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Celebrating Our 25th Year

A Guide to Selecting Sustainable Textiles

Textiles' good looks hide an ugly environmental legacy, but there are five straightforward ways to make responsible design choices.

By Brent Ehrlich

Textiles can make a space what it is. Through a carefully chosen combination of texture, color, and pattern, they create a feel of opulence, coziness, or no-nonsense practicality. They can encourage a spirit of play and creativity or one of contemplative silence. Found as woven or non-woven fabrics, contract textiles can also improve acoustics, privacy, and daylighting.

We all want the best of both worlds—both beauty and sustainability. But we have to face the reality that the global textile industry has one of the worst environmental and social-equity records of any industrial product. Selecting the most sustainable options should be a priority; yet they are often chosen for visual features alone, even by the most sustainability-driven project teams.

Finding healthier, lower-impact alternatives that meet aesthetic needs and budget constraints is difficult, but it can be done. In our guidance on textiles, you will learn rules of thumb to manage the complexity of selecting fabrics, which can include:

- the materials and chemicals that go into fiber production and finished fabrics
- water pollution and other life-cycle concerns
- the problematic chemistry of surface treatments
- performance standards and certifications used in the industry

In this article, we'll take a look at textile types, including some of the most sustainable options available, where they are used, and why they may or may not work for your project.

What Is a Textile?

Textiles can be made from natural materials like wool, cotton, linen (flax), hemp, and silk or from synthetic materials, such as petroleum-based polyester (PET), nylon, polyethylene, and vinyl.

The process of turning these raw materials into textiles is complex and varies from material to material, but woven fabrics all share some basic steps. According to *Textiles: A Handbook for Designers*, fibers go through the spinning process, where they are turned into yarn, which is then sent to a mill and turned into woven or knitted fabrics. The fabrics are then finished and sold.

Non-woven fabrics, such as vinyl or polyurethane, are made using melted plastic or films.

Choosing a Textile: Natural vs. Synthetic

There are a lot of good-looking contract textiles available and almost as many applications for them. Both natural and synthetic materials have their environmental pluses and minuses, so you have to choose wisely to get the most-sustainable options for your end use.



Photo: Carnegie Fabrics

This solution-dyed woven upholstery is bleach cleanable, does not require any surface coatings, and is available with a waterproof backing, making it a suitable replacement for PVC in high-performance applications.

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Photo: Maharam

Climatex Lifecycle fabrics are 91% wool and 9% ramie and are certified Cradle to Cradle Gold.

Although organic natural fabrics that use best industry practices for raw materials and processing can be a good choice for the environment, they are not common in contract work, where synthetic textiles are far more popular. "Most [designers] in the U.S. won't go the natural fiber route," according to Patty Grossman, cofounder of Two Sisters Ecotextiles, a 2008 BuildingGreen Top 10 product winner. Her company promotes certified organic, natural textiles that have been responsibly processed, but she says the contract market has not fully embraced truly sustainable fabrics—though, she concedes, "Synthetics are a lot less expensive, and they tend to be bombproof."

As a result of this indifference, Grossman's company has changed its focus from contract to residential products, though it still does some contract work.

But synthetic materials can make a legitimate sustainability claim when used in the right application; they are typically very durable, can resist staining without added fluoropolymers or antimicrobial coatings, and are available with high recycled content.

Matching textile and use

Using the right material for the right application is key to choosing a sustainable textile: no option is "green" if it has to be sent to a landfill after a year of use because it couldn't stand up to wear and tear.

For upholstery, an organic wool fabric might be the best environmental choice *and* be durable enough for a chair in a low-traffic, high-end office, but it probably wouldn't hold up in a hospital waiting room or a restaurant, where spills, wear, and cleaning would stain and damage the fabric (see Four Credible Certifications That Can Aid Contract Textile Selection for more on durability and other performance criteria).

For these applications, "high-performance" fabrics are used. "Healthcare is a very challenging environment for fabrics," says Jean Hansen, FIIDA, sustainable interiors manager at HDR Architecture. "You've got a lot of potential for soiling," she says, so designers have to carefully weigh functional performance against sourcing concerns. Vinyl is still popular in these applications, but non-woven polyurethane and woven synthetics with waterproof backings are sometimes substituted (see Textile Choices: Cleaner Options for Every Application).

Draperies and panel fabrics, on the other hand, have to meet specific fire codes, be resistant to UV light, and meet other desired performance requirements, such as light transmittance. Flame resistance is complex and a key driver in selecting the right drapery material and some panel coverings. Although natural fibers such as wool are inherently flame resistant, the weave and weight of the material can also impact flammability, so local codes may still require the material to pass flame tests, effectively requiring flame retardants.

Synthetic fibers, such as polyester, do not catch on fire so much as melt, so they can meet stringent fire codes using an organophosphor flame retardant built into the fiber. While flame retardants are not ideal (see Finding Furniture Without Toxic Flame Retardants), using non-halogenated versions in applications where they cannot wash or leach out is preferable to added surface treatments, where occupants could be directly exposed to them (see more on fire codes in Three Hazardous Textile Treatments and How to Avoid Them).

Design choices to enhance sustainability

There is more to the story of sustainable fabrics and application. Hansen tries to stay away from solid colors in woven fabrics because they don't hide soil well. "We are seeing more and more clients trying to use a non-woven for the seat and a woven for the back (which could be a more sustainable fabric)," she said. "That allows more interest and variety on the back, but the seat can be something that can more easily be wiped down."

For Michael Tam, interior designer at Perkins+Will, selecting a sustainable textile "is a balance between bringing in light, color, and design and something that will hold up." Selecting upholstery fabrics for the

Summit Foundation headquarters in Washington, D.C., which is pursuing the Living Building Challenge Materials Petal, was straightforward, according to Tam. The LBC Red List is similar to Perkins+Will's Precautionary List in that they both prohibit halogenated flame retardants and perfluorochemicals (PFCs), he said, and by comparing textile labels, he was able to select wool and polyesters that met durability and material requirements and did not have chemicals of concern.

Chemicals on fabric are a small, albeit important, part of its sustainability picture, but some coatings and additives have questionable benefits and potentially serious consequences to human health. (More on this in Three Hazardous Textile Treatments and How to Avoid Them.)

5 Rules of Thumb for Choosing Sustainable Textiles

Textile products can't be selected based entirely on the fiber used. With natural materials, there are significant life-cycle differences between standard fibers and organic fibers processed with environmentally responsible chemicals and practices. Virgin synthetic materials have much higher embodied energy than recycled plastics. Recycled polyester, for instance, requires 70% less energy to produce than virgin fiber, according to the Natural Resources Defense Council.

In some cases, natural fibers (namely cotton) can be worse for the environment than synthetics, with significant water pollution from processing and dyeing (see Textile Choices: Cleaner Options for Every Application).

To improve the sustainability of contract textiles:

1. **Avoid PVC.** Vinyl can pose environmental problems throughout its life cycle. Non-woven polyurethanes, polyethylene, and other synthetic materials with moisture-resistant backings can replace PVC materials, and design choices can reduce the need for it when clients are intent on using it.

2. **For natural fibers, choose organic.** Natural fabrics, such as wool or hemp, are good choices where budget and performance needs can be met, but we recommend going a step further and choosing those certified Cradle to Cradle Gold or to the Global Organic Textile Standard (GOTS), when possible. Fabrics made with conventionally produced natural fibers can still contain chemicals of concern or be made into fabric in ways that compromise their environmental performance, but C2C and GOTS-certified textiles look for best practices throughout the entire fabric life cycle. Unfortunately, there is not much organic cotton available, and we caution against using it in contract applications because it consumes a lot of water during production, absorbs moisture, and lacks durability.

3. **For synthetic textiles, choose recycled content.** Some biobased plastics, such as biobased Xorel (which is used in place of PVC), can be a reasonable option. Otherwise, using solution-dyed, recycled-content polyethylene is the best option. Recycled bottles (polyester) or carpet (nylon) undergo a complex process that transforms post-consumer waste into fiber that is basically indistinguishable from virgin materials. The chemistry required to complete this transformation is not benign (more on this in the companion articles), but the use of post-consumer plastic keeps bottles and carpet waste out of landfills and the environment, and recycling reduces energy and fossil fuel consumption.

4. **Consider recyclability.** Though there is limited recycling of textiles, selecting textiles that don't blend natural and synthetic fibers (e.g., wool and polyester) and those that don't use one fiber and a disparate backing (such as wool with an acrylic backing) will help the recyclability of these materials at the end of their lifespans (see sidebar in Textile Choices: Cleaner Options for Every Application).

5. **Avoid surface treatments.** When antimicrobials, fluorocarbon stain repellants, and flame retardants are added as surface treatments to fabrics, the chance of human exposure to these hazards increases. Surface treatments also have a higher risk of finding their way into the environment. Fluorocarbons and antimicrobials can be avoided through material choices and maintenance protocols. Wool or recycled synthetic fabrics with phosphates built into the fiber can meet most fire codes.



Four Credible Certifications to Aid Contract Textile Selection

Textile standards and certifications look at fiber production, life cycle, chemistry, and more, but in the U.S. they are just gaining traction.

By Brent Ehrlich

With all the different fibers, chemicals, dyes, and coatings used for textiles coming from all over the world, assessing the sustainability of a textile is nearly impossible for most designers.

Many turn to certifications to simplify the decision process, but which ones should you trust? There are standards that look at functional performance, indoor air quality, organic fibers, fabric production, life cycle, and chemistry (see table).

The Association for Contract Textiles Voluntary Performance Guidelines are a good place to start when looking for performance metrics, but for gauging environmental performance, the Global Organic Textile Standard, Cradle to Cradle, the Facts label, and Oeko-Tex 100 are the most credible labels.

They all have slightly different niches in the market, and some are stricter



Photo: Designtex

Designtex Loop to Loop is made with 99% recycled content (87% post-consumer) and is certified Gold under the Facts label, which is based on NSF/ANSI 336-2011.

than others, but all can be valuable for helping select a textile with lower environmental impacts.

Tracking Functional Performance

Choosing the right textile for a job is critical for maximizing its lifespan and thus shrinking its overall environmental footprint, but it hasn't always been easy for designers to get information on a textile's performance.

The Association for Contract Textiles stepped in and developed its ACT Performance Guidelines, which provide voluntary performance metrics—for colorfastness, flammability, physical properties such as pilling and tear resistance, wet and dry crocking (transfer of dyes from a fabric to a surface), and abrasion—for a number of fabrics and applications. It also developed symbols for each that give designers a visual reference so they can quickly match a fabric to an end use.

Though these guidelines aren't associated with an overall third-party certification, each performance metric is associated with an ASTM test that is performed by an independent lab. There can be controversy, however: the abrasion metric in particular is a source of contention among those concerned with sustainability. There are two standards used for abrasion:

- The Wyzenbeek test (ASTM D4157), whose test mechanism uses a back-and-forth motion—called the "double rub"—and is relevant to high-performance applications
- The Martindale test (ASTM D4966), which uses a figure-eight motion and is relevant to lighter-use applications

For high-traffic applications, 40,000 double rubs is the standard. But designers often want the most durable material available, specifying products that meet 100,000 or even 200,000 double rubs. That level of performance may be overkill for the job, though, and it can prejudice fabric selection against natural materials because synthetic fabrics more easily exceed the ASTM standard. ACT even states, "Double rubs exceeding 100,000 are not meaningful in providing additional value in use and not predictive of significant extension of a fabric's service life."

"Double rubs is a huge controversy," said Jean Hansen, FIIDA, sustainable interiors manager at HDR Architecture. "Manufacturers have clients who expect 100,000 double rubs, but it is not the be-all and end-all of how a fabric is going to look in the long run." She claims that a fabric can "ugly out pretty fast even if it had high double rubs"—namely, pilling or having its surface texture or look change.

For Patty Grossman, founder of Two Sisters Ecotextiles, a company that specializes in high-end natural textiles, inflated performance requirements and high cost drove her company from contract work and into the residential market. "We tried to go contract," she said, but "design firms told us to come back when we had 100,000 Wyzenbeeks. It was just too expensive for us."

Environmental Certifications: Are They Strict Enough?

Textile certifications range from those that look primarily at VOC emissions, such as Greenguard, to those that look at the entire life cycle of the fabric, such as the Global Organic Textile Standard.

Though meeting emissions criteria is important since fabrics can be made with a number of volatile chemicals, most fabrics certified to the multi-attribute standards below must undergo testing for formaldehyde and other VOCs.

Global Organic Textile Standard

The Global Organic Textile Standard (GOTS) is the strictest certification for fabrics. It applies to natural, organic textiles—not just the fibers. Some synthetic fibers can be used, but to be considered grade 1 (organic) requires greater than 95% organic fibers; and for grade 2 (made with organic), the requirement is 70%.

GOTS requires that production be monitored throughout the textile's life cycle, and it prohibits toxic heavy metals, formaldehyde, aromatic solvents, functional nanoparticles, genetically modified organisms (GMO), chlorine bleach, and azo

ACT Performance Guidelines



Image: Association for Contract Textiles

The ACT Performance Guidelines provide at-a-glance information on textile properties like flammability, colorfastness, and abrasion resistance.

dyes that release carcinogenic amine compounds. It also has requirements on worker rights.

GOTS is a rigorous standard that results in only the highest environmental performers being certified. Two Sisters Ecotextiles is the only company offering GOTS-certified products in the U.S., according to the GOTS website (this company now sells primarily to the residential market).

Cradle to Cradle

Cradle to Cradle is a third-party, multi-attribute standard that reviews a product's entire life cycle based on material health, material reutilization, renewable energy use, water stewardship, and social responsibility. Products are then rated Basic, Bronze, Silver, Gold, or Platinum.

The water-quality requirements and an extensive list of banned chemicals—which includes halogenated flame retardants and other persistent chemicals (see Cradle to Cradle Gains Independence: A First Look at the 3.0 Launch)—make the C2C standard particularly appropriate to textiles. So far, nine textile companies have certified products, with only one reaching the Gold level, the Swiss company Rohner Textil AG. Rohner makes Climatex Lifecyle (made from wool and ramie) and Lifeguard FR products (made from wool and regenerated cellulose derived from beech wood).

Third-Party Textile Certifications

STANDARD	WHAT IT COVERS
Global Organic Textile Standard (GOTS)	Through the life cycle of natural-fiber textiles: • organic textile compliance • water consumption and pollution • chemicals of concern • social equity • packaging and shipping
Cradle to Cradle	Through the life cycle of textiles: • material health • material reutilization • renewable energy and carbon management • water stewardship • social fairness
Facts/NSF/ANSI 336-2011	During textile production: • fiber sourcing • material safety • water conservation and pollution • energy consumption • air quality • recycling practices • social accountability
bluesign	During textile production: • water consumption and pollution • energy consumption • responsible sourcing • chemicals of concern • occupational safety
EU Ecolabel	During & after textile production: • use of chemicals of concern • air and water pollution • toxic residues in fibers • performance and durability

Oeko-Tex 100 and STeP

Oeko-Tex 100 tests for harmful chemicals on the finished textile and categorizes the product from Class I (Products for Babies) to Class IV (Decoration Materials) based on the amount of chemical residue in the final product.

Though it does not address all life-cycle concerns—such as social equity, water consumption, or many of the other problems found in the industry—Oeko-Tex uses independent labs to test chemicals in materials at rigorous levels, and the criteria are updated annually to comply with European regulations. A companion label (see below) fills in some of these gaps as well. According to the organization, among the chemicals it tests for are certain azo dyes, phthalates, heavy metals, pesticides, allergenic disperse dyestuffs, formaldehyde, plasticizers, pentachlorophenol, and organotin compounds.

For synthetic fabrics, Oeko-Tex 100 is a good option, particularly if production facilities are certified to the organization's STeP standard, which covers environmental performance across six categories:

- management of chemicals
- environmental performance
- environmental management
- social responsibility
- quality management
- health and safety

Facts: NSF/ANSI 336 Sustainability Assessment for Commercial Furnishings Fabric

The Facts label is the third-party certification to NSF/ANSI 336-2011, a voluntary, multi-attribute fabric standard that addresses fiber sourcing, safety of materials, water conservation, water quality, energy, air quality, recycling practices, and social accountability. Each category has points available for meeting the criteria, up to a total of 100. Point

Third-Party Textile Certifications (continued)

STANDARD	WHAT IT COVERS
Oeko-Tex 100	In finished textiles: • illegal substances • carcinogens • legally regulated substances • harmful (but not legally regulated) chemicals • colorfastness • pH
Sustainable Textile Production (STeP)	During textile production: • chemicals and their use • environmental protection • environmental management • social responsibility • quality management • health and safety
Greenguard/ Greenguard Gold	VOC emissions of final textile
SCS Indoor Advantage Gold	VOC emissions of final textile
CDPH Standard Method V1.1/ CA Section 01350	VOC emissions of final textile
ACT Voluntary Performance Guidelines	Functional performance of final textile

Source: BuildingGreen, Inc.

totals earn Compliant, Silver, Gold, or Platinum certification.

For chemicals, there are also prerequisite limits for metals in dyes and pigments in the fabric; the product is tested to 1,000 parts per million (ppm) for these and other toxic substances, including probable carcinogens, reproductive toxicants, mammalian acute toxicants, alkylphenol ethoxylates, and persistent, bioaccumulative, toxic chemicals (PBTs).

Optional credits offer points for testing for those and additional chemicals, such as aquatic toxicants and endocrine disruptors, to 100 ppm (0.01%). "The section on safety of materials is one of the more stringent in the Facts standard," said Tavio Benetti, manager for the Facts program at SCS Global Services. "There is a list of different metals, and limits for those levels in dyes and pigments," he said. The list references one established by Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers (ETAD), so the criteria change as the list is updated.

According to Nicole Munoz, SCS's operations manager, "What is unique about Facts is it looks at the entire supply chain." That can be a big undertaking because there can be a lot of different processes and companies involved, including those that spin, dye, finish, and more. "You get a full LCA picture whether you own those operations or not."

The standard does not actually provide the full picture, however, because it leaves out sourcing of raw materials. According to Deidre Hoguet, who helped work on the standard and is director of sustainability and material exploration at Designtex, "It is looking at ingredients from fiber forward. It is not going back to farm practices or raw material extraction." And those early impacts can differ greatly from raw material to raw material—think wool versus petrochemicals.

Grossman is skeptical of the standard. In a response to BuildingGreen's 2011 article NSF 336 Sustainable Fabric Standard Now Final, she said, "The new NSF standard is anemic when compared to existing standards, such as Oeko Tex and GOTS, which are both stunningly more strict." Grossman is frustrated that the chemical restrictions are not tighter, and by the pace of change in cleaning up the textile industry in general. "There are existing certifications which would represent giant strides," she says. "What American companies and specifiers do is take tiny baby steps and praise their efforts for doing so."

Hoguet disagrees, saying, "The prerequisites are pretty rigorous." And getting certified to the Gold or Platinum level is difficult, she contends. "There was a little concern that we made it too hard." The challenges manufacturers faced tracking their material supply chain contributed to Facts getting off to a slow start. Though development of the standard—by the Association for Contract Textiles, GreenBlue, NSF International, and other industry groups—began in 2006, the standard was not published until 2011, and there was little initial buy-in from the design community. But Hoguet sees momentum for the standard growing. Though designers are just becoming aware of it, she said, "All the mills we work with have been using it."

As with all multi-attribute standards, there is the concern that manufacturers could game the system by focusing on one area, such as air quality, at the expense of another, such as safety of materials. Hoguet and others defend the rigor of NSF/ANSI 336, stating that the prerequisites alone are difficult to meet. No products have been certified to the Platinum level yet, so selecting those at the Gold level is a good option. Facts might not meet the sustainability level of GOTS organic grade, but wider adoption of Facts is showing that the textile industry is starting to take sustainability more seriously.



Three Hazardous Textile Treatments and How to Avoid Them

You can avoid the most toxic textile treatments with proper fabric selection and maintenance.

By Brent Ehrlich

A textile is only sustainable if it lasts, and designers looking to prolong the life of their furniture or drapery—whether to save the environment or simply to prevent callbacks—typically turn to surface treatments. This alchemy of chemical coatings promises to repel stains, stop fire, and prevent the spread of disease. It sounds too good to be true. It usually is.

Perfluorinated compounds (PFCs), antimicrobials, and halogenated flame retardants have been sold to the design community, sometimes under false pretenses and with aggressive marketing, for years. With limited information on the health and environmental impacts of these compounds, designers have been talked into coating our couches and chairs in toxic chemicals. In most cases, though, these chemicals can be avoided if you choose the right textile for the job.



Photo: Carnegie Fabrics

Art Form acoustical panels use Xorel textiles that do not require added flame retardants, antimicrobials, or PFCs.

Perfluorinated Compounds

PFCs are the active ingredients in most stain-repellant textile treatments. Liquids and oils bead up on these treated textiles so they can be wiped away instead of soaking through the fibers (see The High Price of Stain Resistance: Environmental Persistence). The added stain resistance keeps upholstery looking good, extending its lifespan and reducing the amount of cleaning chemicals required—legitimate environmental features.

But the use of PFCs is contentious. Long-chain PFCs (those with eight or more carbon-fluorine bonds), such as the PFOA and PFOS used in earlier formulations of Scotchgard, are persistent, bioaccumulative toxic chemicals (PBTs). The short-chain varieties (with six or fewer carbon-fluorine bonds) used in newer formulations of Scotchgard and by Crypton, GreenShield, NanoSphere, Nanotex, and others are considered less bioaccumuative and less toxic, but they are extremely persistent in the environment, and there is growing evidence that these compounds are not benign. Short-chain PFCs have been linked to endocrine disruption and nervous system damage. In 2015, more than 200 scientists signed the Madrid Statement asking that PFCs be banned for all non-essential uses.

To lower the quantity of PFCs used in these treatments, Nanotex, NanoSphere, and GreenShield combine nanotechnology and PFCs to create small surface variations that help improve performance. The companies claim the technologies are bound to the fabric, making them safe, and NanoSphere was even developed using the European "bluesign" textile standard. But many designers, organizations, and certifications are taking a precautionary approach. PFCs were recently added to the Living Building Challenge Red List, meaning that no interior finishes with PFCs can be used in these projects. Kaiser Permanente also currently bans them for its projects.

Answering public demand, Crypton is now offering an alternative, PFC-free stain repellent, C Zero; it only works on water-based stains, though, so it will be less effective for those that are oil-based.

Antimicrobials

Antimicrobials are commonly found on healthcare fabrics, yet this choice is puzzling. The Centers for Disease Control (CDC) report *Guidelines for Environmental Infection Control in Health-Care Facilities* concludes that antimicrobial use in textiles does not help control disease or infection (see Antimicrobial Chemicals in Buildings: Hygiene or Harm?). This does not stop companies from offering them, though. Silver-ion compounds are used in Crypton and other textile treatments, and silane-based antimicrobials, such as Bio-Am, are used in Nanotex fabric treatments.

The performance benefits of antimicrobials have been exaggerated to the point that the National Advertising Division of the Better Business Bureau advised Nanotex to stop making false claims about their effectiveness. The CDC recommends proper cleaning and sanitizing procedures instead. Though excess humidity and dirt can be a recipe for mold and mildew, proper cleaning and moisture control in buildings should keep them in check.

With their apparent lack of effectiveness combined with concerns over antibiotic resistance, bioaccumulation, and other health and environmental impacts, many sustainability-focused design professionals and organizations no longer use antimicrobials, including Kaiser Permanente. "Designers have been sold a bill of goods," said Jean Hansen, FIIDA, sustainable interiors manager at HDR Architecture. "I avoid antimicrobials if possible, and if I had a choice of two fabrics that met all the criteria, I would choose the one without it."

Flame Retardants

Due to 2015 changes in California fire codes, which are followed by most furniture manufacturers, most upholstery no longer requires flame retardants (for an in-depth discussion of California fire standard CA TB117-2013, see Finding Furniture Without Toxic Flame Retardants). Some natural textiles, such as wool, are naturally fire resistant, and most others can pass the required tests by using an underlayment, said Hansen.

For cities with tougher fire codes that have to follow TB133 (a test that requires burning an entire piece of furniture), a textile choice is much harder. "Not only do you have to see if the material will upholster well, but what will happen when you add a fire barrier cloth underneath," she said. Plus "it has to look good in the long run." A piece of furniture can be made without the flame retardants, but the added cost and delays of testing for TB133 often result in design teams defaulting to flame-retardant furniture that has already passed the test.

Drapery fabrics are more complicated. Not every flame retardant works for every material, and codes can be onerous. Most states require testing to the National Fire Protection Association's NFPA 701 standards, but some cities, such as Boston and New York (and even individual theaters), have their own codes. NFPA 701 uses an open flame test, so flame retardants will be necessary for most fabrics, and flame-retardant treatments have to last, since cleaning can remove them. Because of this, fabrics are rated as inherently flame retardant, durable flame retardant, semi-durable flame retardant, and non-durable flame retardant, based on how many washings will remove the treatments. Use an inherently flame-retardant fabric when possible.

Halogenated flame retardants, which are PBTs, are being phased out of textile production, often replaced by less-persistent organophosphors. These have their own health concerns, though, having been linked to endocrine disruption and neural toxicity. Organophosphors can be incorporated into polyesters, however, in such as way that they become part of the fiber and do not leach out. Though it's not an ideal solution, fabrics with this type of treatment can meet Oeko-Tex 100 textile standards for environmental performance.

Maintenance Is Key

Ultimately, the longevity of upholstery is in the hands of the maintenance staff entrusted to clean it, and that is a source of anxiety for many designers.

In the quest to minimize their concerns and provide a maintenance-free textile, designers often choose antimicrobials and PFCs, along with waterproof backings. The resulting textile may perform well, but it is a jumble of environmentally troubling chemicals. "Everyone in the U.S. wants their fabric to be absolutely bombproof, whether they need it or not," said Patty Grossman, cofounder of Two Sisters Ecotextiles. "And we are killing the environment."

Avoiding these treatments is not easy for designers, however, and the choices are complex. Selecting an organic natural material is not ideal if it does not last or if it requires a slurry of chemical coatings to meet performance needs. And clients often ask for the treatments, so designers and manufacturers have to play the role of educator.

Deidre Hoguet, director of sustainability and material exploration at Designtex, says her company does not automatically add PFCs to particular fabric types, though they are available as an option. Instead, she promotes proper textile selection for its intended use, stressing the importance of maintenance. In applications where stains are possible and harsh cleaners are required, "one of the best options is solution-dyed nylon or polyester," she says. In some cases, natural textiles, such as wool, can be used. "You can get them without finishes, but you do have to follow a maintenance protocol."

But sticking to it is not easy. Manufacturers may explain cleaning protocols to the designer, who then has to tell the client, who has to communicate it to the maintenance staff. If there are different fabrics—some solution-dyed and some with PFCs—in the same facility, they may require different cleaners. Hansen says, "The cleaning people are not

going to know which are which." Improper cleaning, or none at all, can reduce a textile's lifespan and can remove flame retardants from drapery, posing a fire risk (not to mention a potential code violation).

How to Design Out Surface Treatments

In the end, it's possible to minimize the amount of training required for maintenance staff while still avoiding textile coatings.

- Where staining is most likely, use solution-dyed synthetic materials with recycled content.
- If spills are a concern, use a non-woven polyurethane or other PVC-free material in place of woven textiles (most wovens require PFCs in these applications). Recycled synthetic materials with a water-proof backing can also work.
- Avoid antimicrobials and flame-retardant treatments. If clients or code officials insist on their use, select textiles that have these built into the fibers.
- If clients are intent on an added dirt or stain repellant, select one engineered to use the lowest possible concentration of PFCs for the textile and end use.
- Simplify textile choices across a project to minimize confusion about cleaning chemicals and protocols. Communicate proper cleaning procedures directly to the building owner or facilities crew, and encourage continuing education to maintain procedures over the life of the materials.

Textile Choices: Cleaner Options for Every Application

Standard textile ingredients can have a toxic, devastating impact on our environment. Here are tips so your project can do better.

By Brent Ehrlich

The global textile industry has a poor environmental record.

- It takes 200 tons of water to produce 1 ton of textiles, according to the Natural Resources Defense Council (NRDC).
- Textile dyeing and finishing are responsible for 17% to 20% of the world's industrial water pollution, the World Health Organization estimates.
- Synthetic fiber production can use vast amounts of energy. For example, it takes almost 16 kWh of energy per pound (125 MJ/kg) to make virgin polyester, according to NRDC.

Though this data comes primarily from the apparel industry, and U.S. contract textile manufacturers have cleaner production methods (see next month's product review for exemplary products), many of the raw material concerns are similar. For each of the most significant life-cycle impacts of textile manufacturing, we've developed guidance on environmentally responsible material choices that can meet most designers' needs.

Synthetic Fibers: Textiles from Fossil Fuels

Synthetic fibers make up more than 60% of global textile production, according to the Food and Agriculture Organization of the U.N. The most common synthetic contract textiles are made from polyester (polyethylene terephthalate, or PET), nylon, acrylics (used mainly in textile backings and outdoor furniture), polyurethanes, and PVC. These plastics are durable, resist stains and liquids, are not a food source for insects, and are easy to clean. PET and nylon can also be made from recycled content (see below).

PET and nylon are the two most common synthetics fibers used in contract textiles. Nylon is more durable and dirt resistant than PET, but PET is less expensive, and recycled-content products are more readily available.



Photo: China Daily/Reuters

Dyes and other chemicals from textile production in the developing world, such as China's Zhejiang province (shown here), pollute local water waterways and are a serious environmental problem.

Environmental Comparison of Fiber Types

After extensive research into the textile industry, the Natural Resources Defense Council launched its Clean by Design program in 2009. It laid out the best practices for the textile industry and then began applying them to textile factories in China. NRDC's initiatives are being used to clean up textile production in facilities in Bangladesh and China. Though the initiative is primarily focused on the apparel industry, the raw materials and processing are the same as those for contract textiles. The following table summarizes some of NRDC's findings and recommendations.

	Polyester	Recycled Polyester	Nylon	Tencel (Lyocell)	Wool	Cotton
Land-Use Impact	Broad impacts of global petrochemical industry	–	Broad impacts of global petrochemical industry None for recycled content	FSC-certified wood; higher yield than cotton	Free-range sheep graze on marginal land; few impacts	Uses prime, arable land. Non-organic crops cause pollution from fertilizer and pesticides.
Use of Nonrenewable Resources	Petroleum	Bottles made from petroleum	Petroleum	Significant chemical use in wood pulp manufacture; solvents recaptured	Very little used; some pesticides	Fertilizer and pesticides used in non-organic cotton
Water to Produce and Spin Fiber	Very low			Significant water used in wood-pulp production	Very low, but wastewater can pollute waterways if not properly treated	Very high
Energy to Produce and Spin Fiber	Very high			Less than standard rayon	Very low	Low
Dyeing and Finishing Impacts	High-temperature dyeing process, but shorter process with less chemical use than cotton			Significant use of water, energy, and chemicals; less than cotton	Intensive scouring process to remove lanolin; chemical-intensive process to achieve washability	Very high use of water, energy, and chemicals
Other	–	Two methods of recycling, one with lower impact but inferior fibers		Much less pollution than from standard rayon/viscose factories	Recycled wool of only slightly lower quality than virgin wool is available.	High pollution loading from dyeing; untreated effluent causes major damage.

Sources: Natural Resources Defense Council and BuildingGreen, Inc.

Though made from petrochemicals, these fibers typically have low VOC emissions in their final form; because of this, their longevity, and the availability of recycled content, they are often considered a relatively sustainable material.

Synthetic textiles: What to look for

Look for synthetic textiles that are vetted through Oeko-Tex 100 or have achieved a minimum of Gold certification through Cradle to Cradle or the NSF/ANSI 336 Facts program. These may include antimony-free polyesters and lower-impact polyethylenes.

They are far from environmentally preferred materials, however. Standard virgin PET manufacturing uses xylene (a reproductive toxicant) and ethylene glycol (a carcinogen and developmental toxicant), with antimony (a heavy metal and developmental toxicant) as a catalyst.

Nylon is used in two forms—nylon 6 and nylon 6,6. Both require several toxic intermediaries, including hydroxylamine (a carcinogen), cyclohexane (a persistent, bio-accumulative toxic chemical, or PBT), 1,6-hexanediamine (a PBT and developmental and aquatic toxicant), and others.

Recycling these materials requires far fewer toxicants during production and generates less waste, but nylon 6 has a slight environmental advantage because it can be recycled into fiber that's identical to virgin material.

Using recycled PET or PET that does not use antimony trioxide (currently there is no antimony-free recycled content) is usually environmentally preferable to using nylon because PET is less energy-intensive to produce.

Other plastics

Acrylics are far from ideal with respect to health and sustainability. They are

Recycling PET and Nylon

Recycling nylon and PET (polyester) has many advantages. The process:

- keeps materials out of landfills and incinerators
- reduces the use of petrochemicals
- takes less energy than producing virgin materials—about 70% less energy for PET (according to NRDC), and about 30% less energy for nylon 6 (according to the Shaw-sponsored LCA of the Evergreen nylon recycling facility)

Though it's generally a better option than virgin plastic, most post-consumer plastic used in fiber production is *downcycled*, meaning that recycling produces a lower-quality material that can't be reused in the same way. There are few routes for recycling textiles at the end of their lifespan.

One reason for this is that most textiles are blends of different fibers and often have backings that are made from different materials, which makes recycling almost impossible.

Nylon 6 is the exception: it's recyclable in a closed-loop chemical process that was commercialized in the carpet industry. During recycling, used nylon 6 carpet fibers are subjected to heat, where they "depolymerize," releasing caprolactum that is collected and turned back into fibers that are nearly equivalent in quality to the original material.

Nylon 6,6 is more difficult to recycle, and the process involves mechanically separating fibers from backing and then pelletizing the nylon. Though less energy- and chemical-intensive than chemical depolymerization, this process does not turn the nylon back into virgin-quality material.

Recycled PET (rPET) is a thermoplastic made primarily from post-consumer water bottles. The process is not always a green one, however, since the bottles are usually collected in a home country and then sent overseas for sorting, cleaning, and recycling. The water used to clean the bottles may go untreated before entering waterways in some regions, and labels and other waste are thrown out. Once sorted and cleaned, the bottles are melted, extruded, and processed into fibers and textiles, resulting in plastic that is good quality but not quite as good as virgin materials.

made primarily from acrylonitrile—a carcinogen, acute aquatic toxicant, and PBT—and they are generally not available with post-consumer recycled content. Acrylics can provide important performance properties, though. Solution-dyed versions of acrylics are UV-resistant, so they are found on awnings, some draperies, and outdoor furniture. And acrylic applied in liquid form is used as a backing material.

Polypropylene and polyethylene are considered two of the "cleaner" plastics, (see Scorecard Shows Some Plastics Are "Cleaner" Than Others) because they do not use any chemicals of high concern as primary chemicals.

Natural textiles: What to look for

Textiles labeled "organic" have organically produced fibers, but after these fibers leave the organic farm, there is no guarantee that they aren't infused with toxic chemicals—except through a certification that looks at the entire finished textile.

Select organic fabrics with third-party verification of chemical and environmental performance through the Global Organic Textile Standard (GOTS), which certifies the entire fabric, not just the fiber.

Products certified to Oeko-Tex 100 or NSF/ANSI 336 Facts Gold or Platinum standards are good alternatives.

For details on each of these certifications, see Four Credible Certifications That Can Aid Contract Textile Selection.

Though not as common as PET in contract textiles, polyethylene is used as a PVC replacement in wallcoverings and other applications. UV-resistant, bleach-cleanable, solution-dyed polypropylene is available.

PVC is a durable, versatile material that is popular in some high-performance applications for upholstery and wallcoverings because it is easy to clean and resists harsh chemicals like bleach. But toxicity concerns with its chlorine chemistry (vinyl chloride monomer is a carcinogen and PBT), phthalate plasticizers that leach out during use (many of which are reproductive toxicants and obesogens), and end of life (dioxins from chlorine) have landed PVC on many prohibited chemical lists (see The PVC Debate: A Fresh Look).

Polyurethane is often used in place of PVC. Though isocyanates used in polyurethane production are asthmagens, they are also low-emitting once cured. "We try to use alternatives to PVC," said Jean Hansen, FIIDA, sustainable interiors manager at HDR Architecture, and that can include polyurethane.

Greener Natural Fibers

Natural fibers have been used to make cloth for millennia. Though each textile—cotton, wool, hemp, and others—can have vastly different environmental impacts depending on how the raw materials are raised and processed, all offer an environmental advantage over synthetic fibers at the end of their lifespan: they break down in the environment over time. Most synthetics instead last for hundreds of years, breaking into smaller and smaller pieces that disrupt ecosystems.

Organic fibers and responsible processing dramatically improve the environmental performance of natural materials.

Wool

Wool is used in about 2% of overall global textile production, and it is the most common natural fiber used in contract textiles, with natural performance characteristics that make it a good choice for upholstery and draperies. Yarn made from wool fibers has natural elasticity that helps the fabric retain its shape and keeps the fibers from breaking, improving both looks and durability. Wool also offers some water resistance, yet it absorbs and holds onto dyes well with

Wool: What to look for

Organic wool fibers come from sheep raised without chemical pesticides or overgrazing. Finished wool textiles certified to the Global Organic Textile Standard use best practices regarding water use and disposal.

relatively few chemical additives. It is also naturally fire resistant.

Unfortunately, wool has its share of issues. Wool textiles:

- are susceptible to destruction by insects
- have to be cleaned carefully to avoid shrinkage
- can absorb stains and be damaged by some detergents and bleaches

Its production process also has some glaring environmental problems.

Wool production is very labor-, water-, and chemical-intensive, and its wastewater releases can lead to eutrophication of waterways. Most wool comes from sheep that are treated with pesticides to keep parasites in check. Once the sheep are shorn, the fleece has to be cleaned and scoured of dirt, oil, debris, and these pesticides.

Water and alkali detergents remove the lanolin from the wool, which is saved for other commercial uses, and the wastewater has to be treated and disposed of. According to data compiled by Two Sisters Ecotextiles, a typical scouring plant can use more than 130,000 gallons of water a day. The 930,000 tons of sludge produced by the industry annually contains insecticides and other chemicals, making disposal difficult.

Cotton

Cotton is the most common fiber source in the world, with more than 25 million tons of raw cotton produced each year. Commonly used for clothing, cotton is not as common in contract textiles because it absorbs liquids, but it can be mixed with other fibers and is often found on textile backings.

But conventionally grown cotton is not a sustainable fiber. It accounts for about 8% to 10% of global pesticide use and for 50% of pesticide use in developing countries, according to the World Wildlife Fund report *Cleaner Greener Cotton*.

Cotton: What to look for

Using organically grown cotton eliminates the use of the most toxic pesticides and herbicides while maintaining soil, water, and local ecosystems. GOTS certification ensures the finished textile is also produced in an environmentally sound manner.

It is also a thirsty crop, consuming up to 3,400 gallons of water to grow one pound of cotton, NRDC claims in its *Clean by Design* report. The impacts can be significantly greater in developing countries, where clean water is scarce and workers typically are not protected from chemical exposure.

Genetically modified "Bt cotton," engineered to produce an insecticide that kills bollworm and other insects, now dominates the cotton market. According to the International Cotton Advisory Committee, 66% of the cotton planted in 2012 worldwide was genetically modified. More than 90% of the cotton grown in the U.S. is genetically modified, according to the U.S. Department of Agriculture (USDA). The use of Bt cotton has been shown to increase yield and profits and reduce pesticide and fertilizer use. But in the last decade, insects have developed resistance to Bt crops.

Other natural fibers

Silk is a small part of the commercial textile market, but with a rich history dating back thousands of years, it deserves a mention. Made from the cocoons of domesticated silk worms, silk is labor- and resource-intensive.

Hemp and linen (from flax) are found primarily in mixed fibers in the contract textile market. Hemp used to be one of the most popular fibers in the world and typically does not require pesticides or herbicides. Though rapidly renewable, the fiber from these two plants is contained in the stem and has to be mechanically separated, a low-impact but expensive and time-consuming process.

Although hemp, flax, jute, ramie, and other organic fibers are low-impact crops, finished fabrics from these fibers could still be made with added toxic ingredients or unsustainable processes.

What about bamboo? Bamboo fibers can be used for textiles, but most "bamboo fabrics" are actually a type of regenerated cellulose (a.k.a. rayon).

Regenerated Cellulose: Modifying Natural Materials

Rayon, or *regenerated cellulose*, textiles have been made for more than 100 years and fall somewhere between natural and synthetic. They are soft fabrics and are typically made from wood cellulose using the viscose process: the cellulose is broken down and processed using sodium hydroxide and carbon disulfide (a developmental toxicant). The fiber is then solidified in a sulfuric acid bath and rinsed. Bamboo textiles are also typically made using this process.

An environmentally preferred regenerated cellulose fiber, Tencel, is made by the Austrian company Lenzing Fibers using Forest Stewardship Council-certified eucalyptus. Tencel is the only fiber that uses the "lycocell" rayon production process, which is preferable to standard rayon processing because it requires far-less-hazardous solvents and recovers almost all of them in a closed-loop process that recycles the water. Tencel is more absorbent than cotton, so its use would be limited in contract applications.

Rayons: What to look for

Choose Tencel fiber, which offers the best environmental performance among rayons.

After fiber production

Once fibers are made, they still have to be processed, dyed, and turned into textiles—all processes that have a host of other environmental problems (see sidebar, "Is Dyeing Killing Us?"). Thousands of chemicals are used in textile production, including pesticides, petroleum feedstocks, spinning oils for yarn production,

Is Dyeing Killing Us?

The dyeing process can happen at nearly any phase of textile production, from fiber to fabric, with the timing differing from fiber to fiber. There are three basic steps used for most fibers.

Preparation: Different fibers require different processing, but the preparation step typically cleans the fibers, improves dye penetration, and bleaches out impurities.

Dyeing: Different types of dyes work for different fibers, and a wide variety of chemicals are used to improve dye penetration, make the color more uniform, and improve colorfastness.

Finishing: Chemicals are often added to soften fabrics or make them resistant to stains, static, or fire.

Dyeing can be done in a variety of ways:

- a batch process, where the material sits in a bath of chemical dyes, often at high heat and pressure
- a continuous process, where rolls of fabric pass through a series of chemical solutions and dyes
- a combination of the two

According to the book *Eco-Friendly Dyeing and Finishing*, synthetic azo dyes make up around 60% to 70% of the dye industry. There are a wide variety of these compounds: some appear to be safe, but others, such as benzadine-based dyes, are carcinogens and mutagens that break down into forms that can cause genetic damage. These have been banned in the European Union.

The list of chemicals used in the dyeing process is too long to cover here, with more than 10,000 different dyes and pigments in use as well as halogenated compounds, salts, and surfactants. Up to 200,000 tons of dye from the textile industry end up in the effluent from the dyeing process, according to *Eco-Friendly Textile Dyeing and Finishing*. In many countries, there is poor or no wastewater management. Because these compounds are so stable, they tend to stick around, changing the chemical and biological oxygen demands (COD and BOD) of local watersheds.

New, waterless dyeing processes are becoming available in limited capacity and should be encouraged, since they will reduce chemical use as well as water and energy consumption.

When selecting textiles, chose only those that capture and reuse wastewater from the dyeing process, such as GOTS-certified products. Better yet, for synthetic textiles, use those that are *solution dyed*: this means the dyes are injected directly into the plastic. Solution dyeing uses little energy and almost no water, and the resulting textiles are UV-resistant. Solution-dyed textiles can limit design options, but it is a tradeoff worth discussing with clients.

lubricants, solvents, detergents, bleach, heavy metals, enzymes, softeners, plasticizers, fluorocarbon stain treatments, antimicrobials, and flame retardants.

Product certifications that focus on emissions, such as Greenguard, typically do not look at the manufacturing chemistry. GOTS and Cradle to Cradle look at a fabric's entire life cycle—from raw material harvesting or extraction through recycling or disposal—so select these products when possible.

FROM THE EDITOR

The Big Materials Dream Needs to Include Climate Change and More

We're finally getting vital toxicity information about building products. But let's remember that sustainability is about more than avoiding health hazards.

By Nadav Malin

For years we advocated for alternatives to formaldehyde-based binders in fiberglass insulation. Then in 2008, Knauf made a huge breakthrough, unveiling its EcoBatt fiberglass insulation with Ecose biobased binder. This was clearly the beginning of the end for formaldehyde binders.

But we couldn't fully endorse Ecose at first because the company would not reveal exactly what it was. Today, the company continues to be a sustainability leader, including in the area of ingredient transparency. Knauf was one of the first manufacturers to adopt the Declare label, which revealed its binder as dextrose, or sugar.

That kind of challenge was on our minds when we worked with the Healthy Building Network and leading design firms to create the Health Product Declaration (HPD) a couple of years after Ecose came out. We've also partnered with the International Living Future Institute to highlight Declare participants in our BuildingGreen Approved product guidance, among other things.

The product transparency movement, particularly with what it tells us about material health, is just getting its feet. It remains a huge priority for the industry. So it's a great time to bring it into balance with climate change, biodiversity, and other more conventional green building issues.

Disclosure ≠ sustainability

Spurred on by the momentum behind the HPD, Declare, and LEED v4's Material Ingredients credit, we're getting unprecedented transparency. Manufacturers are revealing what's in their products and even making changes to eliminate hazards along the way. This initiative has become so successful that it runs the risk of being mistaken for the whole story when it comes to Dream Materials.

Minimizing hazardous ingredients is an essential aspect of improving the material supply chain, but if we do that at the expense of attending to climate change, biodiversity loss, or social-equity impacts, we've not made meaningful progress.

Materials that are used to build or refurbish a building represent a large release of carbon dioxide to the atmosphere that can take decades of super-efficient operations to recoup. We don't have that kind of time.

It's not either/or

It troubles me when suppliers get the message that their customers only care about HPDs, then abandon their broader life-cycle-based assessments to focus only on health impacts.



Nadav Malin

I understand the market dynamics behind the Cradle to Cradle Product Innovation Institute's (C2CPII) move to peel off its Material Health assessment and offer that as a separate offering from the full Cradle to Cradle certification. At the same time, this opens the door to single-track optimization, which may run counter to creating products that are the best we can make them from a more holistic view.

Dreaming (and focusing) even bigger

So I was thrilled to hear from C2CPII's Stacy Glass that the program is working on staying true to its original, broad vision, with the theme "healthy materials, perpetually cycled."

Google's internal Portico Tool is also focused narrowly on health, but the company has signaled an interest in expanding its view by helping fund the Quartz Project.

And I've been impressed with the Business and Institutional Furniture Manufacturers Association's efforts to pull all these considerations together into one coherent label (with recent updates to its multi-attribute level certification) that covers health, sustainability, and resilience.

It's been helpful for a time to narrow our focus and get traction on the health front, and we certainly don't want to slow the amazing progress that's being made in that arena. But I'm really encouraged by the signs that we're ready to open that view wider again and address the full spectrum of opportunities for making products that are better in every way.

Are you seeing similar evidence that we're ready to move to a more holistic view of materials?

Have you seen examples of unfortunate trade-offs, where carbon footprint is compromised in the pursuit of health, or vice versa?

How do you think the design and construction industry should work to encourage the best overall choices? Please comment online.

NEWS

Phthalates Absorbed More Readily Than Previously Thought

SVOCs like phthalates are released into the air, according to a new study, so you're breathing and absorbing them, not just eating them.

By Candace Pearson

Conventional wisdom has had us focusing on volatile organic compounds (VOCs) as a top priority for indoor air quality. Designers who know about them at all probably consider semi-volatile organic compounds (SVOCs) and non-volatile compounds as lower priorities.

That's because VOCs can instantly vaporize under normal indoor conditions; they can have an immediate and noticeable impact on anyone who breathes. SVOCs have generally been lumped together with non-volatile organic compounds and thought mostly to represent an exposure risk if rubbed onto the skin or when released from finishes by wear and adsorbed onto dust. Parents are told to vacuum regularly to crawling babies, but the scenarios for this type of exposure have seemed more limited.

However, the exposure pathways of VOCs and SVOCs might be more similar than so far presumed, according to a recent study, led by Charles Weschler, Ph.D., of Rutgers University and published in *Environmental Health Perspectives*. And if those pathways are accounted for, certain SVOCs may quickly rise to a higher ranking of concern.

It's not just dust

Weschler told BuildingGreen that SVOCs may not immediately vaporize, but many do evaporate slowly at room temperature. In fact, the volatility cutoff point that distinguishes VOCs from SVOCs is somewhat arbitrary, according to the U.S. Environmental Protection Agency.

"When a plasticizer or flame retardant is added to a polymer, that compound is not bonded to the polymer," explains Weschler. "Over time, it will desorb from that polymer, convert to a gas stage, and adsorb onto other surfaces."

This reinforces why dust is a concern, as it becomes a vehicle for the compounds to build up in the environment. However, Weschler emphasizes that SVOCs are also present in the air, just like VOCs.

This presents two pathways people don't usually associate with SVOCs: inhalation and uptake through the skin *directly from the air* (called "transdermal" uptake), both of which Weschler and his colleagues argue are significant modes for how these compounds enter our bodies.

The proof is in the chamber

The hypothesis was tested by an experiment focusing on diethyl phthalate (DEP) and di(n-butyl) phthalate (DnBP), two SVOCs that are used in personal care products and common adhesives. Six men were exposed to the compounds in a chamber where phthalate-spiked paint was gradually evaporating.

On half of the experiment days, the subjects wore hoods that provided filtered, compressed air while their skin was exposed. On the other half,

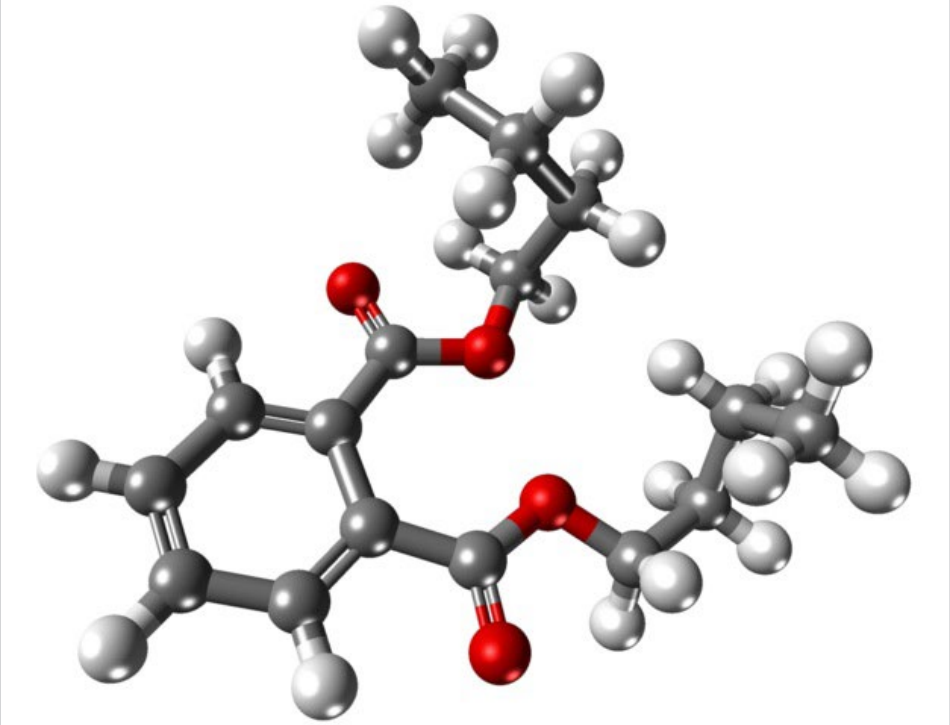


Photo: Kamil. License: CC BY 4.0.

Di-n-butyl phthalate's structure and light weight enable it to quickly pass into our bodies from the air.

they breathed the phthalate-laden air as well.

Urine samples showed individual's phthalate levels jumped significantly in both conditions. In addition, exposure levels approximately doubled from hood days to non-hood days (when the inhalation pathway was added on top of the transdermal pathway), suggesting to researchers that absorbing the compounds from the air through the skin introduced roughly the same level of phthalates as inhalation. At peak levels, concentrations of these compounds in the men's urine were more than two orders of magnitude higher than background levels determined before the study.

A missing piece in risk assessments

The inhalation pathway of SVOCs is sometimes accounted for in risk assessments, according to Weschler, but it can be underestimated. A recent, unrelated study found that chlorinated organophosphate flame retardants (the ones that have been used to replace PBDEs, polybrominated diphenyl ethers) are released into the air at much higher levels than previously thought.

The transdermal pathway, however, is often completely ignored, even though "modeling predicting the permeability from air to skin to blood suggests that this pathway is an order of magnitude higher than inhalation," says Weschler. Given the results with DEP and DnBP—and the fact that there are other low-molecular-weight SVOCs that could be absorbed by the skin directly from the air—risk assessments should start accounting for this pathway, argues Weschler.

"Not all SVOCs go through the skin quickly, but if the organic compound has the right physical properties, it can. And that happens to be the case for these two phthalates."

More on phthalates and potential health impacts

Phthalates in the Womb Linked to Asthma-Prone Kids

Report Warns of Asthma-Causing Chemicals in Building Products

Phthalate Levels Connected to Reproductive Troubles

PRODUCT NEWS & REVIEWS

Rubber Flooring: A Good Use for Old Car Tires?

Rubber flooring is getting greener overall, but tire-derived products are still an iffy proposition.

By Paula Melton

Note: This is part one of a two-part series on finding a positive use for scrap tires. Watch for our follow-up guidance on using crumb rubber for exterior products.

The media exploded last year with panic about the use of crumb rubber as infill in artificial turf fields, which are coming under renewed scrutiny due to hints of a link (as yet anecdotal) between these fields and incidents of cancer among young soccer goalies. Few reports have mentioned, though, that this very same material is the main ingredient in certain resilient flooring products—known as *tire-derived rubber flooring*—that are popular in schools and hospitals.

We wanted to know:

- Do unique toxicity issues come into play when crumb rubber is used in an interior product rather than on a playground or playing field?
- Might the most vulnerable building occupants, including children and hospital patients, be exposed to lead or other toxic chemicals due to the use of crumb rubber in tire-derived interior products?

The answer to the first question is definitely yes, based on our research, while the answer to the second is less clear.

Is rubber ever green?

Rubber flooring, regardless of where the rubber comes from, has major sustainability advantages (see Two Manufacturers Offer Greener Rubber Flooring). But rubber itself has issues. And it's worth asking whether the tradeoffs make sense, suggests Jay Bolus, president of certification services at McDonough Braungart



Photo: Ildar Sagdejev. License: CC BY-SA 4.0.

Scrap tires are a problematic and potentially dangerous waste product, but is making them into school and hospital floors any better?

Design Chemistry, a consultant and assessor for the multi-attribute Cradle to Cradle (C2C) product certification.

"Rubber chemistry in general can be a little bit complicated," Bolus says. "You're trying to take a molecule or series of molecules and put them into a three-dimensional network." This crosslinking process, called *vulcanization*, is what makes rubber rubber, "giving it that elastic property that everybody likes," he notes. But vulcanization can also involve "chemicals that a lot of times are toxic or problematic"—not to mention the fact that 1,3 butadiane (a known carcinogen) and styrene (a likely carcinogen) are the basic building blocks of most synthetic rubber.

What's more, since the resulting polymer can't be melted down, "it is hard to do anything with at the end of use," Bolus points out. C2C advocates for "safe materials, perpetually recycled," he says, and like many other thermoset polymers, rubber "fails on both of those." (A handful of rubber products have achieved lower levels of C2C certification, he notes, because the system encourages gradual optimization over time.)

What about indoor emissions?

Rubber's toxic chemistry doesn't necessarily stop at the factory gate. VOC emissions from rubber flooring can be all over the map—even in different production lots of the same product—according to the most-thorough treatment of the subject to date, the *Tire-Derived Rubber Flooring Chemical Emissions Study: Laboratory Study Report*, published in 2010 by the California Department of Resources Recycling and Recovery (CalRecycle). The research team tested multiple flooring samples, focusing on tire-derived products but also including some virgin-rubber types. They found that a few product samples of both types had high emissions, with some tire-derived indoor/outdoor products standing out as "super-emitters."

Most of the products tested for this CalRecycle study (with notable exceptions) did not emit elevated levels of VOCs that have known health concerns. Many of the samples did, however, emit moderate to high levels of such chemicals, and several emitted multiple volatile chemicals that could not be identified—a concerning pattern, according to researchers, since it is impossible to study health impacts or limit emissions of these chemicals without knowing what they are.

Additionally, many samples had high total VOC (TVOC) emissions. These products tended to continue emitting at high to moderate levels—and not always on a downward curve—over the entire 90-day testing period. The researchers made several recommendations based on their results, including the suggestion that all interior rubber flooring should have third-party verification of low TVOC emissions. This could reduce exposure to unknown volatile chemicals and also protect building occupants from the potentially harmful effects of simultaneous exposure to multiple chemicals (see How "Safe" Chemicals Could Team Up to Cause Cancer).

Why FloorScore certification is not enough

One compound that shows up in VOC testing of rubber flooring (but not in other resilient flooring products) is benzothiazole, or BZT. This is presumably due to the common use of 2-MBZT (2-mercaptobenzothiazole) as an accelerator during vulcanization. In the CalRecycle report, emissions of BZT from tire-derived products were high, but they were even higher in the virgin products (see chart).

BZT is a respiratory irritant and skin sensitizer, and it may be associated with bladder cancer among rubber workers, according to a 2011 study designed to set exposure limits for BZT found in crumb rubber. The authors of this BZT study made tentative recommendations, including a chronic exposure limit of 18 $\mu g/m^3$.

Can a rubber flooring product meet that limit?

The CalRecycle report models air concentrations for different interior uses, finding that the highest tire-derived emitter of benzothiazole would cause BZT air concentrations of 973 $\mu g/m^3$ in a daycare setting and 371 $\mu g/m^3$ in a classroom. For the highest BZT emitter among virgin rubber, concentrations would reach 4,300 $\mu g/m^3$ in a daycare setting and 1,640 $\mu g/m^3$ in a classroom.

These are sky-high compared to the tentatively recommended maximum of 18 $\mu g/m^3$, but the lowest emitters also exceed that limit. The best tire-derived product produced concentrations of 159 $\mu g/m^3$ in a daycare and 62 $\mu g/m^3$ in a classroom, and

Vulcanization: Making Rubber Rubbery

Vulcanization is a chemical curing process that takes sticky, thermally sensitive rubber and polymerizes it, making it elastic and thermally stable. Sulfur is the chemical most commonly used to vulcanize rubber, whether it's natural latex or synthetic styrene-butadiene rubber.

Other chemicals are typically added along with the main vulcanizing agent to affect the process and the performance properties of the material. In tire rubber, these chemicals may include accelerants (like 2-MBZT), retardants (like n-Cyclohexylthiophthalimide), plasticizers (phthalates and aromatic oils), antioxidants (like akylphenols), and more.

Tire manufacturers design their chemical processes to gain a competitive edge in the marketplace, and they're not anxious to release information about what goes into their fine-tuned vulcanization recipes. Because of this—as well as the fact that tires can pick up lead and other contaminants off roadways during use—there is no good way to know what chemicals may be found in a given tire.

the best virgin product 466 µg/m³ and 181 µg/m³.

Unfortunately, there is no way for a purchaser to know whether a given production lot of rubber flooring emits high levels of BZT or other VOCs that don't have established exposure limits. That's because common indoor air quality certifications like FloorScore don't measure it and, like most labels, FloorScore also doesn't set a TVOC limit.

Greenguard does, however. "We see really good low-emitting tire-rubber flooring," says Scott Steady, product manager at UL, which owns the Greenguard label. Despite this, rubber flooring seldom achieves Greenguard certification—let alone Greenguard Gold. "Usually it's the total VOC cap that's getting them," Steady says. He suspects the BZT—but, he adds, "You can get rid of that with processing or with top-coating." According to Steady, thicker rubber products have an even harder time meeting the TVOC requirements of Greenguard. However, two manufacturers have achieved Greenguard Gold.

Neither uses tires as a feedstock, though Steady says there is nothing about the Greenguard standard that would automatically exclude tire-derived products. "It's all about whether you meet emissions criteria."

Getting the lead out

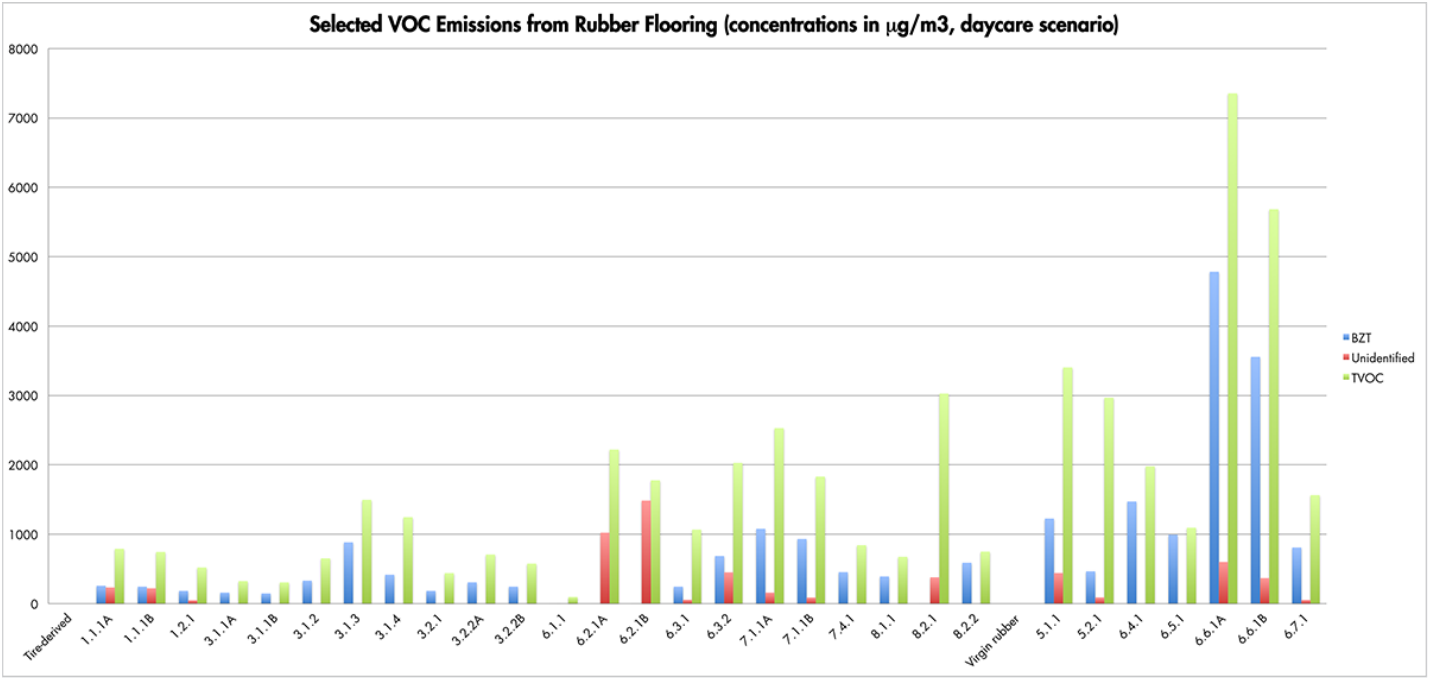
In addition to VOC emissions, some health advocates also worry about hazardous semi-volatile organic compounds (SVOCs), heavy metals, and other substances in interior tire-derived products.

"There's a real concern that tire-derived flooring has taken a pretty strong market niche in schools, where there's a lot more exposure to children to contaminants in the flooring," argues Jim Vallette, senior researcher at the Healthy Building Network and author of HBN's 2013 report *Avoiding Contaminants in Tire-Derived Flooring*. "Among building materials, flooring is probably the closest interface that children have. It's an underexplored area of exposure."

The HBN report raises concerns about aromatic process oils, lead, and carbon black nanoparticles. Although there's no evidence that any of these substances are released from flooring, "abrasion during any floor's service life routinely releases top layer ingredients as particulates," creating pathways of potential exposure that haven't been looked into by the industry, the report claims.

Many experts we spoke with did not share these specific concerns, stating that the likelihood of exposure to non-volatile compounds ought to be very low once crumb rubber is bound in a polymer matrix. However, the extreme toxicity of lead has gotten the attention of at least one manufacturer. Ecore, a major manufacturer of tire-derived flooring, says it has "adopted and implemented the recommendations from the HBN study." In an email statement to BuildingGreen, Ecore claimed it now performs daily testing for heavy metals using EN 71-3—a European standard for toy safety—as its guide.

High Emissions from All Types of Rubber Flooring



Source: Tire-Derived Rubber Flooring Chemical Emissions Study: Laboratory Study Report, published in 2010 by CalRecycle

This chart shows three key metrics associated with rubber flooring emissions: benzothiazole, unidentified VOCs, and total VOCs. Because there are no established health limits for any of these metrics, manufacturers often refer to excessive VOC emissions from their flooring as a "nuisance odor." In reality, the possible health effects are simply unknown.

Daily testing is important because there's no way of knowing which tires may have high lead content. "It can come from either additives from older tires or from picking up lead during their service life," explains Vallette. Though it is not consistently found in tires, Vallette claims excessive levels of lead are detected "more often than once in a hundred" in scrap tires.

In addition to testing for heavy metals, Ecore also maintains that its flooring products avoid odor problems through careful sourcing of its rubber feedstocks, only accepting rubber that is cured with peroxide rather than sulfur. BuildingGreen's research suggests that peroxide curing does not involve 2-MBZT, likely preventing the high BZT emissions associated with many rubber products. Peroxide curing uses other accelerants, however.

Overstating the safety?

HBN released its report, and has continued to analyze a variety of recycled feedstocks, to engage with manufacturers. "Manufacturers are our primary audience," Vallette notes. "They want green products. There is mutual interest."

Ecore's practice of testing for lead daily is a major step forward and to be commended. However, both Ecore and the Recycled Rubber Council—which also sent BuildingGreen an email statement—routinely overstate the safety of crumb rubber.

"Recycled rubber is safe. When it is produced, this rubber goes through a process that renders any harmful chemicals inert," says the statement from the Recycled Rubber Council. Asked for further details, we received the answer that the process referred to was vulcanization. There was no acknowledgment from the trade group that vulcanization is the very thing that introduces most of the chemicals—accelerants, antioxidants, plasticizers, and others, many of which are part of a "secret recipe" used by tire manufacturers to achieve performance properties that are important to safety and durability.

A statement on the Ecore website asserts, "It is unequivocal that exposure to crumb rubber products poses NO risk to adults, children, or pets." Although many studies have suggested that exposure to crumb rubber under particular conditions does not appear to cause elevated risk of acute or chronic harm, the level of certainty apparent in Ecore's statements is not backed up by science.

In fact, notes Michael Peterson, a toxicologist and scientific advisor to the Recycled Rubber Council, "In my statements, I usually talk about the best available evidence showing there is not a concern for health effects." He adds, "We would love to deal in certainties," but it is logically impossible to "prove a negative"—e.g., that any substance presents zero risk to a population.

That said, Peterson adds, "Looking at the data, there really isn't a concern. You hear often that there are areas of uncertainty, things that haven't been looked at. [Crumb rubber] has been a really well studied product, and there is not a reason for concern from a chemical exposure perspective."

Not everyone is convinced, however, including Jay Bolus. "I get it: we're trying to make the best out of a bad situation. Tires are a problem," he says. "They haven't been designed for recycling or best use; they are designed for unique performance properties. That doesn't mean we should try to invent uses for them."

BuildingGreen's recommendations for selecting rubber flooring

After thorough research and consultation with experts, including manufacturers, BuildingGreen has developed the following recommendations.

How to select rubber flooring not derived from tires

1. Most indoor air quality certifications limit VOC emissions of individual compounds, a practice that misses BZT and other rubber-specific chemicals that may have health effects. Choose rubber flooring with Greenguard Gold certification.

2. If Greenguard-certified products aren't a good fit for the project, FloorScore certification should be an absolute minimum requirement. However, FloorScore will not limit total VOC emissions, and occupants may till be affected by BZT emissions, high overall emissions, or combined emissions of multiple VOCs.

3. The vulcanization process may introduce toxic or unknown plasticizers, accelerants, antioxidants, and other additives. Request ingredient disclosure to 100 parts per million.

How to select rubber flooring derived from tires

1. Because of the sourcing issues associated with scrap tires, we have never recommended tire-derived flooring products for interiors. We will maintain this recommendation pending development of a regulatory or third-party voluntary standard for managing the heavy metal content of tire-derived products.

2. If your project does select tire-derived flooring for an interior application, FloorScore certification should be a minimum requirement, though Greenguard Gold certification is preferred. (However, no manufacturers of tire-derived flooring currently carry Greenguard certification.)

3. Also request verification that the manufacturer has policies in place to control its sources of rubber and to test for heavy metals.

Two Manufacturers Offer Greener Rubber Flooring

Is rubber flooring sustainable? The jury is still out on most products, but nora and Artigo offer the best on the market.

By Paula Melton

Rubber flooring has attractive sustainability features, yet the chemistry of rubber manufacturing can be problematic. We took a hard look at the rubber flooring industry and found two manufacturers whose products stand out as the greenest in this tricky category.



Photo: nora systems, Inc.

This Kaiser Permanente project includes rubber flooring by nora.

Green attributes of rubber flooring

Rubber is comfortable to stand and walk on—crucial for nurses, for example, who stay on their feet all through a shift. It also can reduce injury when patients or children fall.

These products are unusually durable even in heavy-duty applications, standing up to heavy hospital carts and thousands of kids in the school hallway at a time. Rubber surfaces have minimal maintenance requirements compared with alternatives; ongoing maintenance of other types of resilient flooring can compromise indoor air quality.

These flooring products also contribute to better acoustics than many alternatives, and the aesthetic palette can be wide ranging, with both bright and neutral colors available, and geometric or biophilic patterns possible.

Rubber flooring can also have high recycled content from a variety of post-consumer sources, from athletic shoes to scrap tires. Tire-derived products divert large amounts of a problematic waste product from landfills (but see our analysis of this particular feedstock).

Problematic life cycle

Rubber flooring tiles and sheets are typically made with styrene butadiene rubber; the 1,3 butadiene used to make this synthetic rubber a known human carcinogen, and styrene is a likely occupational carcinogen.

"Secret recipes" are common in rubber production, as manufacturers add substances during the cross-linking process (called *vulcanization*) that contribute to their particular brand's quality and high performance. Some flooring products bind recycled crumb rubber in a polyurethane matrix, potentially exposing workers to a common and potent asthmagen (isocyanates—see OSHA Puts the Squeeze on Asthma-Causing Polyurethanes).

The National Institute for Occupational Safety and Health (NIOSH) released a report in 1993 concluding that rubber-industry workers in the U.S. were at excessive risk for death from "bladder, stomach, lung, hematopoietic, and other cancers," and for chronic health problems that included respiratory sensitivities, dermal sensitivities, and reproductive problems. Although NIOSH recommended further study, there has been no apparent action taken by the federal government or by industry in the interim that's specific to protecting rubber workers (though exposure to styrene and 1,3 butadiene is regulated in any U.S. manufacturing facility).

Balancing durability and toxicity

That said, many building materials come with life-cycle issues like these. Although we would like more transparency about potential hazards and exposure risks, we typically give products a break if hazardous manufacturing chemistries contribute to high performance, durability, or low maintenance during use: sometimes these tradeoffs seem worth it. (Exterior coatings are a good example, and though we tend to like wood products, the logging industry is the deadliest in the U.S. for its workers.) With reports of high-quality rubber flooring lasting for decades in heavily trafficked spaces, we can perhaps make allowances for a toxic manufacturing process.

But unlike exterior paint, rubber flooring is an interior product that's popular in spaces designed for the most vulnerable building occupants—school children and hospital patients—and some of the chemicals used in rubber processing are VOCs that could be emitted from the finished product. Normally, we'd look to a stringent certification like FloorScore to avoid those emissions, but certain VOCs associated with rubber manufacturing (particularly BZT, or benzothiazole) aren't benchmarked by FloorScore, so it's not an

adequate way to avoid these emissions (see Rubber Flooring: A Good Use for Old Car Tires?). Other ingredients could include semi-volatile organic compounds (SVOCs), namely phthalate plasticizers. Given potential exposure issues for vulnerable building occupants, it's hard to make a case that rubber flooring is inherently green.

But two manufacturers—nora and Artigo—have thought through some of these issues and are producing best-in-class products that meet our BuildingGreen Approved product guidance.

Low indoor emissions

The key green feature of these products is their certification to Greenguard Gold. We recommend that any rubber flooring meet the strict total VOC (TVOC) emissions of this UL-owned standard. The TVOC benchmark is currently the best way to guarantee low BZT emissions.

Although many VOCs found in other types of flooring have established health-based exposure limits in place, BZT does not. Because of the absence of an exposure limit, manufacturers often make statements suggesting that BZT emissions and other VOC emissions not limited by testing protocols are just a "nuisance odor." In fact, there are hints that BZT has health effects. Artigo and nora are the only brands that currently have Greenguard Gold certification.

Other chemicals of concern

These brands do not use scrap tires in their process. Rubber flooring made with crumb rubber binds the crumbs in a polymer matrix, usually polyurethane. But nora and Artigo are completely different. In these products, the rubber itself provides the polymer matrix, which binds together pigmented mineral content.

"We don't use [tires] for health concerns," says Scott Macrury, director of sales and technical services at Mondo, the U.S. distributor of Artigo products. The concerns include not only VOC emissions but also fire resistance, he claims. Additionally, "some technical features of the finished [tire] product will diminish the performance characteristics of our product."

Macrury provided a list of its quality-control procedures, such as "full traceability of every single material," in-house chemical testing of raw materials, and a slate of indoor air quality certifications the flooring has in addition to Greenguard Gold. These include the stringent German government standard, Blue Angel. Products from nora also comply with Blue Angel.

Both Artigo and nora claim they use no phthalates in production. Though its products are not made with polyurethane in the primary material, Artigo applies a polyurethane wear layer, according to its UL-verified environmental product declaration (EPD).

Carol Fudge, marketing research specialist at nora, says her company does not add a wear layer and that nora products don't require finishes when installed.

Several nora products (the noraplan degree, eco, environcare, sentica, unita, and value product lines) and one Artigo product (Massetto) incorporate natural latex, which reduces the need for the toxic styrene and 1,3 butadiene used to make synthetic rubber. But natural rubber doesn't hold up as well against wear from heavy equipment like forklifts, Fudge explains. Although processing should denature the proteins in natural latex, its presence may also be a concern for some building owners due to possible allergies. BuildingGreen recommends product lines that incorporate the highest percentage of natural latex that's feasible for the project.

Artigo touts other environmental achievements, such as its use of renewable energy for manufacturing, and EPDs are available for several products, making these floors potential contributors to LEED v4 Materials & Resources points. Because of the Greenguard Gold certification, both brands should contribute to credits for low-emitting materials in both LEED 2009 and LEED v4 (where TVOC disclosure is newly required).

Nora says it provides LEED v4-compliant EPDs to project teams upon request.

Durability and recyclability

Both nora and Artigo meet or exceed all the relevant ASTM performance



Photo: Mondo/Artigo

Artigo touts environmental features like renewable energy used for production.

standards for resilient flooring, according to the companies. The manufacturers also cite anecdotal evidence of long-term performance.

"Durability for us is measured in the longevity of the references that we have in place that date back almost 50 years in the Milan subway station," says Macrury. "That product is still in use." He also claims the company has never seen its flooring replaced because of wear. "They may not like the aesthetic any longer, but the product will still be in outstanding shape."

Adds Fudge, "We have installations all over the world that are over 25 years old." She notes one installation in Frankfurt Airport, "one of the most heavily trafficked airports in the world, where nora flooring has been installed and maintained with no coatings for over 40 years."

Unfortunately, once rubber flooring *is* replaced, the material cannot be recycled because rubber is a *thermoset* resin (which can't be melted down and re-formed) rather than a *thermoplastic* (which can be recycled multiple times into the same product).

Though it doesn't have a program for post-consumer flooring, "we have sample and construction waste take-back programs," says Fudge. Samples can be mailed back to the company free of charge, and they are reused. "When we receive construction waste, the material is reused in the production of new nora floor coverings, or it's recycled into other products or used to generate energy."

Artigo doesn't have a take-back program, according to Macrury.

What we'd like to see from nora and Artigo

Artigo and nora are focused on providing products that won't compromise the health of hospital patients and school children. We'd like to see these two companies continue to take a leadership role in helping clean up the rest of the rubber flooring industry. Some steps they could take to help this happen:

- Measure and publicly disclose BZT emissions of their flooring products.
- Advocate for research on the possible health effects of BZT, and for the establishment of safe exposure limits.
- Release Health Product Declarations (HPDs) with disclosure to 100 parts per million. (Mondo told BuildingGreen it is already developing HPDs for Artigo products.)

For more information

Nora
nora.com/us

Mondo Contract Flooring
mondocontractflooring.com

BACKPAGE PRIMER

The High Price of Stain Resistance: Environmental Persistence

Perfluorochemicals increase product longevity. Though these PFCs don't last forever on our textiles and carpets, they do stick around in our bodies.

By Brent Ehrlich and Paula Melton

Teflon flu: that's the name workers at a DuPont plant in West Virginia gave to the vomiting, fevers, and other symptoms they had when exposed to high levels of PFOA, a perfluorochemical (PFC) made at the factory. As explained in January 2016 by Nathaniel Rich in the *New York Times*, public discovery of the far-reaching and long-lasting health and environmental effects of PFOA led to its eventual phase-out.

PFOA (formerly the main ingredient of Teflon) and PFOS (formerly the main ingredient of Scotchgard) make it so oils, dirt, and moisture bead up on a surface, an excellent property with many uses. But both are "long-chain" PFCs, with eight or more carbon-fluorine (C8) bonds, and they have been associated with health concerns ranging from testicular and thyroid cancers to obesity. They are considered persistent, bio-accumulative, toxic chemicals (PBTs), and PFOS is listed as a Persistent Organic Pollutant (POP) by the Stockholm Convention; PFOA is under review.



Photo: Gunnar Grimnes. License: CC BY 2.0.

The PFC coating on this white tablecloth causes wine to bead instead of staining the fabric. Treatments like these come with a high environmental price tag, though.

Though long-chain PFCs are no longer used, chemically similar compounds have replaced them as surface treatments on textiles and carpets. These second-generation, "short-chain" PFCs have six or fewer carbon-fluorine bonds and are considered to be less toxic and somewhat less bioaccumulative than PFOA or PFOS.

Bioaccumulation risk is presumed to go down with the length of the chain, so in this group, C4 chemistries have less bioaccumulative potential than C6. But that doesn't mean they are benign. Short-chain varieties are still extremely persistent in the environment, with unknown long-term health and environmental impacts. And because they do not work as well as long-chain varieties, more of the chemicals may be needed.

Short-chain PFCs for the carpet and textile industries include non-branded stain treatments as well as branded formulations like Crypton, GreenShield, NanoSphere, Nanotex, and others. The manufacturers of these compounds tout the dirt and stain resistance as a way to minimize

cleaning chemicals and prolong the lifespan of the textile.

Some companies—GreenShield, NanoSphere, and Nanotex—claim to use "nanotechnology" to improve performance and reduce the amount of the compound needed, but the "nano" in this case refers to the small size of the structure on the fiber, not the molecule size. The small structure produces small hairs that reduce the surface tension, helping provide dirt and stain resistance with smaller amounts of PFCs.

Reducing PFC use is considered a good thing by many in the green building industry, and designers have various strategies for avoiding the chemicals. These include the use of inherently stain-resistant materials, such as solution-dyed fabrics, and a good maintenance program (see Three Hazardous Textile Treatments and How to Avoid Them).

Others are taking a more active role. In 2015, Arlene Blum of the Green Science Policy Institute and others co-authored the Madrid Statement, which "documents the scientific consensus regarding the persistence and potential for harm of poly- and perfluoroalkyl substances (PFAS), and lays out a roadmap to gather needed information and prevent further harm." More than 230 scientists have signed the statement so far.

