

Eliminating Toxics in Carpet: Lessons for the Future of Recycling



An Optimizing Recycling Report by the Healthy Building Network

With Support from Changing Markets and the Global Alliance for Incinerator Alternatives

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This report and an associated series of research papers on optimizing specific recycled feedstocks can be found at <https://healthybuilding.net/content/optimize-recycling>.

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The Healthy Building Network (HealthyBuilding.net) is a nonprofit organization that envisions a day when all people and the planet thrive when the environment is free of hazardous chemicals. Our mission is to advance human and environmental health by improving hazardous chemical transparency and inspiring product innovation. HBN performs independent, foundational research and product evaluations required to provide building product specifiers with unbiased, up-to-date information about chemical hazards, practical product evaluations and comparisons, and recommendations about the healthfulness of widely-used building products.

Changing Markets Foundation (ChangingMarkets.org) was formed to accelerate and scale up solutions to sustainability challenges by leveraging the power of markets. Working in partnership with NGOs, other foundations and research organizations, Changing Markets creates and supports campaigns that shift market share away from unsustainable products and companies and towards environmentally and socially beneficial solutions.

The **Global Alliance for Incinerator Alternatives** (No-Burn.org) is a worldwide alliance of more than 800 grassroots groups, non-governmental organizations, and individuals in over 90 countries whose ultimate vision is a just, toxic-free world without incineration. GAIA recognizes that our planet’s finite resources, fragile biosphere, and the health of people and other living beings are endangered by polluting and inefficient production practices and health-threatening disposal methods. Because of this, GAIA opposes incinerators, landfills, and other end-of-pipe interventions. The organization promotes clean production and the creation of a closed-loop, materials-efficient economy where all products are reused, repaired, or recycled.

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Contents

- Executive Summary** **1**
- Methodology** **8**
- Behind The Ratings** **9**
 - Feedstock Health and Environmental Hazards** **9**
 - Stain Repellency Treatments 10
 - Antimicrobials 14
 - Isocyanates in Polyurethane Backing 15
 - Polyvinyl Chloride Backing 16
 - Phthalates in PVC Backing 17
 - Styrene Butadiene Backing 19
 - Organotins 20
 - Fly Ash 21
 - Flame Retardants 23
 - Flame Retardants in Carpet Cushion 25
 - Installation Adhesives 26
 - Supply Chain Quality Control and Transparency** **27**
 - Current Recycling Practices 28
 - Product Certifications 32
 - Green Jobs & Other Local impacts** **35**
 - Current Operations 35
 - Room to Grow** **36**
- Conclusions and Recommendations** **38**
- Appendices** **44**
 - Appendix 1. Substances of high concern in the carpet waste stream **44**
 - Appendix 2. Certifications, standards, and regulations: coverage of chemicals of concern in carpet **47**
 - Appendix 3. Optimizing Recycling Series - Overall Ratings **50**
- Endnotes** **51**

Executive Summary

- **Feedstock Health and Environmental Hazards**
- **Supply Chain Quality Control and Transparency**
- **Green Jobs & Other Local Economic Impacts**
- **Room To Grow**

OVERALL: Most flooring sold in the U.S. is carpet. Carpets hold a 60 percent share of the U.S. flooring market, with 11 billion square feet sold per year.¹ Of that, only five percent is recycled.² Most carpet is highly complex, contains toxic chemicals, and is difficult to recycle. The California legislature recently mandated that carpet recycling rates more than double from 2015 to 2020. Optimally, the industry will accomplish these rates by recycling old carpet into new carpet without reintroducing legacy toxic chemicals. Achieving this optimization requires a combination of strategies, including product transparency, recycled feedstock screening, and less toxic carpet design. Carpet manufacturers are beginning to respond to owner demands for healthier products and to rating systems like LEED that reward disclosure of ingredients as well as avoidance of hazardous chemicals. But most product certifications and chemical rankings are missing many of the most important toxicants. More focus is needed to accelerate market transformation towards carpet products that have lower toxicity and will be readily recycled at scale.

SUITABLE BUILDING APPLICATIONS: With proper screening and product design, carpet can play a role in the circular economy³ with closed loop recycling systems, turning carpet face fiber back into new face fiber and carpet backing into new backing. Less optimally, carpet components (mainly fibers) are also down-cycled into other building materials including insulation⁴ and decking.⁵

UNSUITABLE USES: Processors should not recycle carpet if they are unable to screen for toxic chemicals identified in this report, prevent workers' exposure to these chemicals, and avoid reincorporating these chemicals into products destined for living spaces.

PATHWAYS FOR OPTIMIZATION:

Design carpet that is easy to recycle and avoids the use of toxic chemicals. Less toxic alternatives exist for all functional ingredients and should be used as substitutions for more toxic counterparts. Publicly identify all ingredients so consumers can make more informed choices. Leverage product certifications that reward disclosure, hazard avoidance, and green chemistry principles to help drive awareness and demand for better products.

The Healthy Building Network (HBN) examined the composition of carpet waste, and innovations in carpet composition, to determine the potential health and environmental impacts of recycling and using these materials in new carpet. HBN identified 44 toxic substances frequently used in face fiber, backing, adhesives, and carpet pad.

Carpet Face Fiber: Carpet manufacturers rarely disclose the presence of toxic additives used to treat most face fibers, including:

- **Stain repellent treatments** that use poly- and perfluoroalkyl substances (PFAS). The U.S. carpet industry phased out the use of treatments based on long-chain PFAS in 2008. These chemicals are potent developmental and reproductive toxicants that persist in the human body and environment. But

the industry continues to use shorter-chain length PFAS about which similar concerns are emerging. People inhale or ingest these chemicals throughout the lifecycle of production, use, and disposal of carpet. Carpet manufacturing plants have polluted downstream drinking water supplies with stain repellants. Building occupants (especially children crawling on floors) can inhale and ingest PFAS that migrates out of carpet. After use, workers and surrounding residents can breathe in PFAS released by carpet shredding operations, where dust fills the air. While technologies exist to remove toxic substances from recycled plastics, many processors simply shred old carpet fibers and sell the feedstock as “fluff”, without further treatment, to manufacturers. Alternatives have recently emerged. At least three carpet fiber manufacturers utilize non PFAS chemistry to provide stain repellency.

- **Antimicrobial preservatives** that protect plastic ingredients from biological degradation, including highly toxic triclosan and formaldehyde. Triclosan is an endocrine disruptor. Formaldehyde is a highly potent carcinogen. While other preservatives may be more common, it is difficult to know: manufacturers rarely disclose the biocides that are in carpets.

Carpet Backings: Carpet backings are highly complex and often contain substances of concern that are dangerous for human health and hinder recycling operations including:

- **Isocyanates**, the main ingredient of **polyurethane** carpet backing. They present a highly potent respiratory hazard through inhalation or skin contact -- so potent that one drop of liquid isocyanate on a person's skin can cause the onset of asthma. At least a dozen carpet manufacturers in the U.S. report isocyanate air emissions. Carpet backing containing polyurethane is unrecyclable, according to industry experts.
- **Polyvinyl chloride (PVC)**, widely used as a binder in carpet tile and broadloom backing. PVC backing in carpet entering the waste stream contains toxic additives, including heavy metal stabilizers such as organotins and phthalate plasticizers. **Organotins** as a class are very toxic to aquatic life. They persist and bioaccumulate in the environment, and are reproductive toxicants to humans. Many **phthalates** have been identified by California and federal regulators as causing cancer, and some can cause developmental and reproductive harm. Scientists are finding alarming correlations between phthalates and asthma and human neurological diseases. Many manufacturers are phasing out phthalates, but even without them, the production of PVC inherently relies on toxic inputs and produces toxic byproducts. At its core, PVC relies upon chlorine chemistry. Most chlorine production in North America is based on either asbestos diaphragms or mercury cells. These toxic technologies are over a century old. The processing of chlorine into PVC emits chlorine and chloroform, highly potent carcinogenic dioxins and vinyl chloride monomer, and ozone-depleting chemicals like carbon tetrachloride. Plasticized PVC products often contain toxic additives, including phthalates and flame retardants, which these products in turn release during use. At the end of life, burning PVC produces more dioxins, a concern given the widespread fate of carpet waste as fuel for cement kilns and “waste-to-energy” incinerators.
- **Flame retardants**, which are most often used in polyurethane and latex backings, and occasionally in specialty fibers. Some flame retardants used in carpet are halogenated (they contain chlorine or bromine). Halogenated flame retardants are among the chemical industry's most notorious products. They are linked to hyperactivity, learning disabilities, reproductive harm, and cancer. Common replacements for the halogenated flame retardants are organophosphate flame retardants, which are linked to endocrine disruption and infertility. Flame retardants can be emitted from carpet into dust and the air both during use and from operations that recycle and dispose of carpet waste. Released into the environment, they can persist and bioaccumulate up the food chain. Halogenated and organophosphate flame retardants are also present, unintentionally, in bonded carpet pad. These

products are made mainly from recycled furniture foam. A study found that workers who recycled foam for bonded carpet manufacturers had body burdens of flame retardants ten times higher than the general public.

- **Fly ash**, a byproduct of coal-fired power plants, widely used as a filler in carpet tile. The carpet industry has become a repository for the coal power industry's waste. Manufacturers have used fly ash to load carpet with so-called "recycled content." Some carpet, by weight, is 40 percent fly ash. It has been a marketing advantage: prominent green building certifications have rewarded recycled content regardless of its origin and contaminants. Pollution control devices on power plants transfer mercury, a potent neurotoxicant, from air emissions into fly ash.

Adhesives: Adhesives are used to keep many carpets in place. Carpet adhesives often contain toxic substances such as bisphenol A and nonylphenol ethoxylates, both of which have been found to have endocrine disruption activity. This means they can interfere with people's endocrine systems and harm their developmental, reproductive, and neurological health. Adhesives become permanently bonded to the carpet and make it hard to recycle, as they contaminate the material stream.

CONCLUSIONS AND RECOMMENDATIONS

Using HBN's established Optimizing Recycling framework, this report examines the impact of these past and present ingredients on human health and the environment, throughout their life cycles. It considers whether the industry has adequate supply chain controls to prevent these impacts from spreading through recycling. It also evaluates the current and potential growth of this feedstock and related "green jobs."

There are systemic barriers to expansion of carpet recycling, many of which are interrelated with product design and content, and the resulting toxic complexities entering the waste stream today. We could find no mass-produced carpet that is verifiably devoid of toxic substances. At the same time, there are alternative, less hazardous chemicals or materials for all of the identified toxics, showing the potential for transformation. For each hazardous chemical or chemical class identified, the report outlines "transformation pathways." These address the carpet that is currently entering the waste stream and the products that are being designed today.

The report concludes with recommendations to overcome current barriers and scale up healthy and environmentally-friendly solutions for all players: manufacturers, processors, consumers, certifying organizations, regulators and retailers. Avoiding toxic content is a prerequisite for a truly circular economy in which old carpet becomes new carpet, replacing virgin materials on a 1:1 basis. The ultimate purpose of recycling is to minimize the need for virgin materials.

Manufacturers should design carpets for recyclability. The complicated structure of carpet, the plastics and toxic additives that comprise most of these products, and the adhesives used in carpet installations, confound industry efforts to recycle. For example, recyclers do not recycle broadloom carpet that has been glued down. Simplifying product design, avoiding adhesives, and detoxifying carpet backing and fibers are crucial steps toward carpet recycling optimization.

Therefore, this report concludes with a call for the fundamental transformation of the carpet industry.

Recommendations include:

- Banning the most toxic substances identified in this report and replacing them with other readily-available, less toxic chemicals;
- Incentivizing the design of fully recyclable carpets and removing substances that impede that process;
- Ensuring that toxic substances in carpet waste are identified and removed before they are recycled into new consumer products including carpet;

- Increasing and enforcing protections for workers in the recycling industry;
- Ensuring that product certifications more comprehensively protect human health;
- Holding manufacturers and certification schemes accountable, if they are misleading consumers;
- And, requiring that manufacturers and retailers fully and publicly disclose all material contents in new carpet.

Industry: scale up solutions, disclose content information and take responsibility

The carpet industry has not developed protocols or policies to prevent the reintroduction of contaminants like PFAS stain repellants and many other toxics from carpet waste into new products. These chemicals should be identified and prevented from being recycled into new carpet. Without adequate screening, recycling workers will be exposed to these chemicals in dusty carpet shredding facilities, residents living nearby may be exposed, and these chemicals will be incorporated into new products. The industry lacks standards for this kind of screening, and there is little regulatory oversight.

A healthy circular economy requires rules of the road that forge a common understanding of what is and is not acceptable, whether the material is virgin or recycled. The carpet industry has established no clear plan to become more circular. The absence of rules reflects this inertia. Establishing best practices will in turn increase the amount of feedstock available to manufacturers seeking recycled materials that are compatible with their product specifications.

Many carpet components manufactured today are unrecyclable. There is little to no evidence of polyurethane or styrene butadiene latex backings being recycled, for example. Eliminating the use of virgin polyurethane and PVC in backings has added benefits, such as reduced demand for chlorine and all its associated pollution, and eliminating the use of organotin catalysts. Carpet industry innovators should develop backing options based on green chemistry principles that avoid the use and release of toxic substances. This includes avoiding the use of fly ash, and replacing it with benign and underutilized post-consumer recycled feedstocks such as recycled glass.

No carpet yet seems to be devoid of all 44 hazardous chemicals identified in this report, but that time may be approaching. An outcome of this research is a realization that alternatives are available today, albeit piecemeal. A quiet transformation seems to be underway. Shaw Industries stopped using PVC over a decade ago, and in the last year, stopped using fly ash as filler. Three major producers sell carpet fibers without fluorinated stain repellants. Interface still relies on PVC, but it seems intent to recycle more carpet backing than any other company, eliminate virgin material consumption, and (except for phthalates) has established useful recycled content screening practices. Tarkett and Mohawk have launched new carpet lines based on recycled PET that are seemingly well-designed for circular recyclability.

The potential environmental and human health impacts of some innovations should be fully evaluated before they enter the marketplace; now that some are on the market, full, independent assessments should be completed with haste. When safer, fully recyclable, fully assessed alternatives are on the market, there is no reason for carpet manufacturers to use toxic substances, or for anyone (from individuals to developers to retailers, cities, and states), to buy, third parties to certify, or regulators to allow carpets that contain them on the market.

Regulators: Protect workers' health, ban the most dangerous toxics, mandate industry responsibility

Anyone encountering carpet and carpet waste is potentially exposed to substances known to harm human health or the environment. Regulators should protect public and workers' health: they are urged to ban PFAS and other toxic substances identified in this paper, starting with those listed in Table 1 on page 40. Workers in carpet recycling are at the highest risk of inhaling or ingesting toxic components of carpet dust. Therefore, regulators should increase surveillance of workers' health, including collectors, processors, and recyclers. Regulators can also play an important role in providing guidance to certification programs on the toxic substances that must be covered to support green claims by the certifiers

and by manufacturers referencing those certifications. They can incorporate this into the FTC Green Guides and similar state level guidance. Further, states should consider incentivizing the use of inherently safer substances and chemicals and improved recyclability via Extended Producer Responsibility (EPR) systems. Other states should follow California's lead in developing mandatory EPRs for carpet.

Consumers have a right to know

An informed marketplace is a great driver of change. Currently, it is a challenge for consumers to inform themselves about toxicity or recyclability of carpet. However, some consumers are knowledgeable of these issues and seek to purchase healthier and recyclable products. This is demonstrated by leading architectural firms and building owners' efforts to avoid products that contain fly ash, PFAS, antimicrobials and flame retardants. Perkins+Will's Precautionary List and guidance by non-profits such as the Green Science Policy Institute's Six Classes and Practice GreenHealth's Healthier Hospital Initiative identify each of these chemical classes of concern for avoidance. Many firms have also tried to avoid products with certain chemicals by meeting the material program requirements of building certification programs including the Living Building Challenge, Green Guide for Health Care, WELL Standard and other building product programs that reward avoidance of these classes of chemicals such as Cradle to Cradle Certified (C2C).

Consumers should always require full disclosure of product contents and any required adhesives before considering buying a carpet. Full disclosure leads to transformation. When some consumers became aware that a lot of the recycled content in carpet was fly ash from power plants, they started requesting fly ash-free formulations. Over time, the industry started to change. In late 2016, Shaw, the largest carpet company in the U.S., stopped using fly ash as filler.

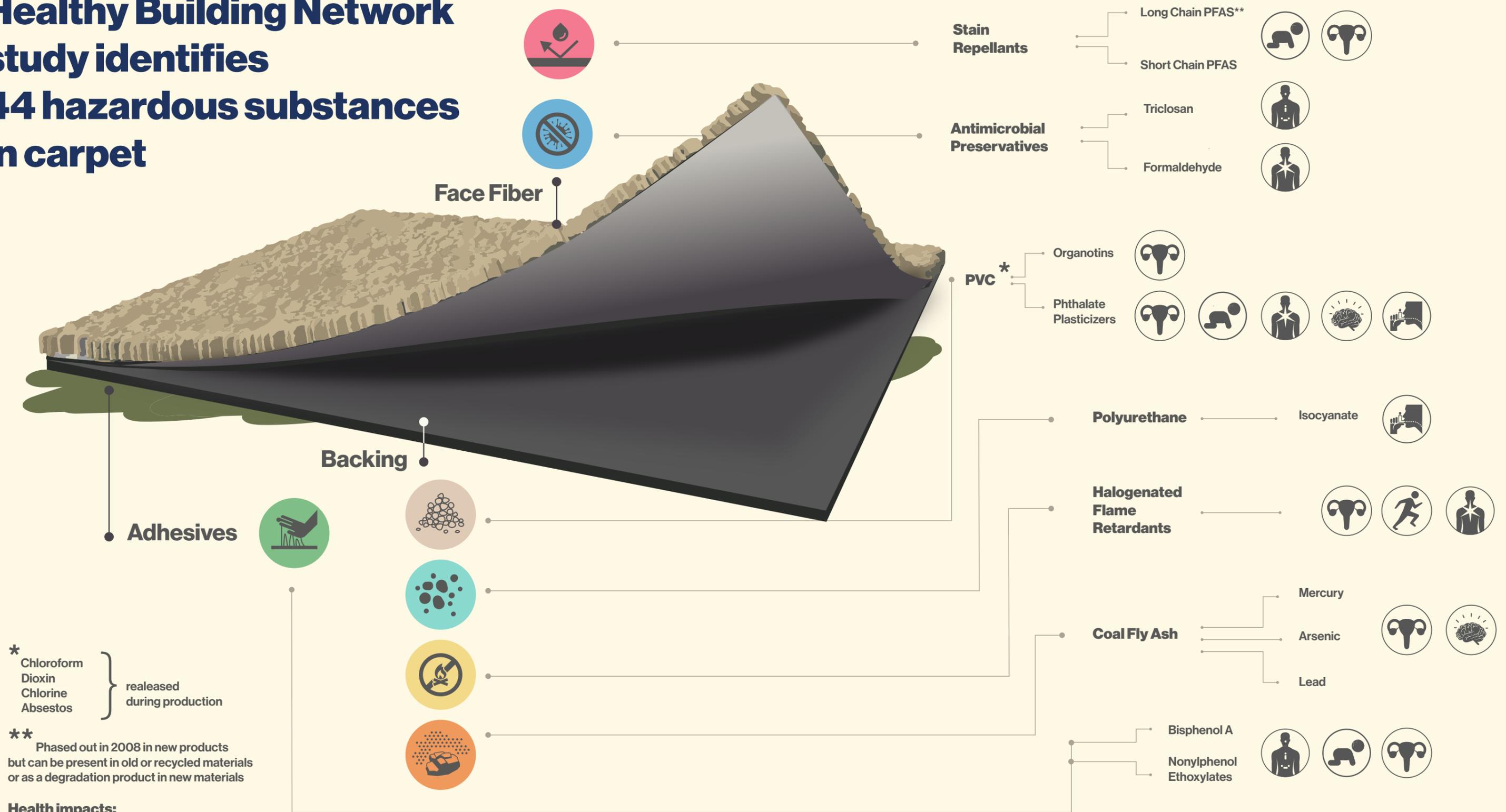
Product certifiers have helped to reduce the carpet industry's use of certain chemicals and increase its use of recycled content. But most certifications do not address most of the toxic substances found in carpet and carpet adhesives. This is especially true for the industry-led GreenLabel Plus program, which relies upon a standard that tests for just one of the 44 toxic chemicals identified in this report. Only one U.S.-based certifier currently tests or screens for more than half of these chemicals. C2C bans just 8 of the 44, but it explicitly limits all but 6 of the 44. The Blue Angel ecolabel in Germany is highly precautionary, banning 34 of the 44 toxic substances. Its database shows these restrictions are reasonable: it lists 50 carpet companies and 114 certified carpets. This report recommends that red lists include all 44 of the toxic substances identified in this report. Carpet containing any of these chemicals should not qualify for the highest level of product certifications.

California – leading the way on non-toxic and recyclable carpet?

California Assembly Bill 1158, which Gov. Jerry Brown signed on October 14, 2017 is a step on the way to optimal recycling. By mandating a doubling of carpet recycling by 2020, it will increase pressure on the carpet industry to start transforming. Recognizing the industry's considerable room to grow, the legislature requires it to develop a carpet stewardship plan that achieves a 24 percent recycling rate for post-consumer carpet by January 1, 2020.

To achieve such a dramatic increase in throughput for post-consumer carpet, without reintroducing toxic substances into the workplace and consumer products, the industry will need to implement far more quality controls, and soon. These controls begin with a full accounting of what is in the feedstock, using either manufacturer disclosure or robust testing to identify toxic substances that are in carpets produced five, 10, or 20 years ago. These procedures must be implemented to ensure manufacturers that post-consumer carpet feedstocks are suitable for inclusion in new products and thus help the industry achieve a 24 percent recycling rate by 2020. Doubling carpet recycling in two years will require a lot of diligence to ensure the feedstock is well-understood and does no harm as it is recycled. California's carpet recycling mandate must be accompanied by efforts to establish best practices to protect worker health and the environment and to accelerate the detoxification of the carpet industry for the future of recycling.

Healthy Building Network study identifies 44 hazardous substances in carpet



"This graphic outlines some of the most hazardous substances and some of their highest possible hazards, but does not reflect all hazardous content that can be found in carpet, or all associated hazards for the chemicals and chemical groups listed. See the report text and appendices for additional information on specific chemical hazard associations."

The 24 percent target should not be the end goal, especially as this allows downcycling carpet, rather than recycling it back into carpet. Ultimately, the industry's integration with a circular economy requires a fully closed loop system. Closing the loop will depend upon the elimination of toxic chemicals at the front end of product design.

About This Report

This report explores the use of these toxic ingredients in carpet and identifies pathways to remove them from recycled feedstocks. Following the established framework of our Optimizing Recycling series, it evaluates post-consumer carpet feedstock as delivered for incorporation into new products against a set of four criteria. The criteria gauge:

- Impacts on human health and the environment;
- Supply chain controls and transparency;
- The availability of "green jobs"; and
- Opportunities to expand use of the feedstock.

Each criterion is judged on a three-part scale, with green indicating "very good," yellow indicating "room for improvement," and red indicating "significant concerns." The review is focused on California, but the analysis of health and environmental impacts and supply chain controls is broadly applicable throughout the United States.

Following this analysis, the report recommends actions for manufacturers, recyclers, regulators, consumers (retail and commercial/institutional) and others that will foster a healthier circular economy of carpet. These actions will protect consumer, occupational and environmental well-being in all stages of a carpet's life cycle: production, installation, use, removal and recycling. They will lead to carpet that is free of toxic materials and easier to recycle into new carpet.

Appendix 1 lists the ingredients of highest concern entering the carpet waste stream, and their environmental and human health hazards. Many of these toxic substances impact vulnerable people like young children, who spend a lot of time on the floor.

Appendix 2 cross-references these substances against mandates to report and restrict them. Many are restricted by other industries and governments outside the U.S. However, federal and state regulations do not restrict most of these chemicals and metals, nor do the standards used to certify carpet sold in the U.S.

Appendix 3 places this overall evaluation of post-consumer carpet feedstock in the context of six detailed reports we have conducted in the Optimize Recycling series. As with most other feedstocks we've examined, only a small percentage of carpet is currently recycled, but there is considerable room to grow. Manufacturers and recyclers can make significant strides to support a healthy circular economy through quality control, improved recycling technologies, and thoughtful product design.

Methodology

HBN examined carpet waste from the perspective of its usefulness as a post-consumer recycled feedstock that can replace functionally equivalent virgin materials in the manufacture of new carpet. For the past decade, the Healthy Building Network has been researching the composition of carpet as part of our Pharos Project, HomeFree, Quartz Project, Data Commons, Portico, and Optimizing Recycling initiatives.⁶

Sources include, but are not limited to, trade association documents, Health Product Declarations (HPDs), Environmental Product Declarations (EPDs), Life Cycle Assessments (LCAs), patents, Safety Data Sheets (SDSs), technical product documents, manufacturers, and government, academic, and other authoritative institutions.

The authors cross-referenced the ingredients found in these sources with our Pharos Chemical and Materials Library (CML), the world's most definitive source of chemical hazard data. The Pharos CML is an online catalog of over 50,000 chemicals, polymers, metals, and other substances that is continuously updated to provide accurate health hazard data. It identifies key health and environmental information using 45 authoritative scientific lists for specific human and environmental health hazards and 29 restricted substance lists, including the California Department of Toxic Substance Control (DTSC)'s Candidate Chemicals list.

From this cross-referencing, HBN identified the most common substances with the highest health and environmental hazards associated with carpet.

Behind The Ratings

■ FEEDSTOCK HEALTH AND ENVIRONMENTAL HAZARDS

Carpets that enter today's waste streams are comprised of multiple layers, including face fibers and backings. Most face fibers typically include stain resistance treatments and biocides. Backings typically include plastic binders, filler material, and additives such as flame retardants.

Carpet floor coverings fall into two categories: broadloom and tile. Tile is more common in commercial buildings than residences, where broadloom predominates. Broadloom (also called sheet) carpet is typically produced in 6- and 12-foot rolls. Tile carpet, also called modular carpet, is processed into squares that are typically 24", 36", 50cm or 1m on a side. Carpet tiles require thicker backing than broadloom carpet to stay flat due to their smaller size.

The most common fibers are nylon 6, nylon 6,6, polyethylene terephthalate (PET) and polypropylene.⁷ The most common backings are based on PVC and polyurethane (in tile and broadloom), and latex (broadloom).⁸

Carpet manufacturers sell carpet in a wide variety of styles, with variations of face fiber, backing and thicknesses. In broadloom carpet, the face fiber may weigh as much as the backing.⁹ Below we discuss the most common and most toxic contents in carpet, and their life cycle impacts. We also suggest "transformation pathways" or strategies to avoid and replace them.



Stain Repellency Treatments

Carpets historically have contained poly- and perfluoroalkyl substances (PFAS) to impart stain repellency to carpet face fibers. Despite the availability of alternatives, a large portion of new carpets still use these treatments. Carpet and other home textile treatments account for a large percentage of global PFAS use. The California Department of Toxic Substance Control (DTSC) “has identified carpets, rugs, indoor upholstered furniture, and their associated care and treatment products, as the largest potential sources of significant and widespread PFAS exposures.”¹⁰

Historically, the carpet industry used long-chain PFAS — mainly perfluorooctane sulfonic acid and perfluorooctanoic acid (PFOS and PFOA, C-8) — in the production of polymers for stain repellent treatments. Long-chain PFAS are widely acknowledged as being very persistent in the environment and human blood. They are developmental and reproductive toxicants that bioaccumulate in the environment over long periods of time, and persist in the human body.

The carpet industry eliminated treatments based on long-chain PFAS from U.S. production by the year 2008. Under pressure from consumers and regulators, companies voluntarily replaced them with treatments based on shorter-chain compounds, including fluorotelomer-based PFAS with six perfluorinated carbons (C-6) and perfluoroalkyl sulfonyl fluoride-based chemistries with four perfluorinated carbons (C-4, PFBS).

Some polymer treatments can contain significant residual monomer PFAS and intermediate fluorotelomers.¹¹ Fluorotelomers can degrade into smaller PFAS, including PFOA — even if PFOA wasn’t used in their production.¹² Studies also indicate that some of the polymers themselves can degrade into fluorotelomers and other PFAS under certain environmental conditions.¹³

Replacing a known toxic chemical with a chemical having similar hazards is often referred to as a “regrettable substitution.” Short-chain PFAS are now in the sights of environmental health scientists and the healthy building community. Many (but not all) short-chain PFAS are on the California Department of Toxic Substance Control’s list of priority chemicals to address.¹⁴ In May 2015, over 200 scientists published the Madrid Statement (see text box), which recommends that consumers should “whenever possible, avoid products containing, or manufactured using” these chemicals.¹⁵ The problem is, for carpet, as with other products, manufacturers do not disclose enough information for consumers to avoid them.

Production Impacts

3M and DuPont are major producers of PFAS. Their production has contaminated air, water, land, fish, animals, crops, and people across the country.

A scientific panel recently found “probable links” between DuPont’s Washington Works, Ohio, production of PFOA and specific diseases in people living near the factory. Diseases include high cholesterol, kidney cancer, pregnancy-induced hypertension, testicular cancer, thyroid disease, and ulcerative colitis.¹⁷

“The most common replacements (for long-chain PFAS) are short-chain PFAS with similar structures, or compounds with fluorinated segments joined by ether linkages. While some shorter-chain fluorinated alternatives seem to be less bio-accumulative, they are still as environmentally persistent as long-chain substances or have persistent degradation products. Thus, a switch to short-chain and other fluorinated alternatives may not reduce the amounts of PFAS in the environment. In addition, because some of the shorter-chain PFAS are less effective, larger quantities may be needed to provide the same performance.”¹⁶

Madrid Statement, 2015

3M's Cottage Grove, Minnesota, plant stopped making the longer-chain PFAS over a decade ago, but continues to produce short-chain PFAS. "The environmental concentration of short-chain [PFAS] now often exceeds those of the longer-chain substances in water and other media, yet there is very limited toxicological data for them, and currently no tolerable daily intake has been established," note Minnesota officials and other scientists who documented the distribution of PFAS from the Cottage Grove plant.¹⁸

So, too, has the carpet industry polluted the land and water with PFAS. In May 2017, the town of Centre, Alabama, sued many of the world's largest carpet companies for contaminating the town's water with PFAS. The chemicals were released upstream, in Dalton, Georgia, where most of the world's carpet is produced in over 150 factories.¹⁹ The nearby city of Decatur, Alabama, filed a similar suit in 2016. Water supplies downstream of Dalton, including the Tennessee and Coosa Rivers, have been found to contain long-chain PFAS above EPA's safety limit.²⁰

Use Impacts

Children are likely to be exposed to PFAS through hand-to-mouth transfer from treated carpet. According to the U.S. Centers for Disease Control (CDC), "Major types of human exposure sources from PFAS include... Hand-to-mouth transfer from surfaces treated with PFAS-containing stain protectants, such as carpets, which is thought to be most significant for infants and toddlers." The CDC also warns that people can inhale PFAS in dust released from carpet.²¹

EPA, in its action plan for long-chain perfluorinated chemicals (PFCs), says "Children are particularly susceptible to exposure from inhalation of PFC off-gassing from carpet and carpet protectants during their earliest years when they are lying, crawling and spending large amounts of time playing on the carpet. The significantly high levels of PFC found by ORD [EPA's Office of Research and Development] in carpet and carpet protectants pose an exposure concern for children through this pathway. Adults can also be exposed to PFCs in carpets through inhalation and dermal contact."²³

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"Abrasion is the mechanical scratching, scuffing, or rubbing away of a material's contents. For example, the fading and wear patterns seen on carpet in high-traffic areas are a result of abrasion," notes a U.S. Green Building Council research paper.²⁴ Those wear patterns betray the release of stain repellants and other treatments in the face fiber. An industry report from 2000 estimates that 50 percent of a fluorochemical treatment may be lost over a nine year lifespan of carpet due to walking and vacuuming.²⁵

A Canadian study "found that the amount of carpeting in the house was positively correlated with PFOS, PFOA, and PFHS [perfluorohexanesulfonate] concentrations in the dust. Older homes, which had less carpeting, also had significantly lower levels of PFOS and PFOA."²⁶

Mechanical wear is not the only mechanism through which perfluorinated chemicals may be released into the environment. Steam cleaning carpet also releases PFAS treatments into water supplies.²⁷ The same industry report referenced above indicates that an additional 45 percent of the fluorochemical treatment may be removed by steam cleaning throughout the carpet's life.²⁸

Recycling/Disposal Impacts

PFAS migrate from carpet over time, through wear, adsorption to dust, and cleaning.²⁹ One carpet industry source says the carpet they receive for recycling rarely has residual PFAS above detection limits.³⁰ Another manufacturer claims, “On average, nylon carpets lose 50 percent of this protection after just three cleanings.”³¹ However, tests have found that old carpet can release considerable amounts of PFAS after about 100 days in landfill conditions. The tests identified mainly short-chain PFAS (C4-C7) in landfill leachate.³² Some of this may originate from stain-repellant treatments, like Scotchgard™, that consumers apply to carpet after installation.³³

Carpet waste shredding facilities supply shredded carpet to cement kilns for burning and to carpet manufacturers for recycling.³⁴ These facilities are filled with carpet dust, and workers may be inhaling and ingesting PFAS. This is the mechanism thought to be responsible for the elevated levels of flame retardants in workers in carpet pad recycling facilities (see p.24). Logic holds that shredders disperse PFAS into the air and dust, but no health or body burden studies for carpet recycling workers appear to have been conducted.

In 2011, the European Commission studied waste issues related to PFOS, and determined that -- given that the average lifetime of a carpet is 14 years -- carpets containing PFOS were still entering the waste stream long after 3M and other U.S. and European manufacturers phased-out its production. The study estimated that old carpet contain, on average, 75 parts per million (ppm) PFOS, and contribute a total of 146,000 kilograms of PFOS (from 1.94 million tons of carpet discarded per year) to the waste stream. In addition, it estimated that carpet still in use contain 1.64 million kg PFOS in 21.7 million tons of carpet.³⁵

The Stockholm Convention on persistent organic pollutants bans the recycling and reuse of carpet containing long-chain PFAS because “many of the products produced from recycled synthetic carpets represent a direct exposure of the environment and humans” to these toxic substances.³⁶ Over 176 countries have ratified this convention, but the United States has failed to do so, even though it signed the agreement in 2001.³⁷ Thus, there are no restrictions on recycling old carpet containing PFAS, whether long- or short-chain, in the U.S.

Alternatives

Unfortunately, carpet manufacturers rarely reveal the chemicals used as stain repellants on face fibers. They usually don’t disclose any additives in product declarations and safety data sheets. For this reason, in the absence of information to the contrary, consumers and recyclers should assume PFAS-based stain repellants are present in carpet fiber.

However, the biggest fiber manufacturers have started selling fluorine-free carpet fibers. Interface signaled the future when it stopped using PFAS-based treatments on its face fibers several years ago. According to Floor Daily, Interface “started in early 2011 by eliminating the treatment from its Aquafil and Universal nylon fiber, which together account for 90% of its fiber offering, and (by 2014) it completed the process by eliminating PFC treatments from its Invista fiber.”³⁸ Interface says “with the stain resist technology that’s built into the fibers, you’ve got added protection against staining with no need for an additional topical treatment.”³⁹

The Stockholm Convention on persistent organic pollutants bans the recycling and reuse of carpet containing long-chain PFAS because “many of the products produced from recycled synthetic carpets represent a direct exposure of the environment and humans” to these toxic substances. Over 176 countries have ratified this convention, but the United States has failed to do so, even though it signed the agreement in 2001. Thus, there are no restrictions on recycling old carpet containing PFAS, whether long- or short-chain, in the U.S.

Universal Fibers describes the use of a “sulfonated nylon copolymer” that “renders the fiber chemically inert to acid dyes and stains.”⁴⁰ The “conventional procedure” according to a Shaw Industries patent, “is based on an addition of a metal salt of sulfoisophthalic acid.”⁴¹ Typical examples described in patents -- including salts of 5-sulfoisophthalic acid⁴²; diaminium bis-3,5-dicarboxybenzenesulfonate and tri-diaminium bis-3,4-dicarboxybenzenesulfonate⁴³ -- are not associated with significant health or environmental hazards, but they have not been fully assessed.

Aquafil markets a nylon 6 fiber (Econyl StayClean) made from “100% regenerated Nylon that ensures stain protection without any topical treatment.”⁴⁴ It does not describe how it achieves this property.

Invista, one of the world’s largest fiber manufacturers, recently obtained a patent for a “fluorine-free” composition that renders carpet fibers “water repellent, soil resistant and stain resistant.” Unlike Universal Fiber and Aquafil, its invention is a topical treatment. According to Invista, “there is an increasing interest in the carpet and textile floor covering industry to replace the presently used C6-fluorochemicals with fluorine-free soil resistant and water repellent products.” Its invention is a mixture of a clay nanoparticle, an anionic acrylic-based copolymer binding agent, and water.⁴⁵ In 2016, Invista announced that its Antron Nylon 6,6 fiber was “now made with a fluorine-free topical soil resistance formula.”⁴⁶

Most of these non-fluorinated replacement stain repellants are imprecisely disclosed. Their health and environmental hazards are largely unassessed.

Transformation Pathways:

- *Manufacturers must eliminate the use of all PFAS, both short and long chain PFAS, as well as treatments that can degrade into them.*
- *To ensure there are no regrettable substitutions, manufacturers should fully assess the human health and environmental hazards of non-fluorinated replacements.*
- *Regulators should ban the use of PFAS in carpet fibers and carpet protection products that consumers later apply to carpet. The California Department of Toxic Substances Control should immediately target PFAS in carpet as a priority product-chemical combination for its Safer Consumer Products program.⁴⁷*
- *Consumers should avoid purchasing carpet and carpet protection products that contain PFAS stain repellants. Consumers should insist that manufacturers provide transparent disclosure of chemical contents in stain repellent treatments, so that customers are able to make informed choices.*
- *Current carpet waste stock should be tested for PFAS and results shared publicly.*
- *To avoid contamination of future feedstocks, the industry should select and develop carpet fibers that utilize fluorine-free topical or built-in treatments or are naturally stain repellent, such as wool. Wool is in about 2.2 percent of the U.S. carpet market (compared to Nylon 6/6,6 43.8 percent, PET 41.8 percent, PP 12.2 percent).⁴⁸ Wool “won’t soil quickly due to its natural soil resistance, making chemical stain protection treatments unnecessary,” says one manufacturer.⁴⁹ While a common belief has been that carpet wool fiber can only be downcycled, not recycled into new face fiber,⁵⁰ the Re.Verso collaboration in Italy is demonstrating the viability of recycling pre-consumer wool textiles, from fabrics back into fabrics.⁵¹ According to Greenpeace, the Re.Verso consortium is beginning to consider post-consumer textiles.⁵² (Note, however, that wool and other animal carpet fiber often contains biocides like permethrin to combat beetles and moths. Manufacturers should disclose and minimize the use of these additives.⁵³)*

Antimicrobials

Antimicrobials are used as preservatives in carpet fibers and backing. These biocides target microorganisms (e.g., bacteria and mold⁵⁴) that consume and inhabit carbon-based ingredients like phthalates, polyurethanes, latex, and polyesters.⁵⁵

Health and environmental impacts vary considerably between different antimicrobials. One of the most commonly used antimicrobials, zinc pyrithione, is a systemic toxicant that can trigger asthma or other allergic reactions. Like most biocides, zinc pyrithione is highly toxic in the aquatic environment. When carpets are steam-cleaned, antimicrobials can be removed and sent into wastewater, and threaten water quality.

Microban International's "Microban Additive B" -- its trade name for the infamous biocide triclosan -- has been permitted for use in carpet at doses as high as one percent of the total weight of the carpet since 1983.⁵⁶ Triclosan, a halogenated phenolic compound, is a known endocrine disruptor widely used in consumer products during the past quarter-century. At least four companies have reported using triclosan in their carpet and rugs.⁵⁷

Formaldehyde, a highly potent carcinogen, has also been used as a biocide in carpet.⁵⁸ Urea formaldehyde polymers, suspected of causing contact dermatitis in clothing textiles,⁵⁹ have been reported as present in carpet tile.

Some carpet contains the nano-scale forms of silver compounds, such as silver sodium hydrogen zirconium phosphate,⁶⁰ which is on the California Department of Toxic Substance Control's candidate list of substances to avoid. Nano-scale particles are 100,000 times smaller in diameter than human hair.⁶¹ Despite their widespread use in consumer products, there has been little testing for silver nanoparticles' potential health and environmental hazards.⁶² The technology is still in its infancy, with major questions outstanding about how these materials may interact with and affect our bodies.

While biocidal preservatives are necessary to prevent plastics from being attacked by microbes, companies sometimes describe their function more broadly as "antibacterial," in ways that might give people the impression that the carpet protects them from germs. Such claims have been reported in children's play rugs and other floor coverings.⁶³ A company that sells silver-based antimicrobials markets their use in carpets this way:

"When applied to carpets, Agion Antimicrobial constantly fights the growth of odor-causing bacteria, resulting in fresher, cleaner carpets. This allows you to wash your carpets less frequently, while keeping the threat of bacteria growth low."⁶⁴

Shaw says its "Healthcare floors can create atmospheres that support patient recovery, provide comfort underfoot, and enhance spaces designed to promote healing. That means there's a lot to consider when it comes to choosing the right floor for your healthcare space. Appearance retention. Moisture resistance and *anti-bacterial properties*."⁶⁵ (*emphasis added*.)

This does not imply "health-based outcomes," Troy Virgo, Shaw's Director of Sustainability and Product Stewardship told HBN. "Shaw does not add biocides to its finished carpet products to provide additional product protection for the end user."

Another company sells an "antimicrobial" entrance mat and claims that it "stops most Gram-positive and Gram-negative bacteria and fungi at the entrance."⁶⁶

Beaulieu proclaims, "For a fresher, healthier feeling home, there's nothing better than carpet with Silver Release(R) antimicrobial carpet treatment." Then it makes this clarification: "The antimicrobial characteristics do not extend to people or animals and in no way affect or improve the health of people or animals."⁶⁷

The architect and design firm, Perkins+Will, recently determined that “there is no evidence” that antimicrobials provide an added health benefit in building materials. Its 2017 report (co-authored by HBN) on antimicrobials explains how this kind of advertising misinforms the market. Consumers may purchase these products believing that their health may be protected as a result. They are confused “because of a lack of disclosure that antimicrobial ingredients are present, their specific identity, the purpose they serve in the product, and the potential health and environmental hazards they pose.”

The widespread use of antimicrobial agents like triclosan and nanosilver “may be contributing to the emergence of microbes resistant to them, and more worryingly, resistant to some therapeutic antibiotics used in the healthcare system,” the authors assert.⁶⁸ “Antimicrobial additives used in building products are outside the jurisdictions of the Centers for Disease Control and the Food and Drug Administration because they are regulated by the US Environmental Protection Agency (EPA). However, this is merely a bureaucratic distinction. Available evidence supports the same conclusion drawn by the EPA’s sister agencies: antimicrobials do not provide health benefits. When this lack of benefit is measured against the many costs of antimicrobials, it is clear that the best policy is to avoid products marketed as being antimicrobial whenever possible.”

Carpet companies infrequently disclose the chemical identities of the antimicrobials in their products. Safety data sheets only require companies to disclose most hazardous contents if they comprise at least one percent of the product by weight.⁶⁹ Antimicrobial dosages are usually less than 0.3 percent.

Transformation Pathways:

- *Carpet manufacturers should not add antimicrobials unless specifically needed for product preservation and should publicly disclose the actual identity and function of all added preservatives. They should choose the least hazardous option available for their application. They should not add antimicrobials for the purposes of making health claims. Consumers should avoid products that claim or imply a health benefit from the presence of antimicrobials.*
- *Regulators should ban the use of high hazard biocides in carpet.*
- *Consumers should choose products that do not contain high hazard biocides.⁷⁰ These actions will prevent the release of toxic biocides in the indoor environment and during subsequent cleaning, removal, recycling or disposal operations.*

Isocyanates in Polyurethane Backing

Isocyanates, a primary ingredient that goes into the production of polyurethane backing, are powerful chemicals. One drop of isocyanate on the skin, according to recently disclosed industry documents, can cause permanent respiratory injury.⁷¹ They are also respiratory hazards when inhaled.

Manufacturing Impacts

In carpet factories, manufacturers combine isocyanates with polyols, various materials as filler to add bulk, and other functional substances like flame retardants to manufacture polyurethane backing.⁷² A typical polyurethane backing contains a reacted mixture of 10 percent isocyanate and 29 percent polyol, plus about 60 percent filler.⁷³ A half dozen carpet and carpet fiber manufacturing facilities in Georgia reported isocyanate air emissions to the EPA in 2016.⁷⁴

Use Impacts

Free, unreacted isocyanates are present in consumer products. Fourteen years ago, an international research team found

these potent asthmagens on the surface of carpet pad and other foam products like polyurethane pillows. The team noted, in 2003, “The prevalence of asthma in the overall U.S. population has increased from 31 per 1,000 to 54 per 1,000 since the early 1980s.”⁷⁵ (It keeps climbing: in 2010, the U.S. asthma rate was 8.2 percent, or 82 out of 1,000 people.⁷⁶ That’s a 165 percent increase in less than three decades.)

“In spite of this and the extensive literature on the hazards of isocyanates, little has been published on the safety of polyurethane foam-containing consumer products. The increasing incidence of asthma, especially in children, as well as its associated high costs for health services, mandate further observational and experimental investigations of these questions,” the researchers wrote.

Polyurethane-backed carpet routinely passes the Carpet and Rug Institute’s Green Label Plus certification. This program, however, does not test for **isocyanates**.

Recycling Impacts

Regardless of whether polyurethane carpet backings and pads expose consumers, including children crawling on carpet, to free isocyanates, this chemistry is not a good fit for a circular economy. Recycling is not a viable option for polyurethane carpet backing. According to Mikhail Davis of Interface, “Polyurethane-backed tiles are inherently unrecyclable (you can’t re-melt this plastic), and the best that can currently be done is to shred them up and either use them to soak up spills or glue them back together as carpet padding (a classic case of “downcycling” to less valuable products in either case).”⁷⁷

According to the Danish government, recycling polyurethane backings can only be accomplished through highly expensive chemical feedstock recycling, and not mechanical processes.⁷⁸

Transformation Pathways:

- *Given the pollution associated with isocyanate production, the unknown potential for people to become exposed to free isocyanates in polyurethane products, and the technical challenge of recycling polyurethane carpet backing, manufacturers should stop making this kind of backing.*
- *Indoor air quality certification programs should test for isocyanates.*
- *Carpet industry innovators should develop backing options based on green chemistry principles that avoid the use of toxic substances.*
- *Among plastic backing types, new products featuring polyethylene terephthalate (PET), if readily separable from the facing and proved recyclable, may be preferable.*

Polyvinyl Chloride Backing

Polyvinyl chloride (PVC, also known as vinyl) is the most common plastic used in carpet tile backing.⁷⁹ The basic formulation is to combine equal parts PVC and plasticizer with higher amounts of filler (such as limestone or fly ash) and smaller amounts of stabilizers.⁸⁰

The concern with PVC begins with its production. Chlor-alkali plants turn brine into caustic soda and chlorine. In the U.S., this process depends upon an antiquated technology that consumes, and ultimately disposes of, a lot of asbestos. Shipping records reveal that the chemical industry imports over 1.1 million pounds of asbestos a year, mainly from Brazil, where miners suffer from mesothelioma.⁸¹ As asbestos expert Barry Castleman points out, “there are many parts of the life cycle that give rise to asbestos exposures of workers and environmental contamination.” These exposures occur in the

mines in Brazil, the chlor-alkali plants that fashion and use asbestos diaphragms, and the disposal facilities that receive spent diaphragms.⁸² Rather than converting to asbestos-free technologies such as membrane cells, the chlorine industry is resisting regulations and insists its use of asbestos “does not pose an unreasonable health risk to workers.”⁸³

PVC is the largest consumer of chlorine.⁸⁴ Nearly half (47 percent in 2016) of PVC goes into building and construction products.⁸⁵ PVC building products are therefore one of the most significant drivers of the continued use of asbestos diaphragms to produce chlorine.

Chlorine plants, especially in the so-called Cancer Alley of Louisiana, are often integrated with plants that use the chlorine to produce ethylene dichloride and vinyl chloride monomer, which are chemical intermediates along the production chain to make PVC. In addition to asbestos, these plants routinely release other potent toxic chemicals like chlorine, dioxins, vinyl chloride, carbon tetrachloride, and chloroform.⁸⁶ PVC in finished goods like carpet does not contain significant concentrations of these manufacturing byproducts. However, PVC carpet in buildings and waste streams usually contains problematic additives like phthalates and fly ash from coal power plants that are discussed below.

PVC, in itself, becomes a considerable hazard when burned, such as in house fires, landfill fires, and incinerators. The burning of PVC is a significant source of dioxins, the most potent carcinogens known, as the Vinyl Institute (an industry association) acknowledges.⁸⁷ A significant amount of carpet (144 million pounds in 2016, according to Carpet America Recovery Effort (CARE)) - almost as much as is recycled - is burned in cement kilns and incinerators.⁸⁸

Transformation Pathways:

- *Given the chronically high impacts of PVC production, manufacturers should stop producing carpet with virgin vinyl backing. Shaw, the leading supplier of carpet in the United States, has not manufactured PVC-backed carpet tile since 2004⁸⁹ (although it still sells a lot of vinyl resilient floors).*
- *Carpet manufacturers who seek to use recycled PVC should test for and ensure toxic additives, such as phthalates, that have been commonly included in vinyl carpet backing are not recycled into new carpet. Leading resilient flooring manufacturers restrict phthalates and other toxic contents in post-consumer PVC.⁹⁰ Carpet companies should do the same.*
- *Carpet industry innovators should develop backing options based on green chemistry principles that avoid the use of toxic substances. Among plastic backing types, new products featuring polyethylene terephthalate (PET), if readily separable from the facing and proved recyclable, may be preferable.*
- *Furthermore, no PVC carpet should be burned in cement kilns, waste to energy incinerators, or as fuel. Carpets backed with PVC should be labeled as containing PVC and not eligible for treatment in any burning process.*

Phthalates in PVC Backing

PVC-backed carpets require heavy doses of plasticizers to make the vinyl flexible. For decades, a class of petrochemicals called phthalates served this function.

Regulators have restricted a small subset of chemicals (generally six or fewer) within the overall compound group of at least 448 individual phthalates. California and federal regulators recognize that some phthalates cause cancer, and some can cause developmental and reproductive harm. Scientists are finding alarming correlations between phthalates and asthma.⁹¹ Further, phthalate esters are structurally similar to quinolinic acid, and have been demonstrated to increase the body's production of it. Quinolinic acid is implicated in human neurological diseases.⁹²

Use Impacts

Phthalate plasticizers migrate from PVC. According to a Danish study, “given sufficient time, a significant part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing.” The European Chemicals Bureau estimates that the leading phthalate used in carpet backing, diisononyl phthalate (DINP), migrates from PVC at a rate of up to 1 percent per year.⁹³

Manufacturers long claimed that phthalates in carpet are safe. “Independent risk assessments indicate that exposure to the extremely low level of emissions from carpet products should not create a safety concern,” insisted the Carpet and Rug Institute trade association in the year 2000.⁹⁴ The American Chemistry Council promoted the “public health benefits” of phthalates, and their “long history of safe use.”⁹⁵

Not everyone was convinced by these claims, so many consumers clamored for phthalate-free products. In its 2014 report, *Phthalate-free Plasticizers in PVC*, HBN identified six alternatives as being readily available on the market, without nearly as significant health hazards.⁹⁶ In April 2015, Home Depot announced it was eliminating phthalates from their flooring products by the end of the year. In short order, most leading flooring manufacturers decided that they too would transition to phthalate-free plasticizers. Most (but buyer beware: not all) carpet sold today is phthalate-free.

Recycling/Disposal Impacts

Tarkett and Interface, the industry leaders in recycling PVC carpet backing, have requested state of California “Safe Use Determinations” (SUDs) for DINP. Interface’s has not yet been granted, but Office of Environmental Health Hazard Assessment (OEHHA) last year granted Tarkett a SUD for DINP if it is not present at proportions over 9% by weight of the backing layer.⁹⁷ Interface claims that exposures to DINP do “not present significant cancer risks under Proposition 65.”⁹⁸ Rulings in their favor allow companies to sell carpet containing post-consumer PVC carpet backing without labeling them per Proposition 65 as containing chemicals known to cause cancer. The state has provided similar waivers to other PVC products like resilient flooring.⁹⁹

However, these rulings are based solely on California’s findings on DINP’s carcinogenicity. DINP’s health effects range beyond cancer to include a range of developmental toxicity concerns that are not addressed by the Prop 65 risk assessment. According to the U.S. National Institutes of Health Reproductive & Developmental Monographs there is “evidence that DINP, like other phthalates such as DEHP and DBP, adversely affects development of the male rat reproductive system.”¹⁰⁰ In 2013, the United Nations Environment Programme/World Health Organization reviewed scientific literature about DINP’s potential endocrine disruptive effects. Researchers identified twenty-two health impacts, including reduced female and male fertility.¹⁰¹

Transformation Pathways:

- *Manufacturers should complete the transition away from phthalates. While it is of high priority to avoid producing virgin PVC entirely, phthalate-free formulations will at least prevent these toxic plasticizers from being recycled into future generations of vinyl carpet backing. Tarkett’s policy is to not allow more than 0.1 percent phthalates (including DINP) in any of its resilient flooring products, including those with post-consumer PVC.¹⁰² Tarkett does not extend this precaution to its carpet.*
- *The carpet industry should adopt the threshold Tarkett established for resilient floors, and not allow phthalates to be reintroduced to consumers through recycled content.*
- *California regulators (OEHHA) should review the evidence that DINP adversely affects development of the male reproductive system as a basis for listing DINP on Prop 65 as a developmental toxicant and for removing the Safe Use Determinations for DINP in carpet and other flooring.*

Styrene Butadiene Backing

Styrene butadiene (SB) latex coatings are the most common materials used to back broadloom carpet. They are also called unitary backings. These water-based coatings contain finely divided particles of styrene butadiene rubber, and, usually, additives like flame retardants and filler. Manufacturers apply latex coatings to the back of the carpet's face fiber and the scrim to which the fiber is woven, then dry and cure it.

Production Impacts

Styrene and butadiene are released in the manufacture of latex carpet backing, along with ethylbenzene (a California Proposition 65 carcinogen and precursor to styrene).¹⁰³

Styrene, a volatile organic compound, is a potent asthmagen and carcinogen. In 2016, California added it to the Proposition 65 list of substances known to cause cancer.¹⁰⁴

1,3-butadiene is also a carcinogen, as well as a reproductive toxicant. Researchers have consistently associated 1,3-butadiene exposures with high rates of leukemia (a cancer of early blood-forming cells) for synthetic rubber workers.¹⁰⁵

Individually and in combination, styrene and 1,3-butadiene are notorious toxicants in the rubber industry. "Increased risks for leukemia, lymphoma, or all lymphohematopoietic cancer were found among styrene-exposed workers" in styrene-butadiene rubber industries, according to the ATSDR.¹⁰⁶

These volatile chemicals are also potential inhalation hazards for residents of surrounding communities. Public health researchers in 2009 identified "significantly enhanced concentrations" of these two chemicals outside a major rubber plant on the Texas Gulf Coast.¹⁰⁷

Use Impacts

Emissions of styrene from building materials, including carpets, "may contribute significantly to indoor air pollution," according to the Agency for Toxic Substances and Disease Registry. It notes that children are exposed to higher amounts of styrene per body weight than adults. "Children are not small adults. A child's exposure may differ from an adult's exposure in many ways. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface in proportion to their body volume."¹⁰⁸

Styrene is a volatile organic compound (VOC), and is measured in standard protocols used for Green Label Plus and other certifications. However, these protocols rely upon thresholds established for occupational settings or for health impacts that are not related to the initial onset of asthma.¹⁰⁹

SB latex used to produce backings also include filler, thickeners and water. Curing agents, surfactants, flame retardants, and foaming agents may also be in the recipe. Of these additives, antimony trioxide flame retardants are the highest concern for consumers. Potential exposure routes and health impacts are discussed in the flame retardants section below.

Recycling/Disposal Impacts

Manufacturers often call unitary backed carpet "recyclable."¹¹⁰ A plant in Germany called Polyamid 2000 indeed recycled SB latex carpet in the 2000s. Using a bank of centrifuges, it separated the latex from face fibers in a pulverized mix of carpet waste. "The rubber goes to an outside plant where it is made into construction materials," according to a *Plastics Technology* article.¹¹¹ Polyamid 2000 declared bankruptcy and closed in 2003.¹¹²

Today, there is no evidence of SB latex carpet being recycled into new carpet. Instead, SB latex backed broadloom carpet mainly winds up in cement kilns and landfills.

EPA estimates that a ton of broadloom carpet burned in a kiln releases 1.67 tons of carbon dioxide (CO₂), including 0.29 tons of CO₂ from the styrene-butadiene latex. If that same carpet were to be recycled rather than burned, they estimate there would be a net global benefit of negative 2.36 tons carbon dioxide per ton of carpet due to avoided emissions from raw materials acquisition and manufacturing for the new carpet.¹¹³

Transformation Pathways:

- *Latex backing is recyclable, according to manufacturers. However, without any capacity to do so, consumers should assume that unitary backing will be landfilled or burned, not recycled.*
- *Carpet industry innovators should develop backing options based on green chemistry principles that avoid the use and release of toxic substances.*
- *Manufacturers should focus on demonstrating recyclability for more promising alternate plastic backings such as PET.*

Organotins

Some chemicals are common to multiple types of backing. Among these, organotins, flame retardants and fly ash raise the most concern.



Organotins are highly toxic organometallic substances commonly used in polyurethane and PVC backing. Almost two-thirds of tin chemicals are organotins used as either stabilizers in PVC formulations or catalysts in PVC and polyurethane production.¹¹⁴

Plastics manufacturers rarely disclose their products' stabilizers and catalysts. The Plastics Industry Association claims that "the use of a specific catalytic complex in a manufacturing process typically is afforded the highest degree of confidentiality within the industry."¹¹⁵ Such pacts of secrecy run counter to the public interest. Organotins are "not solid and will migrate," according to a recent study by the government of Denmark. "Release will take place by migration and wear and tear. Given sufficient time, a significant part of the substance will probably be released."¹¹⁶

The European Union Directorate-General for Health & Consumer protection sees grave potential harm from these releases. "Humans can be exposed to organotins by inhalation of dust particles or to the compounds themselves. Death has been reported in workers accidentally exposed to organotins."¹¹⁷

Dibutyltin dilaurate, the most commonly used organotin in carpet backing, is classified as a reproductive toxicant and endocrine disruptor. Other health and environmental hazards include mutagenicity, eye and skin irritation, organ toxicity, and aquatic toxicity. It is also persistent and bioaccumulates in the environment. Organotins in polymers can be loosened by cleaning and migrate into wastewater and aquatic ecosystems.

Organotins also can carry a social toll: some of the world's tin comes from cassiterite mines in the Democratic Republic of Congo and Rwanda, places of enduring human struggle, where armed groups regularly terrorize local populations to gain control over these globally-sought minerals.¹¹⁸

Transformation Pathways:

- *The need for organotins can be reduced or eliminated by avoiding polyurethane and PVC. If those polymers are used, less toxic alternatives to organotin-based catalysts are available. These are usually bismuth- or zinc-based.*¹¹⁹

Fly Ash

Many carpet backings are filled with recycled content, with mixed benefits and impacts. The most common recycled filler, fly ash generated at coal-fired power plants, raises considerable concerns.

As air pollution control improves, this fly ash is carrying increasing amounts of toxic heavy metals like arsenic, mercury and lead into our buildings.

Fly ash is pre-consumer, rather than post-consumer, recycled content, as it is a product of burning coal. It is powdery, very fine, and spherical; because of these properties, it is a functional replacement for limestone (calcium carbonate) filler.

Loading carpet with fly ash is a low cost way for building product manufacturers to incorporate high percentages of recycled content in carpet, and thus help building projects meet sustainability criteria found in green building codes and rating systems like Leadership in Energy and Environmental Design (LEED) and Living Building Challenge. Recent updates to green building rating systems, such as LEED version 4, have focused less on recycled content as a single attribute and more on holistic environmental attributes such as product-specific life-cycle analysis, raw materials extraction best practices, and material ingredient transparency and optimization. While these multi-attribute criteria for green products are slowly changing the mindset about preferable products, fly ash used for recycled content is still viewed by many as a preferable environmental attribute for products regardless of its toxic content.

Most carpets now contain fly ash generated by coal-fired power plants. Fly ash comprises over 40 percent of some carpets’ weight.¹²⁰ As air pollution control improves, this fly ash is carrying increasing amounts of toxic heavy metals like arsenic, mercury and lead into our buildings.

Customers have been requesting fly ash-free carpet for several years, which some companies have offered upon special request. The largest U.S. carpet manufacturer is leading a reversal of that trend.

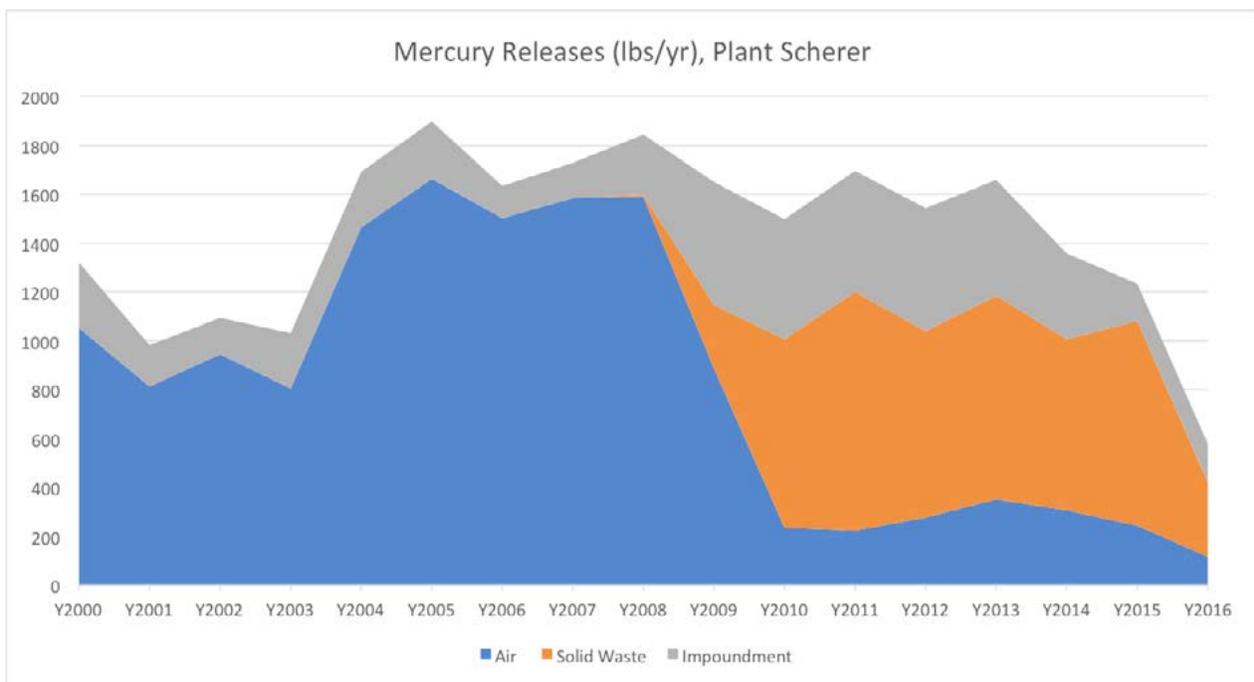
For several years Shaw offered a fly ash free EcoWorx (carpet backing) alternative for those customers that demanded it,” Troy Virgo, Director of Sustainability & Product Stewardship of Shaw Industries, told HBN. “Beginning in late 2016, we decided to make this the across-the-board standard and ceased using fly ash as a filler.”

Production Impacts

The installation of pollution controls in coal power plants transfer toxic heavy metals from air to solid waste. Instead of being released into the atmosphere, mercury concentrates in fly ash. In 2010, EPA scientists predicted, “Changes in [air pollution control] technologies will result in a greater amount of residue generated for each unit of electricity produced and an overall increase in the total content of [mercury] and other hazardous air pollutants in fly ash [and other coal combustion wastes].”¹²¹

Chart 1 provides evidence of that prediction’s foresight. Since the early 2000s, the leading supplier of fly ash to the carpet industry has been the Southern Company’s Plant Scherer in Juliette, Georgia. In 2008, this power station ranked as the third largest source of mercury air emissions in the U.S. After Southern Company installed mercury control devices, Plant Scherer’s mercury air emissions plummeted to about 20 percent of their previous levels by 2011. These control devices capture the previously emitted mercury in fly ash that is used as filler. Instead of going into the air, the mercury now winds up in surface impoundments (coal ash ponds on site), in landfills, and in solid waste, including fly ash used in carpets.

CHART 1. **Mercury Releases, Plant Scherer**



Use Impacts

Four heavy metals, arsenic, cadmium, lead, and mercury, are frequently present in fly ash in concentrations above established safety thresholds. A literature review found a median value of 0.1 ppm mercury in fly ash; at the extreme, one test found 23.5 ppm,¹²² and several other sources found levels over 1 ppm.¹²³ These measurements largely predate the installation of pollution control devices on Plant Scherer and others, so current levels may be much higher.

Mercury is a potent neurotoxicant and global pollutant of the highest order of priority to eliminate. Fly ash is not bound in carpet backing, but like stain repellants and flame retardants, can migrate from it during use.¹²⁴ The potential migration of mercury and other potent, highly toxic, heavy metals from coal fly ash in carpet to surface areas, dust and indoor air does not appear to have been researched prior to its widespread use - or since.

HBN researchers often come across terms like “encapsulated,” “bound in a matrix,” and “fully cured” to counter concerns about the presence of toxic ingredients in products. The carpet industry has used similar phrases too¹²⁵, yet there is a growing body of evidence that people are exposed to supposedly “inert” ingredients. External forces wear products down over time, through abrasion (cleaning), biodegradation, hydrolysis, photolysis, and oxidation. Then there’s the cutting, grinding, smashing, and pulverizing of building materials during construction and demolition. Ingredients, including non-volatile ones like heavy metals, travel through the air, in dust particles, with which people obviously come into contact.

The potential for occupants to be exposed to these toxic heavy metals can be expected to increase as ash-filled carpets age. This is most important for residents of low-income housing because building materials tend to remain past the point of showing wear. A North Carolina Housing Finance Agency survey placed stained/loose carpeting among the ten biggest deficiencies in rental dwellings.¹²⁶

Recycling/Disposal Impacts

The heavy metals in fly ash cannot disappear. Where the carpet goes after it is removed from a building, the fly ash and its mercury, lead, and arsenic will follow – from the dust of carpet shredding plants to the smokestacks of cement kilns.

Transformation Pathways:

- *The use of fly ash as a filler in products like carpet should be prohibited by federal and state regulators. Manufacturers and retailers should follow Shaw’s lead and announce they no longer use fly ash as a filler in carpet. The industry should immediately replace fly ash with less toxic recycled materials, such as post-consumer container glass, which is currently recycled at a paltry 30 percent rate nationally.¹²⁷ It is a much cleaner recycled filler material than fly ash.*

Flame Retardants

Many plastics in carpet backing and fiber are flammable. The federal Flammable Fabrics Act regulates carpet, among other textiles, and requires small carpets or rugs that contain a fire-retardant treatment to be labeled with the letter “T”.¹²⁸

Most often, carpet plastics are treated with mineral based flame retardants, primarily alumina trihydrate (ATH), a byproduct of aluminum manufacturing.¹²⁹ ATH is not known to cause any significant health issues.

While uncommon, **halogenated flame retardants (HFRs)** have been used in carpet, including:

- **Decabromodiphenylether** (DecaBDE) has been “commonly used in styrene rubbers in carpet backing,” according to a 2010 OECD task force report on toxic releases from consumer products.¹³⁰

- The California Environmental Contaminant Biomonitoring Program (CECBP) Scientific Guidance Panel (SGP) in 2008 reported that **bis(2-ethylhexyl) tetrabromophthalate** (TBPH) and **tris(2-chloroethyl) phosphate** (TCEP) were used in carpet backing.¹³¹
- Dover Chemical markets **chlorinated paraffins** for use in carpet backing.¹³²
- Some carpet has contained pentabromodiphenyl ether (**PentaBDE**) flame retardant according to an EPA report in 2015. They also note that if recycled foam is used for the backing, it may contain **2-ethylhexyl-2,3,4,5-tetrabromobenzoate** (TBB) and TBPH as unintentional content.¹³³

The U.S. National Institutes for Health warns that flame retardant “chemicals can leak from products into dust and into the air.”¹³⁴ DecaBDE is a neurotoxicant, gene mutagen, and endocrine disrupting chemical. The other HFRs can also cause great harm and are of the highest priority to identify and prevent from being reintroduced into new products through recycling.

When flame retardants migrate out of carpets, they can become part of household dust that building occupants then inhale or ingest. Many HFRs are persistent, bio-accumulative and toxic (PBT). PBTs are long-lived in the environment (persistent) where they concentrate (bioaccumulate) in the food chain and can transfer easily between air, water, and land for generations.

The National Institute of Environmental Health Sciences warns, “a growing body of evidence shows that many of these chemicals are associated with adverse health effects in animals and humans, including endocrine and thyroid disruption, impacts to the immune system, reproductive toxicity, cancer, and adverse effects on fetal and child development and neurologic function.”¹³⁵

Another highly toxic compound (though not halogenated) sometimes used in carpet backing is antimony trioxide. This compound is listed as a carcinogen and developmental and reproductive toxicant under California’s Proposition 65 program. It is used in PVC backings. The U.S. Antimony Corporation explains, “Plasticized PVC products contain flammable plasticizers and must be flame retarded. They contain a high enough chlorine content so that an additional halogen is usually not necessary.”¹³⁶ A 2004 Carpet Recovery life cycle analysis identifies antimony trioxide as the typical flame retardant in PVC carpet backing.¹³⁷ So, too, did a 2005 presentation by Shaw comparing carpet formulations.¹³⁸

Most of the carpet industry has successfully flame retarded their carpets with alumina trihydrate or other non hazardous options. Germany’s Blue Angel ecolabel for carpets identifies many low hazard options: “To the extent as required by fire protection regulations inorganic ammonium phosphates (diammonium phosphate, ammonium polyphosphate etc.), other dehydrating minerals (aluminium hydrate or the like) or expandable graphite may be used as flame retardants. Antimony oxides shall not be used as flame retardants.”¹³⁹

Transformation Pathways:

- *There is no need for any manufacturer to continue the use of halogenated flame retardants, antimony trioxide or other similarly high hazard substances in carpets. This should be designed out in order to become over time a non issue for recycled material screening.*
- *Consumers can demand that manufacturers disclose any included flame retardants.*
- *Manufacturers should not use antimony oxides or any halogenated substance.*

Flame Retardants in Carpet Cushion

An estimated 90 percent of residential carpet is installed over carpet cushion, also called carpet pad.¹⁴⁰ Over 85 percent of carpet cushion sold in the U.S. is bonded (also known as rebond) carpet cushion made from recycled flexible polyurethane foam (FPF), which comes from furniture and transportation makers, automotive scrap and, more recently, starting around 1993, post-consumer foam.¹⁴¹ Most of these sources have historically contained HFRs.

A suite of flame retardants have been found in bonded carpet cushion, including the HFRs PentaBDE, Firemaster 550, TDCPP, TCEP, TCPP, V6, and the non-halogenated organophosphate, TPP (a component of Firemaster 550).¹⁴² These chemicals are not intentionally added, but are present primarily as a result of historical flame retardant use in furniture foam, and continued recycling of contaminated carpet cushion back into 'new' bonded carpet cushion.

Any new bonded carpet cushion with post-consumer recycled content is expected to contain some quantity of these chemicals. Current levels of PentaBDE in new carpet cushion are relatively low due to the phase out of this chemical in furniture foam in 2005; however, testing from the Carpet Cushion Council (CCC) in 2016 still indicates measureable quantities in new bonded carpet cushion, an average of 180 parts per million (ppm).¹⁴³

As PentaBDE was phased out in furniture foam, it was replaced with the other flame retardants listed above. Post-consumer foam (old carpet cushion) now returning for recycling may contain up to 12 percent by weight of these flame retardants. This old cushion is chopped into small pieces and mixed with pre-consumer foam from current production of furniture and other consumer products. Since the pre-consumer foam is now largely free of flame retardants, this mixing dilutes the overall percentage of flame retardants within the new carpet cushion.¹⁴⁴ The CCC has reported the following test results for chlorinated flame retardants in new bonded carpet cushion — averages for 2014: 8700 ppm, for 2015: 4500 ppm, and for 2016: 2300 ppm.¹⁴⁵ Because of the variability in recycled feedstocks, a wide range in concentration in individual products is likely, but the industry association has only provided average values. Furthermore, since bonded carpet cushion is a heterogeneous mixture of chunks instead of an evenly blended material, accurate measurement of overall concentration levels is very difficult, making it virtually impossible to assure safe levels of exposure for individual products.¹⁴⁶

Hazardous flame retardants in the post-consumer recycled foam and new bonded carpet cushion present a concern throughout the product's life cycle.

Occupants may be exposed to these flame retardants throughout the life of the carpet and carpet pad. An EPA report explains, "as carpet padding ages, foam dust will be generated and become airborne with traffic on carpet. This presents a particular exposure potential for children, who spend time on the floor." Additionally, the flame retardants volatilize and are deposited onto household dust, which creates further potential exposure through both ingestion and inhalation of the dust.¹⁴⁷ TDCPP, Firemaster 550, TCEP, and TCPP have been found both in indoor air and dust, as well as in people.¹⁴⁸

Carpet installers and carpet pad factory workers may also be exposed. In 2008, Heather Stapleton et al. found that FPF recycling workers and people who install rebond carpet cushion "have body burdens [of PBDEs] that are an order of magnitude higher" than the general public. Recycling workers and carpet installers may therefore be at higher risk of the negative health impacts associated with exposure to flame retardants.¹⁴⁹ Conclusive studies on worker exposure or emissions of the replacement flame retardants could not be identified.

Additionally, residents living close to waste and recycling facilities may be exposed. No studies considering emissions from carpet cushion manufacturing facilities were identified. However, the mechanical nature of the process -- the foam is chopped up for mixing with virgin foam, rather than chemically dissolved -- can generate substantial dust, so emissions to the environment are possible.

Transformation Pathways:

- *Flame retardants are unintentional additions to carpet cushion and serve no function in the product. Current testing protocols for the replacement flame retardants are not feasible for use in the manufacturing environment, so real-time screening of scrap foam for safety levels is not currently viable. The most effective way to keep flame retardants out of new carpet cushion is to avoid use of post-consumer bonded recycled foam feedstocks and instead source pre-consumer foam that is known to be flame retardant free.*
- *Manufacturing associations cite a lack of “adequate supply of suitable [pre-consumer] scrap to meet the total U.S. scrap feedstock requirement” and the need for post-consumer scrap in order “to produce higher density grades of bonded cushion” as the main reasons for the continued use of post-consumer scrap in bonded carpet cushion.¹⁵⁰*
- *Consumers can avoid flame retardants by using alternate types of carpet padding (such as fiber, rubber and virgin flexible polyurethane foam).¹⁵¹*

For more detail on flame retardants in bonded carpet cushion, see the HBN report, *Optimizing Recycling: Post-Consumer Flexible Polyurethane Foam Scrap Used in Building Products* at <http://healthybuilding.net/uploads/files/optimize-recycling-fpf-report.pdf>.

Installation Adhesives

Often overlooked during product selection, adhesives add to the toxic burdens of carpet installations and undermine efforts to recycle carpet. Both the carpet and the substrate upon which it was attached are contaminated by the adhesive. This contamination can complicate efforts to recycle both carpet and substrate.

Adhesives are highly specialized concoctions that typically react on-site during and after product installation. They can include plasticizers, fillers, thickeners, surfactants, hardeners, and many other ingredients. Most carpet adhesives are wet-applied epoxy or acrylic systems.

Most epoxy adhesive resins are formed by combining **bisphenol A** and **epichlorohydrin**.¹⁵² Epichlorohydrin (derived in part from chlorine) is listed as a carcinogen and developmental toxicant. Bisphenol A is an endocrine disrupting chemical and a reproductive and developmental toxicant that is also on California’s Proposition 65 list. Epoxy resins containing these chemicals are recognized asthmagens. Skin and respiratory sensitization has been reported from occupational exposures to these compounds in epoxy resins.¹⁵³

Acrylic adhesives typically include **nonylphenol ethoxylate** (NPE) surfactants. NPEs contain and break down into chemicals called nonylphenols, which are highly persistent, bioaccumulative, and toxic. These chemicals, when released to the environment, contaminate the food chain. Nonylphenols are lethal to fish¹⁵⁴ and other aquatic organisms at very low concentrations. NPEs are also suspected endocrine disruptors, which tend to affect children the most. They sometimes mimic hormones, causing issues to a growing fetus and proper childhood development. According to the U.S. Environmental Protection Agency (EPA), “nonylphenol has also been detected in human breast milk, blood, and urine and is associated with reproductive and developmental effects in rodents.”¹⁵⁵ Nonylphenol ethoxylates are mostly phased-out in Europe and Japan,¹⁵⁶ but still common in the U.S., even though the EPA has identified over 200 “safer surfactants” to replace them.¹⁵⁷

Adhesives also contain antimicrobials to prevent spoilage.

Transformation Pathways:

- *The healthiest adhesive choice is to not use one. Avoiding adhesives keeps hazardous chemicals out of interior spaces. It also supports future recycling of those materials, because adhesives make some materials, like broadloom carpet, unrecyclable.*
- *Broadloom carpets may be mechanically installed without adhesives using “stretch in” techniques and tackless strips.¹⁵⁸*
- *Some tile carpet installation systems use connectors to attach squares to one another, which immobilizes them without adhesives.*
- *Peel and stick adhesives - solid-state adhesive strips or squares - are the second-best option for installing tile carpet. They can be factory applied to some products, or be sold separately. Unlike wet-applied adhesives, peel & stick adhesives are fully reacted and no longer contain reactive substances that would otherwise be released upon application. To date, the peel and stick flooring adhesives reviewed by Healthy Building Network have had very simple formulations with few hazards. However, manufacturers rarely disclose the specific composition of these adhesives, making a complete assessment difficult.*
- *Consumers installing carpet with adhesives should at minimum understand the composition of the adhesives that are required to be used with that carpet. This information is necessary for comparing adhesives and avoiding products that include NPEs, bisphenol-A-related compounds, and other toxic substances.*
- *Where disclosure is absent or incomplete, Cradle-to-Cradle (C2C) certifications and their underlying ratings for material health can provide some guidance. Two carpet adhesives have achieved C2C’s “platinum” material health levels: Tandu Centiva B-19¹⁵⁹, made by Tarkett, and TruRenew Carpet Flooring Adhesive SP¹⁶⁰, made by WF Taylor Inc. C2C assessors rated these adhesives’ contents, and the process chemicals used to make them, as being safe for humans and the environment.*

“For more than 60 years commercial carpeting has been made the same way. They are composed of a complex array of chemicals, including latex and PVC, rendering the carpet materials unrecoverable at the end of the products use. The consequence is that a large amount of valuable material is lost, around 3.5 billion pounds of carpet end up in U.S. landfills every year. The value of that material is about 5 billion dollars.”

- Ellen MacArthur Foundation¹⁶¹

Attribute Evaluation: Due to the widespread presence of toxic chemicals, both in historical carpet entering the waste stream and in carpet newly produced, we evaluate post-consumer carpet’s Environmental and Human Health Hazards as “red” for “significant concerns.”

■ SUPPLY CHAIN QUALITY CONTROL AND TRANSPARENCY

Ambitions to increase the recycling of old carpet into new products face considerable challenges. First there is the complex construction and toxic composition of the waste stream.

For some components, especially nylon 6 face fiber, removing toxic substances is possible through chemical feedstock recycling processes. But for many other carpet components, like polyurethane or latex backing, or broadloom with an adhesive, there are no known pathways to detoxify or recycle them.

For materials that can be recycled, there is another fundamental problem: the carpet industry, including processors of post-consumer carpet, has no standard operating procedure for sorting, screening and processing carpet waste.

A healthy circular economy requires rules of the road that forge a common understanding of what is and is not acceptable in a given material for a particular use. The carpet industry has established no clear plan to become more circular. The absence of rules reflects this inertia. Establishing best practices will in turn increase the amount of feedstock available to manufacturers seeking recycled materials that are compatible with their product specifications.



Columbia Recycling, Dalton, Georgia

Current Recycling Practices

The carpet industry has established a network of post-consumer carpet collectors across the country. “We have collectors all around the United States that collect it, bale it, and ID it, and ship it in to us, and then we process it, ID it, and turn it into various products plus sell other companies the fluff to make pellets on their own,” explained Rocky Ponders in 2014. Ponders was then a vice president of the largest processor, Columbia Recycling of Dalton, Ga.¹⁶²

Collection is most active where extended producer responsibility laws (such as in California) or voluntary initiatives are in place. The national coverage of collectors is still thin given the scale of the issue. Ponders said, in 2014, there were about 15 collectors “all over the country, all over the nation and California” and that they are “only accounting for less than 5% of the carpet... and it’s an opportunity going to landfill.”¹⁶⁴



Sorting carpet by face fiber has been complicated by a lack of transparency and labeling. Collectors have relied upon expensive hand-held infrared devices to determine the identity of face fibers on collected carpets. Some scanners do not distinguish between certain fibers, especially polyethylene terephthalate and polytrimethylene terephthalate (PTT).¹⁶⁵

“Post-consumer recyclers of broadloom carpet and carpet tile need a simple way to identify the face fiber content,” noted a Carpet and Rug Institute task force last year. “Technology currently in use is expensive and temperamental.”¹⁶⁶ In response, the CRI published guidelines for back-of-carpet labeling that will print codes for the fiber type, and for carpet tile, the backing type.¹⁶⁷ The labels however do not provide any disclosure of hazardous additives such as antimicrobials, stain repellants, and flame retardants.

Once they receive post-consumer carpets, most recyclers use mechanical processes that cannot remove problematic additives, such as phthalates, from the feedstock.¹⁶⁸ Mechanical processing involves chopping, cleaning and re-melting materials like nylon fiber. It is much less expensive than chemical recycling. But one of re-melt’s challenges, according to Universal Fibers, is that “contaminants are intimately blended with nylon fibers.”¹⁶⁹ “Once plasticizers have been added to PVC they are not removed during the mechanical recycling process,” explains a state of California report.¹⁷⁰

Chemical Feedstock Recycling

Optimally, carpet companies will redesign their products to be devoid of any chemical substances of concern. In the meantime, the only way to remove toxic chemicals from the rest of the carpet entering the waste stream loaded with toxic chemicals is through chemical feedstock recycling.

Chemical recycling—also called depolymerization—breaks down source materials into their original chemical components, allowing each component to be reused in the production of new material, or (in the case of toxic additives) to be segregated from the feedstocks for management as a hazardous waste. It works best with simple polymers, such as nylon 6. A recent examination of barriers to the circular economy notes “that for recycling multi-layers packaging, additional chemicals such as modifiers and stabilizers would be necessary to protect the chain of polymers during



thermo stress and mechanical stress activities, which is expected to lead to a faster 'down cycling' of materials when compared with other packaging types.¹⁷¹ As with any industrial inputs, manufacturers should ensure that modifiers and stabilizers used in carpet depolymerization do no harm.

So far, among carpet components, only nylon 6 depolymerization has been commercialized. Industry has viewed chemical feedstock recycling of other carpet materials - nylon 6,6, PET and polypropylene and backing, pad, or adhesive materials - as being too expensive.¹⁷²

Carpet Fiber Recycling

Nylon 6 represents about 46 percent of the material sorted out of the carpet waste stream, according to CARE's 2016 national survey,¹⁷³ but most of this is not recycled into new carpet fiber. Very few plants worldwide recycle post-consumer carpet fiber into new carpet fiber, and even those depend upon additional sources, such as fishing nets and pre-consumer fibers. The following three carpet fiber recycling operations process either nylon 6 or nylon 6,6 into new fiber. There are no known industrial-scale recycling operations that turn other carpet fibers like PET or wool into new carpet fiber.

- **Aquafil.** Aquafil uses old fishing nets for some of the recycled nylon it produces in Ljubljana, Slovenia. It "rescues" nylon 6 waste "from all over the world," including carpet textiles, upholstery fabric, and fishing nets. Its "Econyl regeneration system" uses depolymerization to create fibers with a mix of post-consumer and pre-consumer waste. In 2012, Aquafil Econyl fibers contained 30 percent post-consumer waste; its goal in 2014 was to produce 100 percent recycled nylon 6, using 50 percent post-consumer and 50 percent pre-consumer sources. However, current certifications provide no insights into whether Aquafil is making progress toward its goal of 50 percent post-consumer content. A third party certification states only that the fiber contains 100 percent recycled content "with post-consumer and pre-consumer content."¹⁷⁴ Aquafil projected that it would reclaim 13,000 tons of post-consumer waste in 2014, but hasn't updated those projections. Several U.S. manufacturers use Aquafil Econyl fibers in their carpets.¹⁷⁵
- **Nylene Canada.** This subsidiary of Polymeric Resources Inc. operates a former Honeywell fiber plant in Arnprior, Ontario (Canada). It employs depolymerization to recycle nylon 6. According to its SCS Global Services certification, this plant "has demonstrated 75% yield of caprolactam from processed waste" and processes both post-consumer and pre-consumer nylon-6."¹⁷⁶ It has been in operation since 1966.¹⁷⁷ Most of Nylene's recycled nylon 6 resins use only pre-consumer feedstock, but it produces one spinning grade polymer, BS-700-RC, with 50 percent post-consumer recycled content.¹⁷⁸
- **Universal Fibers.** This company uses mechanical separation and washing to produce "clean fluff" from post-consumer nylon 6,6.¹⁷⁹ The fluff is combined with virgin nylon 6,6 to create a solution-dyed yarn called Refresh™ fiber. It is certified to contain 30 percent recycled content (20 percent pre-consumer and 10 percent post-consumer).¹⁸⁰

The general trend in recycling carpet fiber has been shrinkage rather than growth. The largest carpet company in the U.S., Shaw Industries, recently closed the Evergreen Nylon Recycling plant in Augusta, Georgia, which it acquired in 2003 from Honeywell.¹⁸¹ This operation depolymerized nylon 6, 70 percent of which came from post-consumer carpets. Shaw re-polymerized the caprolactam monomer into carpet fiber used in its Eco Solution Q fiber. Before it closed the Evergreen facility in 2015, Shaw said this Cradle-to-Cradle-certified fiber had 45 percent recycled content (20 percent pre-consumer and 25 percent post-consumer).¹⁸² Today, Shaw says the fiber "is 100 percent recyclable" but it has dismantled the plant that could be recycling it.¹⁸³ Shaw's websites no longer make claims about recycled content of its Eco Solution Q fiber, nor does the company appear to hold relevant recycled content certifications.¹⁸⁴

California's carpet recycling mandate should help reverse this downward trend. On September 15, 2017, the legislature passed Assembly Bill 1158, requiring the industry to develop a carpet stewardship plan for increasing recycling post-consumer carpet.¹⁸⁵ On the same day, Aquafil announced plans to open its first carpet recycling plant in the United States. It said it will set up its "Econyl regeneration system" in Phoenix, Arizona. "We want to recycle as much carpet as possible by establishing a number of these facilities throughout the U.S.," said Aquafil CEO Giulio Bonazzi.¹⁸⁶

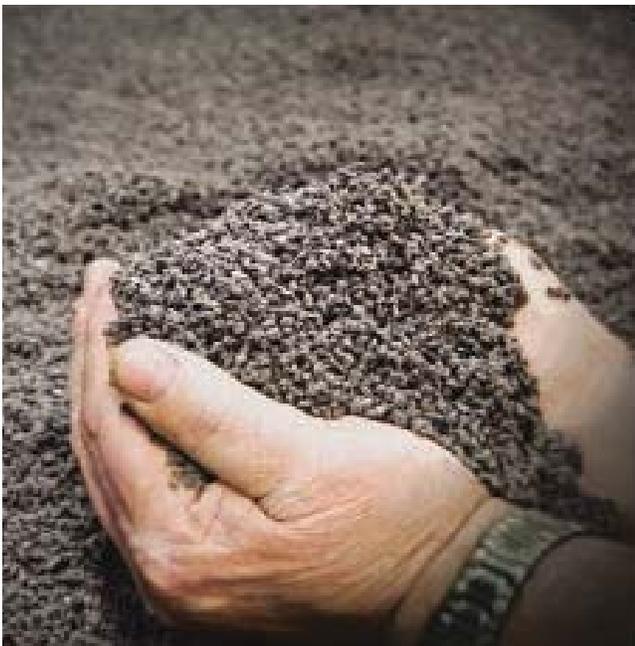
Carpet Backing Recycling

Of the top five carpet manufacturers in the U.S. (Shaw, Mohawk, Beaulieu, Tarkett, and Interface), three now recycle carpet backing into new carpet backing, albeit in small (less than 20 percent) proportions (Interface, and Shaw, and Tarkett).

Interface has a dedicated production line in its Lagrange, Georgia, plant that turns post-consumer carpet crumb into tile backing branded GlasBac RE. This product is certified to contain a minimum of 15 percent post-consumer recycled carpet tile.¹⁸⁷

The carpet industry, as a whole, has not yet developed protocols or policies to prevent the reintroduction of contaminants like PFAS stain repellants into new products, but Interface has extensive screening and testing procedures for incoming carpet waste. Its framework (except for its acceptance of old phthalates) could be a useful starting point for an industry-wide protocol. "Where we use virgin additives, Interface is shifting to greener chemicals, but we cannot retroactively redesign the materials in our waste stream; Interface's approach is to develop screening and testing systems to avoid the most clearly problematic waste streams, especially where PBTs may be involved," said Mikhail Davis, Interface's director of Restorative Enterprise. "Focusing on carpet tile waste makes the screening challenge manageable because we are familiar with the ingredients and how to manage them safely."¹⁸⁸

Shaw has been recycling EcoWorx backing since the mid-2000s, Shaw's Virgo told HBN. Since the inception of EcoWorx carpet tiles, "Shaw has collected and recycled both post consumer EcoWorx carpet tiles and [pre-consumer] scraps from



© Interface, Inc.

At Interface, pellets are loaded into the Cool Blue™ machine and heated to create GlasBac®RE backing

the EcoWorx manufacturing process using a closed loop technology we refer to as ‘Elutriation.’ Elutriation is ONLY used to process EcoWorx backing materials into a new generation of EcoWorx backing materials. It is a grinding/repelletizing/extrusion process done by Shaw within the confines of the same manufacturing plants that make EcoWorx carpet tiles.”

Virgo adds that although Shaw no longer uses fly ash as filler, “There will continue to be low levels of fly ash (less than 1%) in the reformulated EcoWorx tiles, due to its use in previous generations of the tiles. The fly ash was replaced with calcium carbonate.”

At the time of this report’s publication, data were not available for the proportion of old EcoWorx contained in newly produced EcoWorx.

Tarkett recycles some post-consumer carpet tile (along with grinds from vinyl resilient flooring) into new carpet backing called Tandus ER3.¹⁸⁹ ER3 is certified to contain a minimum of 18 percent post-consumer recycled material, but it’s not clear how much of that is carpet tile.¹⁹⁰

As noted earlier, the California Office of Environmental Health Hazard Assessment (OEHHA) granted Tarkett’s requests to allow ER3 to contain up to nine percent DINP without carrying Proposition 65 warning labels. OEHHA is weighing a similar request from Interface for its GlasBac RE carpet.

Product Certifications

Although most carpets contain substances of concern, they are often labeled with product certifications that imply safety. However, most of the certifications do not currently address the significant toxicity issues for carpet identified in this report. Some commonly used certification standards reward recycled content and ignore toxic content. Some, including the industry-led Green Label Plus certification, conduct “indoor air quality” testing that is limited in scope to VOC emissions. Other organizations certify products as being free of substances of concern, but their prohibited lists leave out some commonly used and highly toxic chemicals.

HBN identified 44 toxic chemicals used in carpets and carpet adhesives and cross-referenced these against six certification programs: Green Label Plus, NSF/ANSI 140, Cradle-to-Cradle (Silver-level), Oeko-Tex 100, the International Living Future Institute’s Living Building Challenge (LBC) Red List, and Germany’s Blue Angel label. *See Appendix 2 for further details.*

Most carpet sold in the United States carries the **GreenLabel Plus** (GLP) certification. The Carpet & Rug Institute trade association runs this program.¹⁹¹ It focuses on a narrow set of VOC emissions. It does not address the material health issues identified in this paper, which are primarily focused on SVOCs (semi-volatile organic compounds) and non-volatile compounds, not VOCs. The GLP program relies upon the California Standard Practice (01350) testing protocol. It has certified hundreds of polyurethane backed carpets, but has never tested them for isocyanates. *Just one of the 44 toxic chemicals we identified in carpet (styrene) is part of the testing.*

NSF/ANSI 140 – 2015 – Sustainability Assessment for Carpet is a carpet specific certification program run by **NSF International**.¹⁹² It does not, however, substantively address the material health issues identified in this paper. For purposes of material health it is primarily focused on volatile organic compound (VOC) emissions reduction. It also restricts the long chain C8 PFAS that most carpet manufacturers have already moved away from - *but not the shorter chain versions.*

The **California Gold Sustainable Carpet Standard** requires all carpet bought for use in facilities that the State of California owns, leases or manages must be aligned with NSF 140 Platinum.¹⁹³ Ironically the pressure to meet the recycled content mandates in this program (and until recently, in LEED) may have led to the introduction of increased levels of heavy metals through the use of fly ash as a recycled content filler in carpet backings.¹⁹⁴

Most of the certifications do not currently address the significant toxicity issues for carpet identified in this report.

Cradle-to-Cradle (C2C) Certified is a general product certification program operated by the Cradle to Cradle Product Innovation Institute.¹⁹⁵ The Material Health portion of this certification focuses on reducing chemical hazard across the board, not just on reducing VOCs.¹⁹⁶ Products certified to Cradle-to-Cradle's Silver level may not contain substances on the certifier's Banned List. Only eight of the 44 toxic chemicals are on this list: PVC, three of the six phthalates, three of the eleven flame retardants, and 4-nonylphenol. This certification level also includes an assessment to avoid carcinogens, mutagens and reproductive toxicants at greater than 100 ppm, so the assessment may eliminate more of these chemicals. Higher certification levels include an assessment across more health endpoints and restrictions on organohalogens, which will target most of these chemicals, although they are also subject to an exposure assessment which may permit their use. C2C is also in the process of revising their Banned List.

The **Oeko-Tex 100** standard, run by 18 textile institutes in Europe and Japan,¹⁹⁷ bans or sets maximum allowable amounts of chemicals in certified textiles, including carpet fibers. It does not certify carpet materials other than fiber. *Oeko-Tex 100 restricts*¹⁹⁸ 11 of the 44 toxic chemicals found in carpet: three of the five PFAS, all six phthalates, two of the five flame retardants, and 4-nonylphenol.

The **Living Building Challenge** (LBC) is a building certification program that includes a requirement to avoid a specified Red List of hazardous chemicals in all products used to construct the building. The program makes certain exceptions to the exclusion based on market availability.¹⁹⁹ The LBC Red List includes 21 of the 44 chemicals we've identified as high priorities to avoid in carpet, including two of the five PFAS, urea formaldehyde, PVC, five of the six phthalates, four of the five flame retardants, all four bisphenol A-based compounds and 4-nonylphenol.

The most precautionary standard for toxics in carpet is not used in the United States. The Blue Angel ecolabel is supported by German environmental agencies and a diverse jury of representatives of other institutions.²⁰⁰ "Textile floor coverings may cause environmental impacts throughout their entire life-cycles," notes the Blue Angel criteria for carpet. "That is why the requirements for award of the Blue Angel eco-label refer not only to the materials and substances used during manufacture but also to the period of actual use and the disposal of the products."²⁰¹ **Blue Angel excludes from certification 34 of the 44 toxic substances identified in this report, including all PVC compounds, PFAS stain repellants, individual antimicrobials, phthalates, and flame retardants.** It also prohibits one of the three isocyanates (polymeric MDI) and two of the four Bisphenol A-based compounds. The Blue Angel certified products database shows these restrictions are reasonable: It lists 50 carpet companies and 117 textile floor coverings with the Blue Angel label.²⁰²

Other Initiatives

CARE recently created a new label called Double Green™ "to encourage the inclusion of post-consumer carpet in secondary products... labeled products contain recycled California post-consumer carpet plus at least one other post-consumer recycled material."²⁰³ However, this recycled content label has no apparent restrictions on toxic content. CARE notes on their website that, "If you are currently manufacturing a product using any recycled material, simply adding a second raw material from Post Consumer Carpet, such as Face Fiber or [Post Consumer Carpet Calcium Carbonate], will certify your product as Double Green™."²⁰⁴

Other building industry initiatives and California programs influence the composition of carpet and the ways in which manufacturers communicate information about them.

Leadership in Energy and Environmental Design (LEED)

LEED, the program of the **U.S. Green Building Council (USGBC)**, does not certify individual products or create a list of hazardous chemicals to avoid. However, products can contribute toward several points in the LEED system if they meet certain criteria. The “Building product disclosure and optimization - material ingredients credit” in LEED v4²⁰⁵ has several different pathways with different relevance for screening priority substances:

- “Option 1 Material ingredient reporting” rewards disclosure of contents, not avoidance of hazardous chemicals. All pathways to this credit option reward public disclosure to 1000 ppm (0.1 percent of a product by weight). Manufacturers may withhold ingredients defined as intellectual property or trade secret, but they must disclose the role, amount, and hazard screen flag for those materials. Therefore a product that is indicated to contribute to Option 1 may have useful information available for screening a product. Qualifying for Option 1, however, is not an indication of whether it passes any content hazard screen. Furthermore, some pathways to Option 1 only require disclosure of content to a third party for an assessment process, and so the purchaser will receive no content information to screen for the chemicals of concern discussed here.
- “Option 2 Material ingredient optimization” rewards avoidance of certain chemicals of concern. The credit provides different levels of weighting to product value towards the LEED credit requirements depending on the level to which ingredients in products have been optimized. Achievement is represented through certification in various programs or by manufacturer attestations. Therefore, a product that is indicated to contribute to Option 2 in LEED’s Material ingredient credit may or may not avoid the key chemicals of groups indicated as of highest concern in this report. Program levels in Option 2 which are likely to meet the hazard avoidance criteria suggested in this report include:
 - Cradle to Cradle Gold or Platinum certification
 - GreenScreen full assessments for all contents with results that are Benchmark 2 or higher

Other pathways to Option 2 do not comprehensively avoid the chemicals of highest concern in this report, including:

- Cradle to Cradle Silver
 - GreenScreen List Translator™ assessments
 - REACH Optimization
- “Option 3 Product Manufacturer Supply Chain Optimization” rewards establishing risk assessment programs in manufacturing and does not necessarily indicate any chemical hazard is avoided.

LEED has always rewarded projects that include recycled content. Its latest version (v4) deemphasizes recycled content as a specific attribute, although recycled content still can contribute to a point for “leadership extraction practices,” as one of many attributes that optimize the sourcing of raw materials and likely shows up favorably in Environmental Product Declarations as well.²⁰⁶

California Candidate Chemicals

Many of the toxic substances in carpet and related adhesives are on the California Department of Toxic Substance Control (DTSC)’s Candidate Chemicals list. These are chemicals that select authoritative bodies have determined exhibit hazard traits or environmental or toxicological endpoints.²⁰⁷ The DTSC list includes 27 of the 44 toxic substances listed in this

report, including all three isocyanates, all six phthalates, and ten of 11 flame retardants. However, the list omits organotins, PVC, fly ash, 4-nonylphenol, one of five PFAS, three of four bisphenol A-based compounds, and four of seven antimicrobials.

The DTSC Safer Consumer Products Program, for example, has identified carpet as a potential target product and could challenge the industry to address some or all of these key transformation opportunities, such as eliminating exposures to PFAS, which DTSC has identified carpet as being one of the largest potential sources.

California also has **Proposition 65** (administered separately from the Safer Consumer Products Program). It can be used as a tool to encourage manufacturers to label products which contain some of the chemicals of concern highlighted in this report. It is limited, however, to just the chemicals that have been listed on the state's Proposition 65 list of chemicals. Prop 65 chemicals include ten of the 44 toxic substances listed in this report. The State of California has determined these chemicals to be known to cause cancer or birth defects or other reproductive harm. It also is constrained by the safe harbor limitations discussed above with phthalates which can eliminate the responsibility to label if certain risk criteria are met, which do not always address all the concerns of this report. Nonetheless, California Proposition 65 has been an effective tool to encourage manufacturers to reformulate to avoid some chemicals of concern referenced here.

Attribute Evaluation: The carpet industry is just beginning to establish quality control systems. Carpet companies have demonstrated leadership in product transparency, but it is incomplete. Some recycling technologies and screening protocols are preventing some toxic substances from being reintroduced into consumer products. These efforts should expand as regulatory demand for post-consumer carpet recycling increases. Thus we evaluate post-consumer carpet's Supply Chain Control and Transparency as Yellow, indicating "room for improvement."

■ GREEN JOBS & OTHER LOCAL IMPACTS

A Tellus Institute study in 2011 notes that recycling materials generates many more jobs than waste disposal options like landfills, incineration and cement kilns. "Waste disposal is not labor intensive and generates the fewest jobs per ton of waste (0.1 job per 1,000 tons)," it notes. "Manufacturing using recycled materials creates a relatively high number of jobs per 1,000 tons, varying by material/sector (e.g., about... 10 jobs per 1,000 tons for plastics manufacturing)."²⁰⁸

Current Operations

Recycling carpet right now is not as "green" as it could be because it contains so many hazardous substances. Mechanical shredding generates dust, which can be hazardous to workers who inhale it, and can be combustible.

Columbia Recycling Corp. of Dalton, Georgia operates the largest carpet shearing plant in the country.²⁰⁹ It employs over 500 people.²¹⁰ It collects over 130,000 tons per year of post-consumer (60 percent) and pre-consumer (40 percent) face fibers and shreds them into fluff for conversion into pellets used by the automotive industry.²¹¹ Through its sister company American Fiber Cushion, it also makes carpet cushion from recycled PET.²¹²

Columbia Recycling's annual rate of collection of around 78,000 tons of post-consumer carpet per year outpaces other efforts. The California Carpet Stewardship Program collected an average 50,100 tons of carpet per year between 2011 and 2016.²¹³

Shaw's ill-fated Evergreen nylon recycling facility had ambitions of diverting 50,000 tons of carpet fiber per year.²¹⁴ Interface diverts about one-tenth that amount.²¹⁵ CarpetCycle, the leading processor in the northeast U.S., collects about 7,000 tons of post-consumer carpet per year.²¹⁶

The 664,000 square foot Columbia Recycling facility caught fire six times in the last ten years. In a fire in 2007, a worker died from smoke inhalation.²¹⁷ The Occupational Safety and Health Administration (OSHA) has repeatedly cited the company for safety violations over the last decade. Columbia settled a \$250,000 OSHA fine in 2016.²¹⁸ Christi Griffin, an OSHA official, charged that “Columbia Recycling continues to ignore OSHA’s safety standards and lacks concerns to protect workers at this facility.”²¹⁹

OSHA’s ongoing actions against the largest carpet recycler in the country likely represent the tip of the iceberg of occupational health problems throughout the carpet recycling supply chain. Like most recycling plants, Columbia Recycling is non-union. Workers who are not members of a union suffer higher injury rates than those who are in a union, studies of construction and other dangerous industries have found²²⁰.

Towards Greener Jobs

California’s carpet recycling target should increase the quantity and quality of post-consumer carpet feedstock. The interrelationship of health and recycling rates should create a virtuous cycle of improved working conditions and more jobs.

The Global Alliance for Incinerator Alternatives notes, “Occupational hazards [for recycling workers] can be mitigated, and in some cases eliminated, with a combination of engineering controls, improved safety systems, work practices, and extensive training.”²²¹ Reducing the use of hazardous chemicals in carpet manufacturing is the most reliable path to safer conditions and less occupational exposure for workers.

Aquafil, which employs over 2,600 people worldwide and is expanding in the U.S., says it “organizes training courses and awareness campaigns and carries out major structural works in order to ensure that all of the employees have safe working environments and equipment. In 2015 approximately 4,000 hours of environmental and safety training courses were held.”²²² The company’s wet cleaning and chemical depolymerization technologies should eliminate many of the concerns about dust found in more conventional mechanical carpet recycling processes.

Attribute Evaluation: The lack of controls in some parts of the industry (such as carpet pad recycling) leads us to evaluate this feedstock’s “Green Jobs” potential as Yellow, indicating “room for improvement.” Carpet recycling operations have varied track records, but there is great potential for the development of many new, green jobs as carpet recycling rates increase, better controls are put in place for current carpet feedstock and cleaner, non-toxic feedstock comes back for recycling in the future.

ROOM TO GROW

Nationally, only about five percent of carpet waste is diverted for recycling; in California, the rate is closer to ten percent. “Of the 5 percent that is recycled [nation-wide], only 20 percent is recycled in a closed loop - i.e. turned back into carpet, the rest is down-cycled into less valuable products. That means that only 1 percent of carpet discards are recycled back into carpet each year,” report GAIA and Changing Markets.²²³

But California Assembly Bill 1158 (AB 1158, Chu), which Gov. Jerry Brown signed on October 15, is a step on the way to optimal recycling. It will increase pressure on the carpet industry to start transforming. Recognizing the industry’s considerable room to grow, the legislature requires it to develop a carpet stewardship plan that achieves a 24 percent recycling rate for post-consumer carpet by January 1, 2020.

To achieve such a dramatic increase in throughput for post-consumer carpet, without reintroducing toxic substances into the workplace and consumer products, the industry will need to implement far more quality controls, and soon. These controls begin with a full accounting of what is in the feedstock, using either manufacturer disclosure or robust testing to identify toxic substances that are in carpets produced five, 10, 20 years ago. These procedures must be implemented in order to ensure manufacturers that post-consumer carpet feedstocks are suitable for inclusion in new products and thus help the industry achieve a 24 percent recycling rate by 2020.²²⁴

The 24 percent target should not be the end goal, especially as this allows downcycling carpet, rather than recycling it back into carpet. Ultimately, the industry's integration with a circular economy requires a fully closed loop system. Closing the loop will depend upon radical changes at the front end of product design.

The CRI's voluntary back-of-carpet labeling system is a small step in that direction (it identifies the type of fiber and backing, but not additives). This labelling should be made mandatory and much more comprehensive to include all additives, using structured disclosure standards such as the Health Product Declaration.

Much more — nothing short of reimagining carpet's fundamental design with precautionary principles in mind — is needed.

Toxic chemicals reduce the value of carpet waste and increase the hazards of recycling. The complex mixture of chemical ingredients and failure to design carpets for recycling makes recycling technically challenging — especially closed-loop recycling. In California, these factors have likely contributed to the low percentage of carpet discards collected for recycling actually being recycled.²²⁵

Avoiding toxic content is a prerequisite for a truly circular economy in which old carpet becomes new carpet, replacing virgin materials on a 1:1 basis. The ultimate purpose of recycling is to minimize the need for virgin materials.

Consumers are increasingly knowledgeable and wary of toxic substances in building products. This is demonstrated by leading architectural firms and building owners' efforts to avoid products that contain fly ash, PFAS, antimicrobials and flame retardants. Perkins+Will's Precautionary List and guidance by non-profits such as the Green Science Policy Institute's Six Classes and Practice GreenHealth's Healthier Hospital Initiative identify each of these chemical classes of concern for avoidance. Many firms have also tried to avoid products with certain chemicals by meeting the material program requirements of building certification programs including the Living Building Challenge, Green Guide for Health Care, WELL Standard and other building product programs that reward avoidance of these classes of chemicals, such as C2C.

Manufacturers should design carpets for recyclability. The complicated structure of carpet, the plastics and toxic additives that comprise most of these products, and the adhesives used in carpet installations, confound industry efforts to recycle. For example, recyclers simply do not recycle broadloom carpet that has been glued down. Simplifying product design, avoiding adhesives, and detoxifying carpet backing and fibers are crucial steps toward carpet recycling optimization.

The Blue Angel certification, which certifies carpets from dozens of manufacturers, proves these opportunities are real. This ecolabel prohibits the vast majority of toxic substances identified in this report. It does this to protect human health, the environment, and to ensure, at the end of life, carpets "do not contain any pollutants that could impede recycling."²²⁶

"A carpet is fully recyclable back into carpet (closed loop/circular economy) when the fibers can be easily separated from

the backing and recycled back to carpet, and the backing is also recycled,” note GAIA and Changing Markets. “Carpet that is designed for recycling saves resources, like petroleum, chemicals, and energy. When it is not, the carpet ends up in landfill or incinerators.”²²⁷

Most carpet currently produced does not meet these criteria, but innovative companies are working in that direction. California’s new mandate to the industry should force them to move more quickly.

Attribute Evaluation: The new California’s carpet recycling law’s requirement that the industry achieve a 24 percent recycling rate by 2020 will nearly double the amount of post-consumer carpet feedstock in just over two years. Even more importantly, there is also potential market growth through product redesign enabling closed loop recycling of all carpet in the future. These factors lead us to evaluate this feedstock’s “Room to Grow” as Green, or “very good.”

Conclusions and Recommendations

Through the Optimizing Recycling analytic framework,²³⁷ the Healthy Building Network has reviewed recycled feedstocks used in building materials across many types of products (See Appendix 3). This research consistently finds that toxic and unknown content in these feedstocks complicates recycling and makes use of recycled feedstocks problematic from a human health perspective.

Conversely, we have seen where recycling succeeds: simple recyclable materials, without toxic additives, fully disclosed and tracked throughout the supply chain, are harmonious with a healthy circular economy.

Post-consumer carpets collected for recycling contain substances of concern, including stain repellent treatments, antimicrobials, isocyanates, polyvinyl chloride, phthalates, flame retardants, fly ash, and toxic adhesives. Through our research, HBN identified 44 toxic chemicals commonly used in carpets and carpet adhesives. Neither manufacturers, nor third party organizations that certify carpet products, provide a full accounting of these substances. Many carpets, carpet pad, and carpet adhesives have obtained product certifications that assert certain attributes, like being free of “Red List” chemicals or VOCs; however, the standards upon which the certifications are based do not consider most of the 44 priority toxic substances we identified that are used in carpet.

Manufacturers are beginning to provide more robust information about their products through platforms like the Health Product Declaration and CRI’s new labeling program. These disclosures are important steps for many reasons:

- Processors need the information to efficiently sort and screen out unwanted materials, a prerequisite for increasing recycling rates in the future.
- Consumers need the information to select better carpets and reward manufacturers who improve.
- Regulators need better data to inform regulatory approaches that hold manufacturers accountable and incentivize toxic avoidance.
- Green chemistry innovators need the information to identify opportunities to provide improved chemistry and materials.

Key to dramatically accelerating recycling is an industrial transformation to real closed loop design. This can happen if toxics are designed out in favor of simple clean material streams for products designed for disassembly and recycling. Most of the toxic substances we’ve identified in this report can be replaced by other readily-available, less toxic chemicals.

Transformation Underway?

Two major carpet companies have separately launched product lines heralded with promises to revolutionize the circular economy of carpet. These new designs (AirO, a collaboration of Mohawk and DSM-Niaga, and EcoBase, made in Europe by Tarkett), both feature polyethylene terephthalate (PET) backings. One uses PET fiber as well, the other, nylon 6.

PET has no known health hazards, though like other polymers derived from petrochemicals, it involves toxic chemicals in the course of its extraction and manufacturing life cycle. The companies say these carpets are “100 percent recyclable” into new carpet. The absence of transparency documentation for both products confounds efforts to fully understand them. The manufacturers have not fully disclosed fiber treatments and other additives.

In January 2017, Mohawk launched AirO, a broadloom carpet made from PET face fibers “fusion bonded” to a PET backing²²⁸. Chemical and food industry giant, DSM, developed AirO in Europe, under the brand name Niaga (which spells “again,” backwards).²²⁹ Mohawk has curbside pickup for PET bottles and its own grinding plant in Summerville, Georgia. This grinding plant can also recycle AirO carpet into cushion fiber or face fiber, the company told HBN.²³⁰

According to a 2013 DSM patent, recycling this kind of carpet is simple. It “merely takes heating the floor covering until the textile product de-connects from the sheet, separating the textile product from the sheet, and reusing the textile product and the sheet, for example to produce a new floor covering,” reads the patent.²³¹ Floor Daily says AirO “may well be one of the most important developments in carpet design in the modern era.”²³²

In Europe, Tarkett sells a PET carpet tile backing, branded EcoBase, through its Desso subsidiary. Tarkett/Desso’s PA6 Solution Dyed Carpet Tiles Gold is the only carpet to have a Cradle-to-Cradle’s (C2C) “Platinum” rating for material health. This means that C2C assessors determined that the product’s contents and the process chemicals used in its final manufacture are safe for humans and the environment. Overall, factoring in other attributes (material reutilization, renewable energy, water stewardship and social fairness), C2C certifies the backing and carpet at the Gold level, one step below the top Platinum rating.²³³ The manufacturer says EcoBase “contains a polyolefin based layer that is 100 percent safely recyclable in Desso’s production process.”²³⁴ The product is not yet sold in the U.S.

Neither Tarkett nor Mohawk have fully disclosed the contents in product declarations, so unknowns remain. The companies have not disclosed the identities of stain repellants, antimicrobials, or any other additives. A Mohawk official told HBN that AirO indeed contains a fluorochemical stain repellant.²³⁵ As for Tarkett’s Platinum rated carpet, the C2C certification does not help to clarify whether it contains a PFAS stain repellant. The C2C standard only prohibits long-chain PFAS. (See above for further analysis of what these and other programs do and don’t cover). Diane Martel, VP of Environmental Planning and Strategy of Tarkett North America, told HBN that “we do not use PFOA, nor PFOS chemistry or anti-microbials in this product.”²³⁶

Dozens of carpet companies sell products in Europe that do not contain most of the priority substances. Leading carpet fiber manufacturers have eliminated fluorine-based treatments. Simple, hazard-free backings are also entering the market.

We urge the federal government and states to hasten this long-needed industrial transformation by acting to discourage or prohibit the use of certain highly toxic chemical classes that our research has identified as frequently or historically present in carpet as outlined in Table 1.

California is uniquely well positioned to lead this movement to a closed loop economy of safer carpet due to its leadership position in toxics legislation, hazard assessment across an increasing range of consumer products and the first ever extended producer responsibility mandate for carpet.

In the short term, additional action is needed for the industry to safely achieve California’s mandate to recycle 24 percent of post-consumer carpet waste by 2020. This is because manufacturers never disclosed the contents of most carpets that are being removed from buildings today. Doubling carpet recycling in two years will require a lot of diligence to ensure the feedstock is well-understood and does no harm as it is recycled. These measures should include testing for more than just fiber type in sorting operations, including improved occupational health practices to protect worker health. The industry has much room to grow recycling through a combination of hazard avoidance, product redesign, and transparency. It is making tentative moves in this direction. Fully realized, this is a formula that works: it boosts recycling rates by creating clean material streams, protects human health and the environment, and saves energy and other resources.

A fundamental transformation of the carpet industry is needed if it is to become truly regenerative by design. HBN recommends that manufacturers, processors, consumers, product certifiers, retailers, and regulators and workers take the following actions to optimize carpet recycling.

TABLE 1. Highly toxic chemical classes to eliminate from carpet design

PFAS stain repellants
Certain antimicrobials (especially triclosan and formaldehyde-based)
Isocyanates
Phthalates
Organotins
Fly ash
Halogenated and other toxic flame retardants (including carpet pad)
Other endocrine disrupting chemicals such as bisphenols and nonylphenol ethoxylates (especially in adhesives)

See Appendix 1 for a more detailed inventory of priority substances to eliminate from carpet and their hazards.

For carpet manufacturers

For new carpet:

- **Fully disclose chemical contents in new carpet.** Several carpet manufacturers have been at the vanguard of the building industry's moves towards greater transparency. After HBN launched the Pharos Project in 2009, they were among the first companies to disclose product contents, including their proportion of the product by weight. They are active participants in leading transparency initiatives like the Health Product Declaration and Declare. But our review of their declarations found that the number of carpets that are fully and accurately disclosed is limited, especially in the broadloom sector that serves residential consumers. Publicly identifying key substances like stain treatments and biocides in any carpet, tile or broadloom, remains a rarity.
- **Eliminate hazardous substances in all lifecycle stages.** Priority substances to eliminate include halogenated flame retardants, antimony trioxide, PFAS stain repellants, certain antimicrobials, isocyanates, PVC, organotins, fly ash, phthalates, bisphenol A, and 4-nonylphenol. Most of these substances have immediate and preferable replacements, such as recycled glass in place of coal fly ash as filler. Innovative manufacturers understand that their customers, from all sectors and income levels, have growing and profound concerns about the chemicals that are in most carpet. We are confident they can solve these challenges and design the next generation of carpet to be devoid of PFAS, flame retardants, and other high priority substances and able to be readily recycled.

For post-consumer carpet:

- **Retroactive transparency.** Manufacturers should provide retroactive content disclosure for carpets currently entering the waste stream. Carpet companies provided very little information about carpet contents prior to the recent building product transparency era. This knowledge is crucial for increasing recycling rates in California from 10 percent in 2015 to 24 percent in 2020, as required by AB 1158. Transparency for carpets recently introduced to the market will facilitate future recycling, but in the short term, recyclers need to understand what is entering the waste stream today from carpets that are five, 10, or even 20 years old.
- **Normalize the practice of screening and testing for chemicals.** Establish thresholds and screening procedures for post-consumer carpet to ensure toxic ingredients are not recycled back into new carpet.
- **Protect worker health in the supply chain.** Select post-consumer carpet from feedstock processors that are unionized or otherwise have a clean worker safety record.

For post-consumer carpet processors:

- **Normalize the practice of screening and testing for chemicals.** Establish, in coordination with carpet manufacturers and others, the development of standards and methods to screen toxic substances in recycled carpet feedstocks.
- **Ensure that workers are not exposed to toxic chemicals** in carpets by skin contact or inhalation.

For consumers:

- **Demand transparent, clear information** from retailers and manufacturers.
- **Purchase only carpets for which manufacturers and retailers have provided a complete accounting of contents and that do not have the toxic chemicals identified in this report.**

For organizations that certify products:

- **Expand red lists** to include all 44 of the toxic substances identified in this report. Carpet containing any of these chemicals should not qualify for the highest level of product certifications.
- **Broaden the scope of substances in indoor air quality product testing** to include all VOCs, SVOCs and toxic heavy metals that may be released into indoor air and dust.

For retailers/sellers:

- **Demand information from manufacturers** on toxicity and recyclability of carpet.
- **Inform consumers** proactively on toxicity and recyclability.
- **Stop selling carpets that contain the toxic substances highlighted in this report.**

And, for regulators:

- **Increase surveillance of workers' health**, including: collectors, processors, and recyclers. Establish baseline understanding of worker exposures to the toxic substances identified in this report.
- **Encourage a flame retardant-free supply chain through procurement policy adjustments.** Encourage the purchase of bonded carpet cushion made only with pre-consumer content or verified to be flame retardant-free. If flame retardant-free materials are unavailable, seek full transparency about all material contents including the presence of residuals and contaminants by preferring products with disclosure down to at least 100 ppm (0.01% of a product's total content) by a standardized format such as the Health Product Declaration.
- **Support consumers' right to know what is in the carpets they buy with mandatory content labelling.** In California, enforce Proposition 65 labelling requirements for the substances that fall under Prop 65 regulations.
- **Provide guidance for certification programs** on toxic substances that must be covered to support green claims by the certifiers and by manufacturers referencing those certifications. Incorporate this into the FTC Green Guides and similar state level guidance.
- **Prohibit the use or release of PFAS and the other toxic substances** identified in this paper, starting with those listed in table 1. Considering its environmental and public health impact, the carpet industry is vastly under-regulated.
- Consistent with the Stockholm Convention, **ban the recycling of carpet fibers containing long-chain PFAS.** The federal government should ratify this important global pact.
- **Incentivize the design of healthier carpets.** In California, the Department of Toxic Substances Control's Safer Consumer Products program should identify carpets containing the toxic substances in this report as Priority Product-Chemical combinations. This program advances "safer substitutes for hazardous ingredients in consumer products sold in California."²³⁸ Safer carpets in the marketplace will increase recycling rates in the long-term.
- **Incentivize the use of inherently safer substances and chemicals and improved recyclability via Extended Producer Responsibility (EPR) systems.** Other states should follow California's lead in developing mandatory EPRs for carpet. Meanwhile California should encourage carpet stewardship plans that optimize closed loop recycling. To accelerate recycling of existing carpet, California officials should only approve plans that directly support technologies to detect and remove toxic substances from carpet waste before it is recycled. Stewardship plans implementing the California carpet bill should

incentivize the design of safe and recyclable carpets via modulated fees, subsidies and grants, so that producers that make non-toxic and recyclable products are rewarded and investments are made in toxic-free, recyclable product innovation. It is recommended that the plans set concrete targets to phase out toxics in carpet products and waste.

- **Incentivize the procurement of carpets that have eliminated substances of concern and have the highest recyclability.** California is developing a new version of its California Gold standard to accomplish much of this.²³⁹ Procurement policies serve as demand side drivers for manufacturers to produce non-toxic, recyclable carpet as well as increasing demand for safe, recycled products. Local, state, and federal agencies should buy carpets that don't contain the toxic chemicals reviewed in this report, if and when manufacturers sell them. As the industry stops using toxic chemicals, it will take time for reformulated carpets to enter the waste stream and get recycled into new carpet. Removing toxics from products in the first place will create a much cleaner long-term supply of post-consumer carpet for recycling. Hazard avoidance and recyclability go hand-in-hand. In California, Section 40051 of the California Public Resources Code requires state and local government to "maximize use of all feasible source reduction, recycling, and composting options in order to reduce the amount of solid waste that must be disposed of by transformation and land disposal."²⁴⁰ The removal of toxic substances from carpet waste is consistent with this requirement. By enhancing the market acceptance of recycled carpet, the proliferation of these technologies will increase recycling rates and reduce the amount of solid waste disposed of by transformation and land disposal.

Appendices

APPENDIX 1. SUBSTANCES OF HIGH CONCERN IN THE CARPET WASTE STREAM

Human Health and Environmental Hazards listed are taken from the Pharos Chemical and Material Library as of September 8, 2017. For more information on how these hazards are assigned, see the Full Systems Description here: https://www.pharosproject.net/uploads/files/library/Pharos_CML_System_Description.pdf.

Substance	CAS No.	Human Health and Environmental Hazards
Per- and Polyfluoroalkyl Substances (PFAS) used in Stain Repellants		There are at least 3,000 chemicals in the PFAS chemical group. ¹ They are also sometimes referred to as PFCs (perfluorinated chemicals). Some, like PFOA (C-8) are relatively well-researched and regarded as developmental and reproductive toxicants. Most have not been individually assessed for health and environmental hazards. “[Perfluorinated Chemicals] break down very slowly in the environment,” notes the National Institute of Environmental Health Sciences. It can take several years for PFASs to leave the human body. As a class, these chemicals “have potential similarities in chemical properties and toxicity.... More research is needed.” ²
2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl ester	2144-53-8	Unknown.
2-Propenoic acid, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl ester	17527-29-6	Unknown.
Perfluorohexanoic acid (PFHxA, C-6)	307-24-4	PBT (Persistent Bioaccumulative Toxicant), Potential Endocrine Disruptor
Perfluorobutanoic acid (PFBA, C-4)	375-22-4	Potential Endocrine Disruptor, Skin and Eye Irritation
Hexane, 1,6-diisocyanato-, homopolymer, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluoro-1-octanol-blocked	357624-15-8	Unknown. This polymer is based on fluorotelomers.
Antimicrobials		
IPBC (3-iodo-2-propynyl butylcarbamate)	55406-53-6	Developmental, Potential Endocrine Disruptor, Serious eye damage, Skin sensitization, Organ toxicant, Very toxic to aquatic life (Acute and chronic)
Methylchloroisothiazolinone (CIT, CMIT)	26172-55-4	Mammalian, Eye and skin irritation, Acute aquatic toxicant, Very ecotoxic to terrestrial vertebrates.
Silver nanoparticles	7440-22-4	Nano-form hazards unknown. Skin sensitizer, organ toxicant, acute aquatic toxicant.
Silver sodium hydrogen zirconium phosphate	265647-11-8	Nano-form hazards unknown. Skin sensitizer, organ toxicant, acute aquatic toxicant.
Triclosan	3380-34-5	PBT, Endocrine Disruptor, Acute and chronic aquatic toxicant.
Urea Formaldehyde	9011-05-6	Respiratory (sensitizer-induced asthmagen)
Zinc Pyrithione (ZPT)	13463-41-7	Reproductive, Mammalian, Eye and skin irritation, Skin sensitizer, Organ toxicant, and acute and chronic aquatic toxicant.

¹ “Work Plan Implementation: Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs) in Carpets, Rugs, Indoor Upholstered Furniture, and Their Care and Treatment Products.” Safer Consumer Products Branch, CA Department of Toxic Substances Control, November 15, 2016. <https://www.dtsc.ca.gov/GetInvolved/ReviewPanel/upload/DTSC-Work-Plan-Implementation-Perfluoroalkyl-and-Polyfluoroalkyl-Substances-in-Carpets-Rugs-Upholstered-Furniture-and-Their-Care-and-Treatment-Products-11-15-16.pdf>.

² Perfluorinated Chemicals (PFCs).” National Institute of Environmental Health Sciences, July 2016. https://www.niehs.nih.gov/health/materials/perfluorinated_chemicals_508.pdf.

Substance	CAS No.	Human Health and Environmental Hazards
Isocyanates		
There is strong evidence that, as a group, isocyanates cause the onset of asthma disease.		
Diphenylmethane diisocyanate (MDI) - non isomer specific	26447-40-5	"A skin, eye, and respiratory tract irritant; Allergic contact dermatitis, contact urticaria, asthma, and hypersensitivity pneumonitis reported from occupational exposure." (National Institutes for Health Haz-Map) ³
Methylene bisphenyl diisocyanate (pure MDI)	101-68-8	Developmental, respiratory toxicant.
Polymeric MDI (PMDI)	9016-87-9	Developmental, respiratory, mammalian, and organ toxicant.
Organotins		
Dibutyltin sulfide	4253-22-9	PBT.
Dibutyltin dilaurate	77-58-7	PBT, Reproductive, Endocrine disruption, Gene mutation, Eye and skin irritation, Organ toxicant, Ecotoxic to terrestrial vertebrates, Acute and chronic aquatic toxicant.
Dibutyltin bis(2-ethylhexyl thioglycolate)	10584-98-2	PBT
Polyvinyl Chloride (PVC)		
Most direct health and environmental impacts of PVC occur during production -- where highly toxic chemicals like dioxins, vinyl chloride, carbon tetrachloride, and chloroform -- are released; through the use of toxic additives like phthalates; and, at the end of life, via emissions from incinerators and cement kilns that burn PVC.		
Poly(vinyl chloride-co-methyl acrylate)	25035-98-7	
Polyvinyl Chloride	9002-86-2	Asthmagen (likely dust form).
Phthalates		
Butyl Benzyl Phthalate (BBP)	85-68-7	Developmental and Reproductive Toxicant, Endocrine Disruptor. Possible carcinogen. Very toxic to aquatic life (acute and chronic).
Dibutyl Phthalate (DBP)	84-74-2	Developmental and Reproductive Toxicant, Endocrine Disruptor. Evidence of carcinogenic effects. Skin sensitizer. Organ Toxicant. Very toxic to aquatic life (acute and chronic).
Diisooheptyl phthalate (DIHP)	71888-89-6	Developmental and Reproductive Toxicant.
Diisononyl phthalate (DINP-1, mixture of isomers as manufactured)	68515-48-0	Carcinogen. Developmental Toxicant. Endocrine Disruptor.
Diisononyl phthalate (DINP-A)	71549-78-5	Carcinogen. Reproductive Toxicant.
Diisononyl phthalate (DINP-2 or DINP-3, mixture of isomers as manufactured)	28553-12-0	Carcinogen. Developmental Toxicant. Endocrine Disruptor.
Filler		
Fly Ash	68131-74-8 and 69012-84-6	Many hazards associated with constituents of fly ash, including heavy metals and polycyclic aromatic compounds.
Styrene	100-42-5	Carcinogen, Developmental and Reproductive Toxicant, Neurotoxicant, Endocrine Disruptor, Mutagen, Asthmagen, Acute Aquatic Toxicant.
Flame Retardants		
Decabromodiphenyl ether (Deca-BDE)	1163-19-5	PBT, Neurotoxicant, Developmental Toxicant, Gene Mutagen, Endocrine Disruptor.
bis(2-ethylhexyl) tetrabromophthalate (TBPH)	26040-51-7	PBT, Developmental Toxicant, Endocrine Disruptor, Acute and chronic aquatic toxicant.
tris(2-chloroethyl)phosphate (TCEP)	115-96-8	Carcinogen, Reproductive Toxicant, Gene Mutagen, Organ Toxicant.
Antimony trioxide	1309-64-4	Carcinogen, Developmental, Reproductive and Organ Toxicant.

³ "Methylenediphenyl Diisocyanate." *Haz-Map*. Accessed October 10, 2017. <https://hazmap.nlm.nih.gov/category-details?id=13260&table=copytblagents>.

Substance	CAS No.	Human Health and Environmental Hazards
PentaBDE	32534-81-9	PBT, Carcinogen, Developmental Toxicant, Neurotoxicant, Endocrine Disruptor, Acute and Chronic Aquatic Toxicant.
TDCPP	13674-87-8	PBT, Carcinogen, Endocrine Disruptor, Acute and Chronic Aquatic Toxicant.
V6 (2,2-bis(chloromethyl)propane-1,3-diyltetrakis(2-chloroethyl) bisphosphate)	38051-10-4	PBT, Endocrine Disruptor.
Firemaster 550 component IPTP (isopropylated triphenyl phosphate)	68937-41-7	PBT, Developmental Toxicant, Neurotoxicant, Chronic Aquatic Toxicant.
Firemaster 550 component TPP (triphenyl phosphate)	115-86-6	Endocrine Disruptor, Acute Toxicant, Acute and Chronic Aquatic Toxicant.
Firemaster 550 component TBB (2-ethylhexyl-2,3,4,5- tetrabromobenzoate)	183658-27-7	PBT, Developmental Toxicant, Endocrine Disruptor, Acute and Chronic Aquatic Toxicant.
Firemaster 550 component TBPH (Bis(2-ethyl-1-hexyl) tetrabromophthalate)	26040-51-7	PBT, Developmental Toxicant, Endocrine Disruptor, Acute and Chronic Aquatic Toxicant.
Adhesives (Bisphenol A and related compounds)		
Bisphenol A (BPA)	80-05-7	Developmental and Reproductive Toxicant, Endocrine Disruptor, Eye Irritant, Skin Sensitizer.
Bisphenol A Diglycidyl Ether (BADGE)	25085-99-8	Endocrine Disruptor. See BPA above for hazards associated with monomer.
Bisphenol A, epichlorohydrin polymer, diethylenetriamine adduct	68610-56-0	Monomers (BPA and epichlorohydrin) have multiple health hazards. BPA: listed above. Epichlorohydrin: Carcinogen, Reproductive Toxicant, Gene Mutagen, Developmental Toxicant, Endocrine Disruptor, Mammalian Toxicant, Eye and Skin Irritant.
Bisphenol A - epichlorohydrin condensate	25068-38-6	See row above.
Adhesives (surfactant)		
4-Nonylphenol (branched)	84852-15-3	PBT, Endocrine Disruptor, Developmental & Reproductive Toxicant, Eye and Skin Irritant, Aquatic Toxicant (acute and chronic).

Note:

PBT = Persistent, Bioaccumulative Toxicant (PBT)

APPENDIX 2. CERTIFICATIONS, STANDARDS, AND REGULATIONS: COVERAGE OF CHEMICALS OF CONCERN IN CARPET

Unless otherwise noted, the following identifications of chemical contents and their functional uses in carpet are derived from the [Pharos](#), [Portico](#) and [Quartz](#) building product online libraries.

Substance	CAS No.	Median % (by weight of carpet, when present)	Green Label Plus (tested) ⁴	C2C Silver (Ban) ⁵	ILFI v 3.0 (Ban) ⁶	Oeko Tex 100 (max%) ⁷	Blue Angel (Ban) ⁸	Calif. Prop. 65 ⁹	Calif DTSC List ¹⁰
PFAS Stain Repellants¹¹									
2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl ester	2144-53-8 ¹²	0.13%	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes	Limit (g)	Yes
2-Propenoic acid, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl ester	17527-29-6 ¹³		Limit (g)	Limit (g)	Limit (g)	0.5%	Yes	Limit (g)	Yes
Perfluoronoic acid (PFHxA, C-6)	307-24-4		Limit (g)	Limit (g)	Yes	0.05%	Yes	Limit (g)	Yes
Perfluorobutanoic acid (PFBA, C-4)	375-22-4		Limit (g)	Limit (g)	Yes	0.05%	Yes	Limit (g)	Yes
Hexane, 1,6-diisocyanato-, homopolymer, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluoro-1-octanol-blocked	357624-15-8 ¹⁴		Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes	Limit (g)	Limit (g)

⁴ "Standard Method For The Testing And Evaluation Of Volatile Organic Chemical Emissions From Indoor Sources Using Environmental Chambers Version 1.1," California Department of Public Health, Updated February 2010, http://standards.nsf.org/apps/group_public/download.php/11782/CDPH-IAQ_StandardMethod_V1_1_2010%5B1%5D.pdf

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Substance	CAS No.	Median % (by weight of carpet, when present)	Green Label Plus (tested) ⁴	C2C Silver (Ban) ⁵	ILFI v 3.0 (Ban) ⁶	Oeko Tex 100 (max%) ⁷	Blue Angel (Ban) ⁸	Calif. Prop. 65 ⁹	Calif DTSC List ¹⁰
Antimicrobials¹⁵									
IPBC (3-iodo-2-propynyl butyl-carbamate)	55406-53-6	0.15%	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes	Limit (g)	Limit (g)
Methylchloroisothiazolinone (CIT, CMIT) ¹⁶	26172-55-4		Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes	Limit (g)	Limit (g)
Silver nanoparticles	7440-22-4		No	No	No	No	Yes	No	Yes
Silver sodium hydrogen zirconium phosphate ¹⁷	265647-11-8		No	No	No	No	Yes	No	Yes
Triclosan ¹⁸	3380-34-5		Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes	Limit (g)	Yes
Urea Formaldehyde	9011-05-6		Limit (g) (a)	Limit (g)	Yes	Limit (g) (b)	Yes	Limit (g)	Limit (g)
Zinc Pyrithione (ZPT)	13463-41-7		Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes	Limit (g)	Limit (g)
Isocyanates									
Diphenylmethane diisocyanate (MDI) - non isomer specific	26447-40-5	4.02% (f)	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes
Methylene bisphenyl diisocyanate (pure MDI)	101-68-8		Limit (g)	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes
Polymeric MDI (PMDI)	9016-87-9		Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes	Limit (g)	Yes
Organotins									
Dibutyltin sulfide ¹⁹	4253-22-9	0.04%	No	No	No	No	No	No	No
Dibutyltin dilaurate ²⁰	77-58-7		Limit (g)	Limit (g)	Limit (g)	Limit (g) (c)	Limit (g)	Limit (g)	Limit (g)
Dibutyltin bis(2-ethylhexyl thioglycolate)	10584-98-2		No	No	No	Limit (g) (c)	No	No	No
Polyvinyl Chloride									
Poly(vinyl chloride-co-methyl acrylate)	25035-98-7	9.7%	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes	Limit (g)	Limit (g)
Polyvinyl Chloride (PVC)	9002-86-2		Limit (g)	Yes	Yes	Limit (g)	Yes	Limit (g)	Limit (g)
Phthalates									
Butyl Benzyl Phthalate (BBP)	85-68-7	7.5%	Limit (g) (d)	Yes	Yes	0.1%	Yes	Yes	Yes
Dibutyl Phthalate (DBP)	84-74-2		Limit (g) (d)	Yes	Yes	0.1%	Yes	Yes	Yes
Diisooheptyl Phthalate (DIHP)	71888-89-6		Limit (g)	Limit (g)	Yes	0.1%	Yes	Limit (g)	Yes
Diisononyl phthalate (DINP-1, mixture of isomers as manufactured)	68515-48-0		Limit (g)	Limit (g)	Yes	0.1%	Yes	Yes	Yes
Diisononyl phthalate (DINP-A)	71549-78-5		Limit (g)	Limit (g)	Limit (g)	0.1%	Yes	Yes	Yes
Diisononyl phthalate (DINP-2 or DINP-3, mixture of isomers as manufactured)	28553-12-0		Limit (g)	Yes	Yes	0.1%	Yes	Yes	Yes

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Substance	CAS No.	Median % (by weight of carpet, when present)	Green Label Plus (tested) ⁴	C2C Silver (Ban) ⁵	ILFI v 3.0 (Ban) ⁶	Oeko Tex 100 (max%) ⁷	Blue Angel (Ban) ⁸	Calif. Prop. 65 ⁹	Calif DTSC List ¹⁰
Filler									
Fly Ash	68131-74-8 and 69012-84-6	23%	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Limit (g)	Limit (g)
Styrene	100-42-5		Yes	Limit (g)	Limit (g)	Limit (g) (e)	Limit (g)	Limit (g)	Limit (g)
Flame Retardants									
Deca-bromodiphenylether (Deca-BDE)	1163-19-5	6.3% (carpets); 0.55% (car- pet pad)	Limit (g)	Yes	Yes	0%	Yes	Limit (g)	Yes
bis(2-ethylhexyl) tetrabromophthalate (TBPH)	26040-51-7		Limit (g)	Limit (g)	Yes	Limit (g)	Yes	Limit (g)	Yes
tris(2-chloroethyl)phosphate (TCEP)	115-96-8		Limit (g)	Limit (g)	Yes	0.1%	Yes	Yes	Yes
Antimony trioxide	1309-64-4		Limit (g)	Limit (g)	Limit (g)	Limit (g) (e)	Yes	Yes	Yes
PentaBDE	32534-81-9		Limit (g)	Yes	Yes	Yes	Yes	Yes	Yes
TDCPP	13674-87-8		Limit (g)	Yes	Yes	Yes	Yes	Yes	Yes
V6 (2,2-bis(chloromethyl) propane-1,3-diyltetrakis (2-chloroethyl) bisphosphate) Firemaster 550 component	385051-10-4		Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes	Limit (g)	Limit (g)
IPTP (isopropylated triphenyl phosphate) Firemaster 550 component	68937-41-7		Limit (g)	Limit (g)	Limit (g)	Limit (g)	Yes	Limit (g)	Yes
TPP (triphenyl phosphate) Firemaster 550 component	115-86-6		No	No	No	No	Yes	No	Yes
TBB (2-ethylhexyl-2,3,4,5-tetrabromobenzoate) Firemaster 550 component	183658-27-7		Limit (g)	Limit (g)	Yes	Limit (g)	Yes	Limit (g)	Yes
TBPH (Bis(2-ethyl-1-hexyl) tetrabromophthalate)	26040-51-7	Limit (g)	Limit (g)	Yes	Limit (g)	Yes	Limit (g)	Yes	
Adhesives (Bisphenol A-based compounds)									
Bisphenol A (BPA)	80-05-7	11%	Limit (g)	Limit (g)	Yes	Limit (g)	Limit (g)	Yes	Yes
Bisphenol A Diglycidyl Ether (BADGE)	25085-99-8		No	No	Yes	No	No	No	No
Bisphenol A, epichlorohydrin polymer, diethylenetriamine adduct	68610-56-0		Limit (g)	Limit (g)	Yes	Limit (g)	Yes	Limit (g)	Limit (g)
Bisphenol A - epichlorohydrin condensate	25068-38-6		Limit (g)	Limit (g)	Yes	Limit (g)	Yes	Limit (g)	Limit (g)
Adhesives (surfactant)									
4-Nonylphenol (branched)	84852-15-3	10%	Limit (g)	Yes	Yes	10 ppm	Limit (g)	Limit (g)	Limit (g)

Notes:

- The Green Label Plus program tests for formaldehyde.
- Oeko Tex Standard 100 prohibits any detectable formaldehyde.
- Dibutyltin monomer is prohibited by Oeko Tex Standard 100.
- The Green Label Plus program uses the California 01350 indoor air quality testing protocol, which does not test for phthalates. The GreenGuard Gold protocol, which the carpet industry does not use, tests for these individual phthalates.
- Limits antimony to 30 ppm.
- Percentages of isocyanates listed as material content in manufacturer disclosures typically represent the proportion of isocyanates prior to their reaction with polyols in the manufacture of backing. Manufacturers generally do not report the amount of residual isocyanates in polyurethane backing.
- This substance is not on the banned list but would be automatically subject to the 100 ppm restriction and/or exposure assessments as a carcinogen, mutagen, reproductive toxicant and/or organohalogen.

APPENDIX 3. OPTIMIZING RECYCLING SERIES - OVERALL RATINGS

As of this report, the [Optimizing Recycling](#) series has evaluated six feedstocks against a framework that considers Feedstock Health and Environmental Hazards, Supply Chain Control and Transparency, Green Jobs & Other Local Impacts, and, Room to Grow. Here are how the feedstocks compare to date.

Recycled Material (Feedstock)	Feedstock Health and Environmental Hazards	Supply Chain Control and Transparency	Green Jobs & Other Local Impacts	Room to Grow
Glass Cullet (in California)	GREEN	YELLOW	GREEN	GREEN
Polyethylene	GREEN	GREEN	YELLOW	YELLOW
Carpet	RED	YELLOW	YELLOW	GREEN
Reclaimed Asphalt Pavement	RED	RED	YELLOW	GREEN
Flexible Polyurethane Foam	RED	RED	YELLOW	YELLOW
Polyvinyl Chloride	RED	RED	RED	YELLOW

GREEN = VERY GOOD
 YELLOW = ROOM FOR IMPROVEMENT
 RED = SIGNIFICANT CONCERNS

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Individual records:

Healthier Choice Flooring (Dalton)

https://oaspub.epa.gov/enviro/tris_control_v2.tris_print?tris_id=30720CSTMC401JO&pPrev=1

Milliken (Lagrange)

https://oaspub.epa.gov/enviro/tris_control_v2.tris_print?tris_id=30240LVKCR300IN&pPrev=1

Mohawk (Calhoun)

https://oaspub.epa.gov/enviro/tris_control_v2.tris_print?tris_id=3070WMHWKN296SU&pPrev=1

Shaw (Dalton, Plant 1 / 3)

https://oaspub.epa.gov/enviro/tris_control_v2.tris_print?tris_id=30720SHWNDEASTF&pPrev=1

Tarkett (Calhoun)

https://oaspub.epa.gov/enviro/tris_control_v2.tris_print?tris_id=30701SPRNGNINDU&pPrev=1

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 - Nipple retention
 - Decreased testis weight
 - Reduced anogenital distance
 - Cryptorchidism
 - Reduced accessory sex organ weights
 - Lesion of the rete testis Hemorrhagic testis
 - Cleft phallus and hypospadias
 - Multinucleated gonocytes
 - Agenesis of the seminal vesicles and coagulating glands
 - Agenesis of bulbourethral glands
 - Agenesis of ventral prostate
 - Agenesis of gubernacular cords
 - Agenesis of epididymis and vas deferens
 - Histopathological changes of testis
 - Delayed preputial separation
 - Reduced fertility
 - Reduced fecundity
 - Reduced cauda epididymal sperm numbers
 - Reduced daily sperm production
 - Reduced plasma and/or testicular testosterone levels
 - Increased serum testosterone levels
 - And, Reduced serum inhibin B levels

And in females:

 - Uterine abnormalities and, Reduced fertility. (Bergman, Åke, Jerrold J. Heindel, Susan Jobling, Karen A. Kidd, and R. Thomas Zoeller. "State of the Science of Endocrine Disrupting Chemicals - 2012." World Health Organization and United Nations Environment Programme, 2013. <http://www.unep.org/chemicalsandwaste/UNEPsWork/StateoftheScience/tabid/105913/Default.aspx>.)

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 199. Declare is a building product label that encourages transparency of product contents and supports the LBC by identifying products that meet LBC requirements. The LBC program includes Perfluorinated Compounds in its Red List of banned substances. Some challenges keep this program from being a reliable indicator of key chemical hazard avoidance in carpets:
 - 1) ILFI’s Declare label has exemptions that allow a manufacturer to withhold from disclosure one ingredient or up to 1% of multiple “proprietary” contents by weight. Thus carpets with stain repellants can qualify as “Declared,” even if these treatments are not disclosed.
 - 2) While the LBC Red List includes the class of “Perfluorinated Compounds” in its Red List of banned substances, the program requirements only specify select compounds, not the entire class. As a result, some carpets that contain perfluorocarbons are labeled as “Red List Free” because of the limits of the LBC list.
 - 3) Some other classes of toxicants identified in this report that are known to be used in carpets are not included in the LBC Red List at this time, most notably isocyanates. See for example, <https://access.living-future.org/nexstep%C2%AE-cushion-tile>.
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Eliminating Toxics in Carpet: Lessons for the Future of Recycling

Healthy Building Network Mission

To advance human and environmental health by improving hazardous chemical transparency and inspiring product innovation.

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