraction that is utilised for energy purposes. The remaining part contains material resources that are essential components of the cement clinker, meaning that used tyres can be completely recycled in cement production without any residual material. This is ecologically beneficial, as not all used tyres can be sent for material recycling. With regard to the conservation of resources and the reduction of CO_2 emissions, the use of used tyres and other refuse-derived fuels is ecologically acceptable, provided that some principles and requirements set out in Zeschmar-Lahl et al. (2020) are observed or fulfilled.

Rubber granulate from used tyres is used in various applications where there is direct contact with the human body. In the past, the use as infill granulate in artificial turf was common. In recent years, rubber infill material has been the subject of relatively extensive media coverage – especially with regard to PAH and their carcinogenic effect.

ECHA is currently proposing to restrict the use of rubber granulate from used tyres in certain products, e.g. synthetic turf pitches and playgrounds. The proposal was originally submitted by the Netherlands because of concerns about the content of eight carcinogenic polycyclic aromatic hydrocarbons (REACH-8-PAH) in rubber granules. In 2019, the Committee for Risk Assessment (RAC) and the Committee for Socio-economic Analysis (SEAC) of ECHA reviewed the relevant information and commented favourably on the proposal. ECHA considers rubber granules problematic with regard to their use on playgrounds and in artificial turf and the resulting health risk to athletes, children playing on the fields or pitches and workers who lay and maintain the surfaces (ECHA, 2019). It should be noted that the PAH limits for rubber granules used in these products can be up to 100 to 1000 higher than the REACH limits for articles supplied to the public.

The European Commission requested that ECHA prepare an ANNEX XV investigation report on PAH. In its recently published report, ECHA (ECHA, 2020) concluded that

> "4. In relation to content limits, based on the German Annex XV report (2010) on migration of PAHs from articles (2017), actual content limits may not guarantee a low level of migration of PAHs from consumer articles and safe use for all types of plastic and rubber matrices. Germany has, therefore, recommended that the current limits are kept or even reduced.

8 Assuming that the vast majority of E_{LVs} are older than ten years.

9 The IMDS is a joint development of Audi, BMW, Daimler, DXC, Ford, Opel, Porsche, VW and Volvo. Other manufacturers have joined the network in the meantime, making the IMDS a global standard used by almost all global original equipment manufacturers (OEMs). In addition, talks are being held with other manufacturers about participation in the IMDS.

… Overall, taking all available information into account, ECHA is of the opinion that it is necessary to perform a risk assessment to conclude if a migration limit could be set in addition to or as an alternative to the content limit."

Tyres contain industrial soot (carbon black) as a reinforcing filler. While the PAH content of the plasticisers added to tyres is limited according to REACH, there is no limit for PAH in the carbon black in tyres. On the other hand, there is a strict limit of 0.1 mg/kg (based on individual PAH) for products that can be manufactured from ELT and that may come into contact with human skin or oral cavity either directly or through abrasion (REACH Annex XVII, amended 2013) such as fall protection mats, tool handles, gloves. PAH concentrations in rubber granulate derived from ELT could be up to 19.8 mg/kg dry matter (sum of eight ECHA PAH) (Oomen and De Groot, 2017). The levels of PAH in carbon black vary widely and so do PAH concentrations in scrap tyres. Since the threshold values cannot usually be met when using scrap tyres as a material basis, these products will disappear from the market. A look at the SCIP database would only be of interest if the PAH contents in industrial soot and thus in tyres were reduced to such an extent that recycling would be possible again.

3.6. End-of-life footwear

In the EU Member States, 2.5 billion pairs of shoes end up in household waste every year, over 380 million pairs in Germany alone. Not even 5% of them are recycled (Anon, 2018a). Most shoes are imported to Europe, mostly from China, Vietnam and other Asian countries.

Shoes consist – depending on type and manufacturer – of up to 40 different materials (Staikos et al., 2006). According to consumer test magazines (Anon, 2011a, 2011b, 2016, 2019) and non-governmental organisations (NGOs) (Greenpeace and Discounter, 2014), shoes can contain the following problematic materials:

- Dimethylformamide used as a solvent in the production of polyurethane-coated textiles such as artificial leather, rainwear, protective clothing and shoes
- PAH which can be introduced into rubber and plastic parts via plasticiser oils
- Phthalate plasticisers in plastics (Anon, 2018b)
- Organotin compounds as stabilisers in PVC
- Chromium or chromium-VI in leather as a result of chrome tanning (Van Rensburg et al., 2020)
- Chlorocresol and short-chain chlorinated paraffins (SCCP) in leather
- Carcinogenic colour components, such as aromatic amines and aniline

The goal must therefore be to obtain pure recyclates that can be redirected into the production of identical products. However, this has so far failed mainly due to the large variety of materials/chemicals used in shoes, the poor separability of the components and the lack of labelling. So far, only two plants for shoe recycling exist in Europe. One is located in Germany (SOEX in Wolfen, Saxony-Anhalt). The material fractions obtained there (30% rubber, 30% foam material/leather light fraction, 10% metals) can be utilised. There is no information available about the content of heavy metals and organic pollutants in these fractions and their fate during material recycling. The residual textile fraction (30%) is currently still used for energy recovery, as no more appropriate use has been found (Anon, 2018a).

At another plant in Meerhout (Belgium), old sport shoes taken back by NIKE, one of the leading sport shoe manufacturers, are reprocessed. The shoes are disassembled into different fractions, each of which is shredded and processed into granules and marketed under the brand name Nike Grind. Nike Grind also contains shredded material from production waste and unsold footwear, which is used for new sportswear or flooring for sports and play areas (Bjuhr and Wargsjö, 2017).

Data on SVHC in materials used for shoes will be available in SCIP in the immediate future. However, in the case of textiles and shoes marketed in Europe, the share of imported products is well over 50%. Declaration of materials containing SVHC must therefore be strictly enforced because importers are obliged to deliver the SCIP information. Due to the high number of materials used, it will hardly be possible to check every shoe for potential contaminants. This necessitates appropriate labelling of shoes, with the aim of creating a high level of transparency with respect to the materials used. Labelling in conjunction with a database containing essential information on the components is an idea that is currently being developed for textiles, e.g. circular.fashion or DiTex. Moreover, taking recyclability into account at the design stage (design for recycling), so that shoes can be broken down into their original components, would be very helpful.

4. Discussion

One of the aims of the REACH Regulation was to improve the flow of information in the supply chain about substances of concern. To this end, requirements for manufacturers have been established according to Art. 31, 32 and 33 in order to transport information on substances and mixtures on the one hand and on articles on the other. The application of Art. 31 and 32, i.e. the preparation of safety data sheets and similar information on substances meeting the requirements of the CLP Regulation or included in Annex XIV of the REACH Regulation (Art. 33), is more or less well established along the supply chain, including the end user. If the presence of a substance of concern is known, further information (e.g. on safe use) can be obtained from the published data sheets of the manufacturers. The "extended SDS" contains additional information on the areas of application which may be helpful for the recycling industry. Normally, the SDS is no longer available at the end of a product's service life. The supply chain is interrupted, and there is currently no requirement to pass on substance information beyond the waste stage.

SCIP intends to close this gap. It will provide information on SVHC in articles manufactured now and in the future. Information from SCIP will this be available for the manufacturing of all articles in the next few years.

The recycling company or a potential re-user needs a link between the respective old product (produced in former years, i.e. before 2021) and the database. How can this be established? For the cases presented in chapter 3, we assume that the recycler can at least identify the character of the end-of-life product (e.g. kitchen mixer, PVC flooring, electric toy …).

Furthermore, it needs to be clarified which alternative sources of information are available in order to estimate possible interfering contents or to explore more specifically in SCIP in a second step. This is discussed on the basis of the results obtained for the respective examples (chapter 3). The findings from the discussion of the examples can be summarised as follows:

a) More and precise information on SVHC in waste and also on waste free of SVHC is needed (Friege et al., 2019; Janssen and van Broekhuizen, 2016). SCIP will provide information on SVHC in articles manufactured from January 2021 and in the future.
b) Information from SCIP can already be obtained for the manufactured products/articles from January 5, 2021 if manufacturers and importers are already delivering the necessary data.
c) The recycling company or a potential re-user needs a link between the respective old product and the database. In the case of re-use after repair, the devices in question are mostly separated before the waste phase, e.g. handed in to a repair shop. In such cases, the device is identified and repair instructions are available in accordance with the WEEE Directive. In the case of recycling, only the character of the end-of-life product can be identified, but detailed

information about the producer, the production year, etc., which is necessary for a search in SCIP, is not available. This means that a link is missing between the recycling facility and SCIP.

d) Besides SCIP, important databases for WEEE (I4R) and end-of-life vehicles (ELV) exist (IMDS, GADSL), which provide similar information to SCIP. The question therefore arises regarding to what extent integration into SCIP is possible, also in order to avoid double expense.

e) Besides hazardous compounds, recyclers need information about interfering compounds or modules which are not toxic (e.g. Li batteries, fibre reinforced plastics), which are not provided by SCIP.

f) For end-of-life products in mixed waste fractions, i.e. residual waste, it is usually impossible to clean single waste parts with the goal of identifying the product and its origin. For this type of waste, the SCIP database is useless.

These findings underline the assessment of German waste management associations (BDEBDSVBVSEVDM, 2020) that – at present – SCIP does not lead to any practical improvements for the recycling industry. For some important product groups, the problem of double expense for parallel databases (SDSs, SCIP, I4R, IMDS …) should also be considered (Summary Report of the Public, 2018). According to a publication by the chemical industry, information on SVHC in polymers will be available from the Safety Data Sheets Service for Plastics Recycling (SDS-R) tool (Polymer Comply Europe (PCE), 2020) offered by Polymer Comply Europe (PCE), but the SCIP database should give access to a broader set of data (Wood Environment) [10].

The contamination of used products and residues of materials with hazardous substances occurring in waste has different sources. The examples presented here refer to materials and substances that have been added to the product to achieve certain properties or functions and which hamper recycling. In addition, there are other sources that are not covered by SCIP but may be relevant for the decision for or against recycling (Fig. 1). SCIP does refer to case I and II, but not to the other cases, which remain a problem for some of the materials to be recycled.

5. Conclusions

The consultation (The European Parliament, 2018; Summary Report of the Public, 2018) addressed, among other questions, the added value of a compulsory information system on hazardous substances in products that is accessible to the waste management industry. There was general agreement among the stakeholders "concerning the need to improve the traceability of end-of-life products as well as support for the general objectives of enhancing protection of human health (from both the worker and the consumer perspectives), protection of the environment and the use of cleaner secondary raw materials that are suitable for re-entering production streams … However, other respondents from a range of stakeholder categories expressed uncertainties regarding the framework for implementation and the real benefits of introducing such a system. They indicated that it would not be useful in the case of mixed waste streams and that it would not take account of accidental contaminations, for which analytical approaches could be the most appropriate" (Summary Report of the Public, 2018). This view is confirmed by the results presented here. According to a study in the framework of the 7th EAP concerning a non-toxic environment, the first precondition for "non-toxic recycling material streams" means: "article waste streams, and the components therein, that contain toxic substances can be distinguished from those that do not contain toxic substances potential/substance content" (Milieu Ltd et al., 2017).

Especially in waste streams from households or small-scale industry, this is mostly not the case. The identification of single products and a link between SCIP and labels on the products are necessary in order to implement recycling processes which are competitive with the production of primary materials. Moreover, in the case of products for construction and buildings, successful use of SCIP requires a documentation of installation and use of products without gaps. Today, big data are available and used in many industrial areas. This was the prerequisite for the introduction of Building Information Modelling (BIM), which is already being utilised for large construction projects (infrastructure, office buildings …). BIM enables the permanent documentation of materials used in buildings and thus their identification, including pollutants, after the end of the building's service life (Won and Cheng, 2017; Honic et al., 2019). When BIM is used, the building is first created as a three-dimensional computer model (digital twin) in which all components are documented. Environmental product declarations (EPDs) and SDSs can also be integrated. This is facilitated by the standardisation of an Extensible Markup Language (XML) data format for environmental product declarations (EPDs) and EU-SDSs.

In the case of separately collected waste fractions, e.g. used packaging from households or plastic waste from construction sites, unwanted materials which disturb the sorting process are first removed from the pre-separated waste (e.g. wood particles in a plastic fraction), then the different materials (e.g. polyethylene, polystyrene, metals) are separated from each other and concentrated into fractions for further cleaning. Only after this process can materials potentially containing pollutants be separated. In most cases, however, the products are no longer identifiable, meaning that SVHC contents cannot be reliably excluded. This makes it necessary to eject products containing SVHC at the beginning of the recycling process. However, this necessitates a completely different way of managing material flows in products.

This requires.

- a machine-readable labelling of all affected products (e.g. a printed bar code), from which their composition can be deduced during the initial treatment,
- new extended producer responsibility (EPR) regulations for products such as textiles or furnishings in addition to those already in place for packaging, batteries, electrical appliances and vehicles,
- the development of practicable mechanisms to motivate the stakeholders involved in the respective value chains to achieve much higher collection rates for used products than before (e.g. WEEE average 47% in 2017 (EUROSTAT, 2020b), spent batteries average 48% in 2018 (EUROSTAT, 2020c)),
- the prevention of incorrect disposal, cross-contamination, etc., especially by private households and small businesses, as known from the collection of packaging (Eriksen et al., 2018),
- the introduction of penalties to support the implementation of such regulations and to ensure consistent enforcement towards all participants in the value chain.

To use wastes as resources is a necessary part of the circular economy, provided they can be used without harm. Therefore, "… 'the end of waste' (with its criteria and regulations) should be seen as a powerful tool in reaching a full circular economy and not be its barrier" (Ragossnig and Schneider, 2019). However, this also requires a change in the design of products with regard to the use of material combinations. Nowadays, a large proportion of plastic products cannot be

[10] This study contains some important recommendations: "Information at the article level from the SCIP database will require grouping into families/groups of articles, components, material types, etc. in order for the information to be of use to waste management (separation) companies. Depending on the information passed on to recyclers, the information could also be relevant to them. Industry sectors have indicated that they could support further with defining nomenclature to facilitate grouping and structuring of information coming out of the database. To facilitate more accurate data entry (e.g. on concentrations) and hence on outputs, for some waste streams where it is clear that SVHC can be found, ECHA could consider pre¬filled declarations/fields (e.g. on specific substances in specific polymers and the typical concentration ranges e.g. lead in rigid PVC compound at between 0.1% and 2%)."

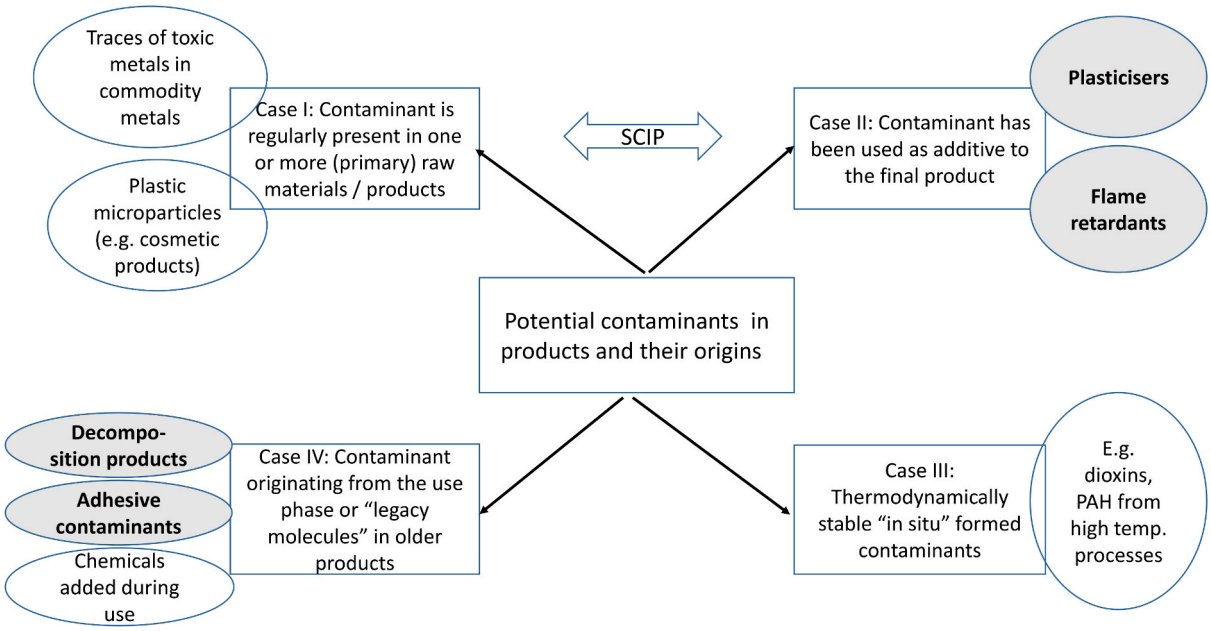

Fig. 1. Potential contaminants in products and their origins covered by SCIP (Case I and Case II, see upper part); examples in green are discussed here. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

recycled, even at high technical cost, because the individual components and multi-layers cannot be separated (Eriksen et al., 2018).

Once these challenging tasks have been initiated, the question of how to deal with contaminated materials (SVHC or legacy substances) will become more and more urgent due to increasing collection volumes. In principle, we agree with the European Environmental Bureau's (EEB) policy recommendation: "Ensure that the legal framework is not less protective for products made of recovered materials" (EEB, 2017). However, we should realise that re-use and recycling never bear zero risks. This is also true regarding various risks associated with a linear economy, such as mining or energy recovery from waste (Gehandler and Millgård, 2020). It is thus expedient to differentiate between the application areas of materials and products, with the aim of a rational risk assessment to protect vulnerable groups and the environment on the one hand and resource recovery including greenhouse gas savings by means of recycling processes on the other. It is therefore very important to develop applications in which secondary materials including a certain content of critical compounds can be used safely (Janssen and van Broekhuizen, 2016).

Author statement

Author names in the authorship list have been rearranged. The reasons are as follows:

- Beate Kummer focused on business oriented journals and could not contribute to the revised version.
- Jörg Wagner was also not in the position to work out the revised version of the article.
- The revision was performed by Henning Friege and Barbara Zeschmar-Lahl.

The rearrangement in the authorship list has been agreed by all authors:

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Abbreviations

ABS	Acrylonitrile butadiene styrene
AgPR	Arbeitsgemeinschaft PVC-Bodenbelag Recycling, Troisdorf (Germany)
BBP	Benzyl butyl phthalate
BIM	Building Information Modelling
Cd	Cadmium
CLP	Classification, labelling and packaging (of chemicals)
DBP	Dibutyl phthalate
DEHP	Diethyl hexyl phthalate
DIBP	Diisobutyl phthalate
DMF	Dimethylformamide
EAP	Environmental Action Programm[e]
ECHA	European Chemicals Agency
EEB	European Environmental Bureau
EEE	Electrical and electronic equipment
ELT	End-of-life tyres
ELV	End-of-life vehicles
EoL	End-of-life
EPD	Environmental product declaration
EPR	Extended producer responsibility
EPS	Expanded polystyrene
EWC	European waste catalogue
GADSL	Global Automotive Declarable Substance List
HBCD (HBCDD)	Hexabromocyclododecane
HIPS	High-impact polystyrene
HP	Hazardous property
I(C)T	Information (and communication) technology
I4R platform	Information for Recyclers Platform
IMDS	International Material Data System
Li	Lithium

NGOs	Non-governmental organisations
Ni	Nickel
OSB	Oriented strand boards
PAH	Polycyclic aromatic hydrocarbons
PBB	Polybrominated biphenyls
PBDE	Polybrominated diphenyl ethers
PCE	Polymer Comply Europe (PCE), a service provider for the plastics industry
POPs	Persistent organic pollutants
PPE	Polyphenyl ether
PS	Polystyrene
PVC	Polyvinyl chloride
RAC	Committee for Risk Assessment of ECHA
RC	Recycled
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RoHS 2	Restriction of Hazardous Substances (Directive, 2011/65/EU)
SCCP	Short-chain chlorinated paraffins
SCIP	Substances of Concern In articles as such or in complex objects (Products)
SDS	Safety data sheets
SDS-R	Safety Data Sheets Service for Plastics Recycling
SEAC	Committee for Socio-economic Analysis of ECHA
SLF	Shredder light fraction
SVHC	Substances of very high concern
TBBPA	Tetrabromobisphenol A
UNEP	United Nations Environment Programme
WEEE	Waste electrical and electronic equipment (Directive, 2012/19/EU)
WFD	Waste Framework Directive (2008/98/EC)
WtE	Waste-to-Energy (formerly waste incineration)
XML	Extensible Markup Language (XML), a simple text-based format for representing structured information
XPS	Extruded polystyrene

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