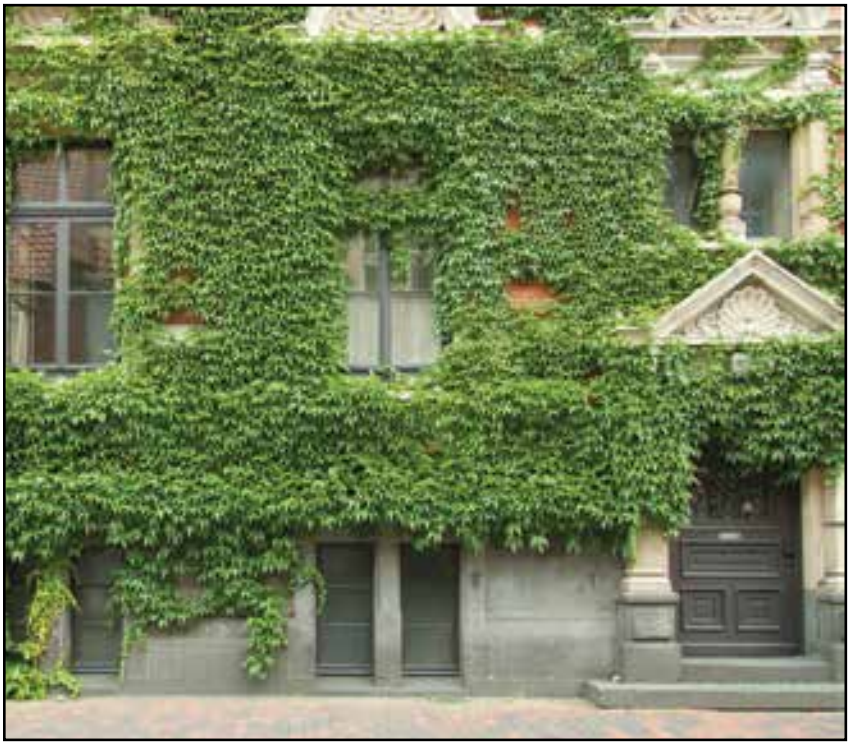
Green Building Materials
Deconstructing the Toxic Home



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Over 86,000 commercial chemicals are manufactured or processed by U.S. industries, with many of them employed to manufacture building materials. The average American spends about 90% of their time inside buildings. So healthy building materials have a pronounced effect on healthy people.

In 1991, the City of Austin established one of the first green building programs in the world to integrate energy use, water consumption, building-site waste reduction, solid-waste recycling and composting, and healthier building materials into the environment. It played a formative role in establishing strategies and concepts in what would become a global trend.

While great progress has been made in most areas of green building since the 1990s, efforts to remove toxic chemicals from building materials have been more limited. Volatile Organic Compound (VOC) air emissions from materials such as paint, caulking, and carpet have indeed gotten lower, but many common materials are still highly toxic to manufacture. Some of the poisons in the materials migrate into the indoor environment and can expose construction workers and building occupants. Many of those exposed are children, who are more susceptible than adults due to their low body weight and high metabolism.

The use of toxic building materials is even more pronounced in homes inhabited by people in lower income groups. Most low-income residents are tenants, and have no control or scant control over the products used to build and maintain their home. Often the cheapest available materials for apartment builders and owners are also the most toxic. Even homebuyers who purchase tract (entry-level) homes are exposed to cheap, more-toxic materials because homebuilders feel they need to keep costs down.

Apartment managers that take healthy materials into account do exist. One good example is Foundation Communities, an Austin non-profit that owns and manages a number of affordable housing rental complexes. The managers replace their carpet with tile (which is much easier to clean and usually lasts longer), use least-toxic paints, and encourage their tenants to clean their homes with baking soda and vinegar instead of toxic (and more expensive) commercial cleaning products. However, such shining examples in the rental sector are relatively scarce.

Up-scale green homeowners and builders are much more likely to purchase non- and least-toxic building materials than tract home builders, and exponentially more likely than apartment builders. This unequal access to healthy homes exemplifies the importance of using building codes and incentives to begin regulating and eliminating toxins in building materials.

Use of toxic building materials can adversely influence the health of building occupants for decades. And they can affect the world for literally hundreds of years, as some of the toxic chemicals used in building materials do not completely biodegrade for centuries. Instead, they bioaccumulate in the environment, in the food chain, and ultimately, in our bodies.

The materials in these articles were selected because: 1) they would directly affect the indoor environment; 2) they were likely to be selected for existing homes in retrofit and maintenance situations as well as new ones.

While these articles drew on various sources for information, they were greatly instructed by the research and assistance of the Healthy Building Network. It is a research and advocacy organization educating the U.S. building industry and consumers on ways to eliminate or reduce toxic chemicals in buildings and building materials. This organization also inspired the color-coded product ranking charts in these articles, though the author sometimes modified them based on his own research and judgments.

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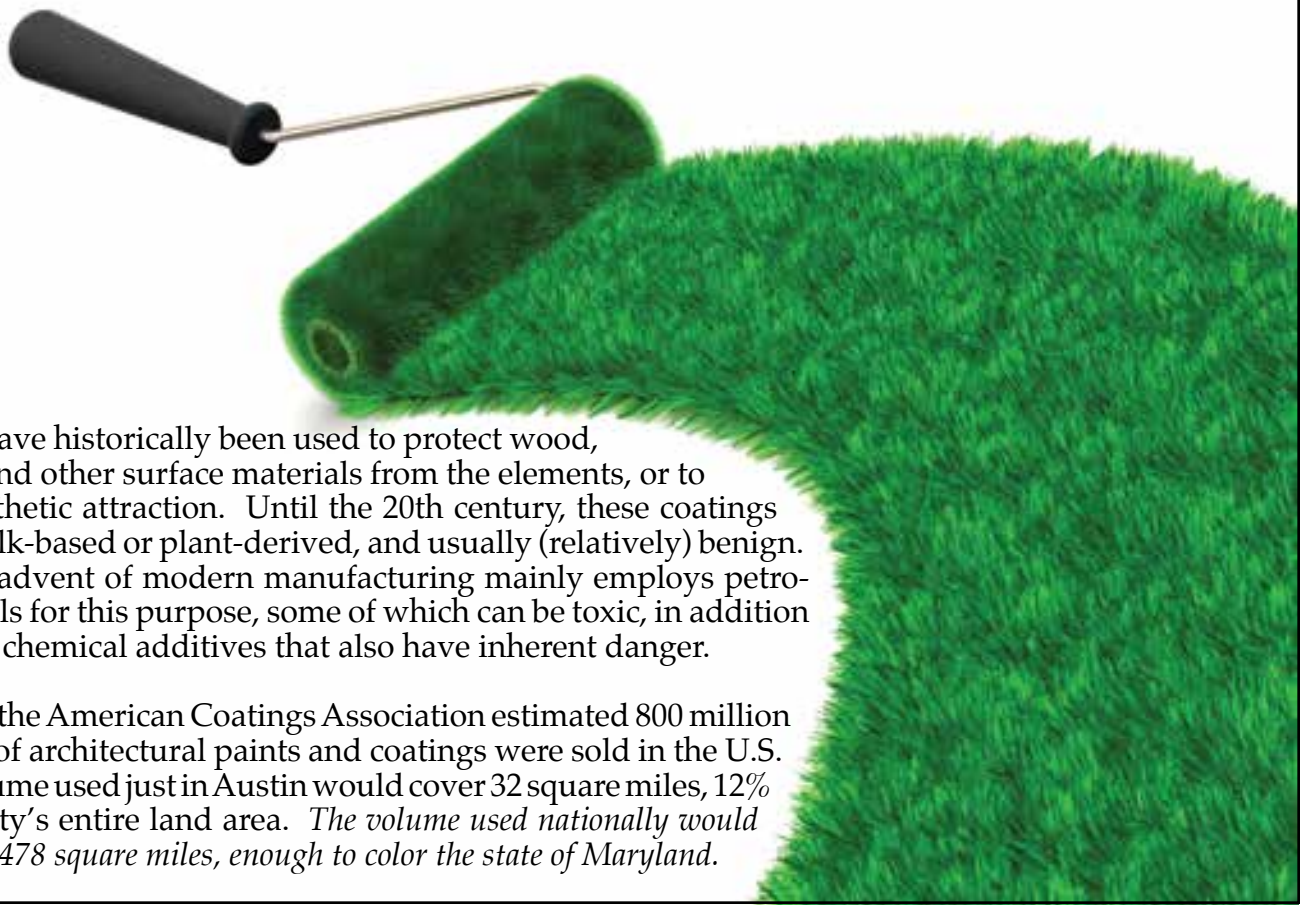
PAINT & THE ENVIRONMENT
If Walls Could Talk



Paints have historically been used to protect wood, metal, and other surface materials from the elements, or to add aesthetic attraction. Until the 20th century, these coatings were milk-based or plant-derived, and usually (relatively) benign. But the advent of modern manufacturing mainly employs petrochemicals for this purpose, some of which can be toxic, in addition to other chemical additives that also have inherent danger.

In 2017, the American Coatings Association estimated 800 million gallons of architectural paints and coatings were sold in the U.S. The volume used just in Austin would cover 32 square miles, 12% of the city's entire land area. *The volume used nationally would cover 11,478 square miles, enough to color the state of Maryland.*

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Toxins in Paint

In the known list of ingredients in various types of domestic and industrial paint, there are 18 known carcinogens, 6 probable carcinogens, and 22 possible carcinogens (though many of these carcinogens are more frequently found in commercial, industrial, and infrastructure applications than residential ones). It should therefore be no surprise to find high incidences of bladder and lung cancer in professional painters. (International Agency for Research on Cancer, *Chemical Agents and Related Compounds*, 2012, p. 519.)

Given these chemical hazards, there is also no surprise of a positive association between maternal exposure to painting (including pre-conception and pregnancy) and leukemia in their children.

Paints and coatings basically have 4 components: a resin, a pigment, a solvent, and additives. The resin usually is mixed with a pigment for color. Depending on the ingredients, all of these can be toxic to people and animals in or near buildings where they are applied, as well as harmful if they are released to the general environment.

Watching Paint Dry: Volatile Organic Compounds

Solvents, resins, and some additives emit fumes (or "offgas") as they dry. Depending on the product, these *Volatile Organic Compounds* (VOCs) can offgas for weeks and sometimes years at reduced levels after application.

Studies demonstrate children exposed to VOCs at high levels are four times as prone as adults to develop asthma. (Rumchev, K., et al. *Thorax*, V. 59, 2004, pp. 746-751.) Other studies show a link between VOCs and childhood asthma. (*Indoor Air Pollution in California*, California Air Resources Board, February 2005.)

In 2013, the California South Coast Air Quality Management District identified 338 distinct VOCs emitted from paint in the state, amounting to 19 million pounds of annual emissions. To give a relative sense of the harm, the *Directory* looked at the top 17 chemicals (Chart P1) that make up 80% of this total volume. About half of this quantity is made up of chemicals used as solvents.

While acute health effects are dependent on the dose, frequency, and individual tolerance, the chart indicates caution should be used when applying paint. Some of these VOCs are relatively benign. One, propylene glycol, is actually used as a food preservative. But others can cause

symptoms related to chemical illness such as sinus irritation, difficulty breathing, dizziness, nausea, and drowsiness. If exposed repeatedly or for a long period of time, some can be carcinogenic, neurotoxic, endocrine disruptive, and cause developmental and reproduction problems.

VOCs are also an air quality hazard to the larger environment. Paint emissions eventually migrate into the atmosphere. They can combine with nitrogen oxides to create ozone pollution. 2014 data from the Texas Commission on Environmental Quality showed that about 2% of all state VOC emissions from human sources came from paint.

There is some good news in that, over the past 25 years, most paint manufacturers have developed products that greatly reduce or completely eliminate VOCs. In the past, 250 grams of VOCs per liter was considered common. Most of today's interior paints emit no more than 50 grams per liter. However, there are many paint products with emissions between 0 and 10 grams per liter.

This is a relative thing though, as darker colored tints often increase stated VOC levels measured in interior base paint, some by as much as 50 grams per liter.

Part of the reason for the reduction in VOC content is the paint industry's switch from chemical- to water-based solvents. About 90% of total U.S. paint volume in 2017 was water-based.

Leaden Legacy: Metal and Mineral Toxins

Toxic metals and minerals have historically been used in various paint products. While the U.S. government has gradually recognized the harm from these substances and phased out their use through regulation, painted surfaces and products with these hazardous substances can be found in older buildings throughout the country.

Lead is the most well known of them. It was used for pigments, as well as for primers and driers, as far back as Colonial times. Its use in U.S. home paint products was reduced by a voluntary standard in 1955. A mandatory limit of 0.06% by weight was subsequently created in 1978. This limit was further decreased to 0.009% in 2009.

However, the legacy products used in older homes before 1978 can still cause harm, particularly to children. Paint chips tainted with lead can break off and be eaten by them.

Chart P1 – Health Effects of Common Volatile Organic Compounds in Paint

Stoddard Solvent	Carcinogen; mutagen; toxic to lungs, central nervous system, mucous membranes. Repeated/prolonged exposure can produce target organ damage.
2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate (Texanol)	Relatively benign.
Ethylene Glycol	Ingestion or repeated absorption through skin can cause damage to kidneys, liver, central nervous system. May cause adverse reproductive effects and birth defects based on animal tests.
Propylene Glycol	Relatively benign.
Distillate (Petroleum), Hydrotreated Light	May cause headache, dizziness, tiredness, nausea, and vomiting.
Ethanol	May cause irritation of respiratory tract and affect behavior/central nervous system. Carcinogen; developmental and reproductive toxin; birth defects.
Hydrocarbon Solvent, Bin #22 (Aromatic-100)	May cause drowsiness, dizziness, and irritation to respiratory tract. Carcinogen; long-term damage may occur to nervous system, respiratory system, liver and kidneys.
Medium Aliphatic Solvent Naphtha	Vapours may cause drowsiness and dizziness. Slightly irritating to respiratory system.
2-Ethylhexyl Benzoate	Relatively benign.
Aggregated VOCs < 0.1%	Not Available.
Hydrocarbon Solvent, Bin #21 (Xylene)	Vapor causes respiratory tract and mucous membrane irritation. May affect central nervous system and behavior; may also affect blood, sense organs, liver, and peripheral nerves. Chronic inhalation may affect the urinary system, blood (anemia), bone marrow (hyperplasia), central nervous system, and cause mucosal bleeding.
Petroleum Distillate (Mineral Oil: CAS #8042-47-5)	Relatively benign.
Diethylene Glycol Monobutyl Ether	Chronic: May cause kidney injury and central nervous system damage. May cause cyanosis, acidosis, and quick, shallow breathing.
2-Butoxyethanol	Developmental and reproductive toxin. Skin: Irritation: penetrates skin and can cause systemic effects and depression. Inhalation: irritation of the respiratory tract; may cause headache, drowsiness, dizziness, stuttering, coma, weakness, ataxia, slurred speech, loss of coordination and judgment, personality changes, analgesia, blurred vision, tremor, excitement, somnolence, nausea, vomiting, liver damage.
Methanol	Can cause headaches, dizziness, drowsiness, coma, narcosis, blindness, vision impairment, irritant effects, nausea, vomiting, agitation, spasms, inebriation, and rough/chapped skin.
Hydrotreated Heavy Naphtha	Carcinogen; mutagen; high vapor/aerosol concentrations irritating to eyes and respiratory tract; may cause headaches, dizziness, anesthesia, drowsiness, unconsciousness and other central nervous system effects, even including death.
Benzyl Alcohol	Inhalation: nose/throat irritation; coughing; shortness of breath. May be absorbed into the blood stream with symptoms similar to ingestion (adbominal pain, nausea, vomiting, diarrhea). May cause adverse reproductive effects based on animal test data.

Lead particles from deteriorating paint can attach to house dust, and be inhaled, or ingested by anyone, though young children are more vulnerable because they frequently place their hands in their mouths. And degraded lead paint on the outside of homes can leach into soil that adults garden on and children play on.

U.S. National Center for Health Statistics data from 2011-2016 revealed that 1.2% of children under 6 years old had over 5 milligrams of lead per deciliter of blood. Every milligram of lead shaves one IQ point from these children.

The U.S. Dept of Housing and Urban Development estimated that in 2006, 37 million homes (26% of all U.S. housing units in 2019) had some level of lead contamination. Some 23 million of these were significantly contaminated.

Lead has been known to be a poison for thousands of years. At high levels, it can lead to lethargy, convulsions, coma, and even death. It can also cause anaemia, hypertension, kidney impairment, endocrine disruption, and toxicity to the reproductive organs. At *low* levels in *children*, it can act as a neurotoxin to cause reduced attention span, increased anti-social behavior, lower academic performance and IQ levels, and affect the endocrine system. It can also cause anaemia, hypertension, kidney impairment, endocrine disruption, and toxicity to the reproductive organs. The neurological and behavioral effects of lead are believed to be irreversible.

Mercury was used as a biocide in interior paint until mid-1990, and in exterior paint until 1991. Similar to lead, children can be exposed to mercury via paint chips, house dust, and outside soil, though there is limited evidence to suggest that the quantity and impact of exposure is greatly reduced compared to lead. (*Chemosphere*, 2008, pp. 882–885.)

The largest health problems attributable to inorganic mercury are kidney dysfunction and acrodynia. Mercury ingested by nursing mothers can be transferred to infants. Animal studies indicate long-term oral exposure to inorganic mercury salts causes kidney and nervous system damage, affects blood pressure and heart rate, and creates digestive disorders. Immune system reactions can also occur.

Asbestos was used by several companies as a filler in textured paint, and other specialty paints, until 1990, when regulation prevented its use. It was also used as a filler in various wall texture products that paint was applied on. If asbestos fibers are broken loose, they can become airborne. If the exposure is great enough, they can cause lung cancer.

Cadmium and *chromium* pigments can also appear in legacy paint. *Nickel* has also been identified. These are carcinogenic at sufficient doses, and each of them have various other health consequences. Again though, these metals usually appear in small quantities compared to lead.

Chart P2 – Metals and Minerals in Paint

Asbestos	Lung Cancer, Mesothelioma
Cadmium	Birth Defects, Carcinogen, Endocrine Disruptor, Neurotoxin, Reproductive Toxin, Respiratory Toxin
Chromium	Carcinogen, Developmental Toxin, Liver Toxin, Mutagen
Lead	Cardiovascular and Kidney Problems, Carcinogen, Childhood Developmental Problems, Premature Birth, Neurotoxin, Reproductive Toxin
Mercury	Acrodynia, Kidney Dysfunction, Neurotoxin
Nickel	Asthmagen, Carcinogen, Skin Sensitizer

Other Additives

Paints usually have additives that can cause harm to the environment and people exposed to them. Antimicrobials or biocides, (including algaecides, mildewcides, and fungicides) are added to paint to keep bacteria from impairing its quality, longevity and durability. These chemicals are registered pesticides, and can cause adverse reaction in chemically sensitive people, as well as chronic, long-term health damage to less sensitive people, and harm to the general environment. Other additives include antifreeze, antisettling agents, fillers, catalysts, curing agents, driers, emulsifiers, fire retardants, plasticizers, and thickeners. Some of these chemicals and compounds can also be hazardous.

Antimicrobial pesticides (biocides) are used in most paints as a preservative in the container, as well as to prevent bacteria, algae, mold, and mildew and other fungus in the applied coatings over time. This is particularly important for outdoor paints that are designed to withstand the elements for many years, and for indoor paints in humid environments such as bathrooms and kitchens.

There are two basic kinds of biocides in products: "in-can," which acts as a preservative while the product is inside a paint can; and "dry film," which protects the product after it is already applied. Depending on the product and the purpose, in-can biocides can make up between 0.05 and 0.5% of paint by weight, and dry-film can make up between 0.15 and 3% of paint by weight. ("Industrial Biocides, U.S. Product Guide," ISP Corporation.)

Biocides used on outdoor paint will leach off over time. A small percentage of this run-off will end up in the watershed, with possible harm to aquatic species and ecosystems.

There are dozens of different biocides used in the paint industry. While some are relatively benign, many have potential to cause harm. Chart P3 gives a relative sense of the effects of certain biocides on health and the environment. Limiting these toxins to the greatest extent possible is a prudent strategy.

Some specialty paint products specifically eliminate biocides as additives, but care has to be taken as to: 1) where they are applied (paint longevity in humid areas may suffer without them); and 2) avoiding contamination of the paint can (pouring the paint that is used in a tray rather than using the paint directly from the container will

Chart P3 – Select Paint Biocides and Their Health Effects							
Product Name	**Active Ingredients**	**Acute Toxicity**	**Percent**	**Carcinogen**	**Cholinesterase Inhibitor**	**Development/ Reproductive Toxin**	**Endocrine Disruptor**
Bcm technical	Carbendazim	☠	99%	Possible	No	?	Suspected
Bioban 2000	2-methyl-4-isothiazolin-3-one	☠	3.7%	Unclassifiable	No	?	?
Diuron 4l	Diuron	Slight	0.4%	☠	No	☠	Suspected
Fungitrol 404-D	Chlorothalonil	☠	40.4%	☠	No	?	?
Fungitrol 420S	3-iodo-2-propynyl butyl carbamate	☠	20%	Not Likely	☠	?	?
Ipbc rtu	3-iodo-2-propynyl butyl carbamate	☠	0.5%	Not Likely	☠	?	?
Nuosept 515	2-methyl-4-isothiazolin-3-one	☠	0.37%	Unclassifiable	No	?	?
Proxel bz preservative	Zinc 2-pyridinethiol-1-oxide	☠	5.75%	?	No	☠	?
From Pesticide Action Network Database of Pesticide Products: pesticideinfo.org/Search_Products.jsp#ProdSearch							

limit cross contamination from the paint brush); 3) dealing with a reduced shelf life of the product.

Almost all mainstream paints use biocides. However, the name and percentage of weight may not be listed. Contacting the manufacturer may be required to get more information. (Some manufacturers may not be completely forthcoming because of trade secrets.)

Ammonia, employed as a paint dryer and antimicrobial, has replaced chemicals that offgas VOCs. Though it evaporates relatively quickly, with enough exposure, it can cause inflammation of the sinus and upper respiratory tracts. It can also be a severe irritant to the skin and eyes, and act as a sensitizer to magnify harmful effects of other chemicals.

Antifreeze is used to ensure storage life. Ingestion or repeated absorption through skin can cause damage to kidneys, liver, and the central nervous system, as well as adverse reproductive effects and birth defects based on animal tests.

Alkylphenol ethoxylates (APEs) are surfactants that stabilize and improve a paint's ability to coat the surface, while also increasing shelf life. This class of chemicals includes nonylphenol ethoxylates (NPEs) and octylphenol ethox-

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ylates (OPEs). They break down into chemicals that are persistent in the environment, bioaccumulate in the food chain, are acutely toxic, and endocrine disruptors.

Fluoropolymers, which add the element fluorine to the petrochemical carbon paint base, are used in paints for commercial buildings and high-end residential homes. These "Teflon™" perfluorocarbons (PFCs) produce a highly durable coating, most frequently used on metal roofs and wall facades, which is resistant to oil, water, salt corrosion, chemicals, dirt, UV radiation, and to a degree, even graffiti. They can also reflect and insulate from heat to make the building more energy efficient.

Unfortunately, their high durability makes them ecologically suspect. They do not biodegrade easily, persisting in the environment. Biological traces of PFCs have been identified around the world in the bodies of most people and wildlife that have been measured, even in remote regions like the Arctic. They appear with more frequency though around sites where they are manufactured or used as an ingredient in products, and at sites such as airports where they were historically used to extinguish fires.

Health effects associated with exposure to certain PFCs include high cholesterol, increased liver enzymes, decreased vaccination response, thyroid disorders, pregnancy-induced hypertension and preeclampsia, and testicular and kidney cancer.

Over time, some of the coating is likely to sluff off due to the elements or building maintenance. While the author does not know of any studies to show localized contamination from fluoropolymer paints, the harmful chemicals will be released into the larger environment, in addition to the toxins emitted in the original manufacture of them.

Phthalates, used as plasticizers, were once often employed in paint products. Some of these chemicals can be carcinogens, developmental and reproductive toxins, endocrine disruptors, and environmental toxins. While their use is now discouraged by the paint industry, phthalates can still be found in certain specialty products such as anticorrosion coatings.

More worrisome is their use in legacy paints. As an example of their harmful effects, phthalates in house dust have been associated with behavioral changes in children such as problems in communication and increased hyperactivity. (Philippat, et al., *Environmental Health*, June 26, 2015.)

Short chained chlorinated paraffins (SCCPs) are organochlorines used as plasticizers and flame retardants in certain specialty paints. Like PFCS, they are persistent bioaccumulative toxins, and can be found in the bodies of humans and wildlife worldwide. They are toxic to aquatic organisms at low concentrations, and a possible human carcinogen.

Painting the Town Green

The chart below depicts a relative hierarchy of how different classes of paints perform in regards to health and the environment.

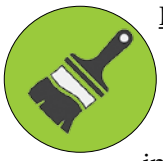
CHART P4 – PAINT RATINGS FOR THE INDOOR ENVIRONMENT (From Best/Green to Worst/Red)
Natural Paints
Low Biocide/Low Additive Paints
Mineral-Based Paints
Greenseal-Rated GS-11 with No APEs and Low Volatile Organic Compounds (VOCs)
No APEs and Low Volatile Organic Compounds (VOCs)
Air Purifying Paints
Least-Toxic Paint Removers
Low-VOC Paints
Standard Paints
Recycled Paints
Specialty Paints
Antimicrobial Paints
Lead Paint in Older Houses
Teflon™-like Paints

Natural Paints, Stains, and Varnishes: Some commercial coatings are made with all-natural or partially natural ingredients, including vegetable oils, plant resins, minerals, plant and earth pigments, and milk. Some manufacturers make their products with 100% natural ingredients, while others mix least-toxic synthetic solvents with their brands. These coatings are often durable and wash easily. But they can cost 2 to 3 times that of conventional products due to the cost of materials, the small scale of the manufacturers, and the fact that some of them are imported. The variety of colors is not always as great as conventional paints, and they are available only by mail order or through a few specialty stores. See Chart P5.

Low-Biocide/Low-Additive Paints: Some coating products use conventional synthetic materials, but reduce or eliminate toxic additives that make them unbearable to chemically-sensitive people and somewhat harmful to the general public. These paints reduce or eliminate exposure to biocides and fungicides

that are normally put in paints to preserve them from bacteria, mold, mildew, and insects, and that protect the painted wood.

These paints will usually have no- or low-VOCs, and also avoid other conventional additives like ammonia and antifreeze. Some of these products may supplement their ingredients with biobased materials. These paints have similar quality characteristics compared to conventional products, and some brands provide a wide array of colors. But the shelf life is greatly reduced, particularly after the can is opened. And these paints may be difficult to use in areas of high humidity, like bathrooms, or exteriors in wet climates, because they are susceptible to attacks by fungus and mildew. A problem with this category is that there is no independent rating criteria for "least-toxic paint," or third-party organization to enforce such a criteria if it existed. Consumers are advised to order samples to determine how it affects them personally. See Chart P6.



Mineral-Based Paints: There is a growing niche market for coatings that employ minerals instead of organic resins as a coating. Liquefied potassium silicate, often mixed with mineral pigments, can be used on both interior and exterior walls to create a durable "waterglass" paint. Unlike organic resins that can eventually wither with moisture, temperature, and UV radiation, mineral-based paint bond with the substrate it is applied to and can last for decades. There are some buildings in Europe where the coating has stayed intact for over a century.

The paint is permeable, allowing the walls to breathe, with zero VOCs. Since it is not organic, it is mold, mildew, and algae resistant, eliminating the need for biocides. Any unused paint from the application solidifies as pure minerals and is non-toxic.

Most of these products are applied to mineral-based building materials such as stone, brick, plaster, and cement, but variations can also be used for wallboard and wood.

Chart P5 – Natural Paint Coating Manufacturers

Manufacturer	Product Name	Phone	Web Site
Anna Sova	Natural paints with milk and food-grade ingredients.	(214) 742-7682	annasova.com
Auro	Natural paints, primers, finishes, stains, oils, and adhesives.	(541) 733-8204	aurousa.com
BioShield Paint	Paints, finishes, thinners from natural materials.	(505) 438-3448	bioshieldpaint.com
Eco Safety Products	Partially biobased paints, stains, finishes, and paint strippers.	(877) 366-7547	ecosafetyproducts.com
Livos	Organic paint, stains, oils, and waxes made from plant oils, fibers and minerals.	(208) 317-3545	livosusa.com
Master's Blend	Tung and nut oil for woodwork and floors, furniture, brick and concrete.	(860) 651-5536	mastersblendfinish.com
Natural Soy Products	Partially biobased wood stain, sealer, and paint stripper.	(844) 606-9558	naturalsoyproducts.com
Sansin Corporation	Partially biobased wood stains, sealers, and paint strippers.	(877) 726-7461	sansin.com
Sinan	Natural paints, primers, waxes, stains, lacquers, and enamels.	(530) 753-3104	sinanco.com
The Real Milk Paint Co.	Milk paint with earth pigments, natural paint removers, oils, and waxes.	(800) 339-9748	realmilkpaint.com
Timber Pro	Partially biobased wood finishing products.	(888) 888-6095	timberprocoatingsusa.com
Unearthed Paints	Paints and oils made with plant base, cellulose, earth, mineral pigments.	NA	www.unearthedpaints.com
Weather-Bos	Natural oils and resins designed to protect roofs, decks, masonry, and boats.	(800) 664-3978	weatherbos.com

Chart P6 – Low Biocide/Low Additive Coating Manufacturers

Manufacturer	Product Name	Phone	Web Site
AFM Safecoat	Least-toxic and plant-based paints, stains, and finishes. Zero or low-VOCs; no biocides.	(619) 239-0321	afmsafecoat.com
Earthpaint	Least toxic and plant-based paints, stains, finishes, and solvents.	(828) 258-2580	earthpaint.net
EarthSafePaints	Zero- and Low-VOC line of paints and finishes, craft paints, and BPA-free epoxy.	(803) 597-5037	earthsafefinishes.com
ECOS Paints	Zero-VOC, no ethylene glycol, hypoallergenic paints, varnishes, and wood stains. Also specialty VOC absorbing paints. Ingredients are third-party verified.	(866) 587-3586	ecospaints.net
EnviroSafe Paint	Hypoallergenic paint with no VOCs, biocides, crytalline silica, or antifreeze.	(512) 326-4474	envirosafepaint.com
Green Planet Paints	Zero-VOC, partially biobased interior paints with no biocides.	(866) 995-4442	greenplanetpaints.com

Chart P7 – Mineral Paint Coating Manufacturers

Manufacturer	Product Name	Phone	Web Site
Edison Coatings	Mortar and concrete coatings supplier includes two sillicate-paint products.	(800) 341-6621	edisoncoatings.com
KEIM Mineral Coatings of America	Sales rep for first commercial manufacturer of mineral paint (1878). Its products coat ceramics, stone, and wood. (Wood coating has oil-based primer.) Products include paint that photochemically cleans air.	(866) 906-5346	keim-usa.com
PermaTint	Silica-based paints, stains, and primers for interior & exterior use.	(905) 764-7503	permatint.com
Romabio	Potassium silicate paint with small percentage of inert/organic binders. Can be used on wood and sheetrock as well as ceramics and stone.	(678) 905-3700	romabio.com
Silacote	Liquid potassium silicate base with mineral pigment for use on masonry, concrete, and wallboard.	(800) 249-1881	silacote.com

(Products appropriate for wood use a small amount of organic ingredients.) See Chart P7.

Paint with No Alkylphenol Ethoxylates and Low VOCs: Conventional paint that emits low VOCs without the addition of endocrine disrupting chemicals is considered a high standard. Green Seal, a third-party certification organization for environmental products, currently has a "GS-11" standard for such paints. Unfortuntaely, only one company has officially attained this status with some of its products, and only one other company has produced no-APE/low-VOC products (without verification). See Chart P8.

Air Purifying Paints: As air quality became a larger environmental concern over the last few decades, paint companies began making products with very low or no VOC emissions. However a few companies have gone even further by offering paint that actually eliminates VOCs emitted from other sources.

Used indoors, these products remove emissions from sources such as carpets, furniture, cleaning chemicals, and indoor combustion such as gas stoves. Outdoors, they can reduce emissions from autos and industrial sources. One of the side benefits of this paint class is that it keeps the exteriors of buildings as well as the infrastructure on the sides of highways (such as walls, bridges and tunnels) cleaner. This technique can be used in either organic or mineral-based paints.

There are two different chemistries to achieve this. One is a photocatalytic process using a form of titanium dioxide. In the presence of natural light and some forms of artificial light, the catalyst degrades noticeable percentages of VOCs, ammonia, carbon monoxide, as well as airborne bacteria and fungi, into nitrates, carbon dioxide, and water vapor.

Some products in this paint class have their flaws. In organic-based paints, the catalyst can wear away over time, particularly when exposed to the weather. The catalyst can also attack organic paint itself even when indoors, shortening the life of the paint and making the photocatalyst less effective. However, Keim, the producer of a mineral-based photocatalytic paint, believes little or no degradation will occur because the catalyst is protected by the product's water-glass finish, and because there is little organic material in the coating to begin with.

The second approach uses a non-toxic zeolite "tube" or crystal that allows smaller molecules to pass through it unimpeded while trapping larger VOC molecules in the lattice. This approach can also degrade over time as the paint becomes saturated. At least one of the U.S. suppliers suggested that a new coat of this paint be applied every 2 to 7 years for optimal air-purifying effectiveness. (The frequency of reapplication is dictated by the amount of pollutants in a given location.)

Tests for this paint class have shown measured VOC reductions on both a generic and individual product level in laboratory tests as well as real-world building interiors and exteriors, removing between 10 and 100% of various pollutants.

Chart P9 lists products in this paint class sold in the U.S.

Least-Toxic Paint Removers: Certain chemical paint stripper ingredients are highly toxic. Among the most dangerous is Methylene Chloride. This chemical can cause severe burns to the skin and eyes, and irritates sinuses and the respiratory tract. It is acutely toxic to the central nervous system, causing dizziness, nausea, memory loss, and even death at high dosages. It has been linked to more than 60 deaths in the U.S. since 1980. Further, it is damaging to internal organs, carcinogenic, and mutagenic. There is limited evidence that it causes spontaneous abortions. It is also flammable.

N-Methylpyrrolidone (NMP) dangers include being a developmental toxin that can cause miscarriages and stillbirths. It can cause decreased fetal weight, which can lead to developmental problems throughout a child's life. NMP can also cause weight reduction, kidney and liver toxicity, and neurotoxicity.

Chart P8 – Manufacturers of Low-VOC Paint without APEs

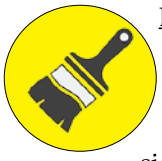
Manufacturer	Product Name	Phone	Web Site
Benjamin Moore & Co	**Eco Spec WB®:** Primer; Flat; Eggshell **Natura® Interior:** Primer; Flat; Eggshell **Ultra Spec 500®:** Primer; Flat; Eggshell; Semi-Gloss; Gloss	(855) 724-6802	benjaminmoore.com
Sherwin-Williams Company	**Emerald®:** Flat; Satin; Matte; Semi-Gloss **Harmony®:** Flat; Primer **ProMar 200®:** Low-Gloss Eg-shell; Eg-shell; Zero-VOC Semi-Gloss	(800) 474-3794	sherwin.com
Benjamin Moore GreenSeal-certified. Sherwin Williams reported but not certified.			

Chart P9 – Air Purifying Paint Manufacturers

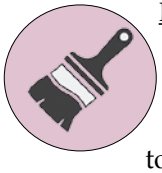
Manufacturer	Product Name	Phone	Web Site
ECOS Paints	Air Purifying Paint; Primer; Varnish; Anti-Formaldehyde Paint; Anti-Formaldehyde Radiator Paint; Trim & Furniture Paint	(866) 587-3586	airpurepaints.com
KEIM Mineral Coatings of America	Ecosil®-ME	(866) 906-5346	keim-usa.com
Sherwin-Williams Company	Harmony®	(800) 474-3794	sherwin.com

Several major chain stores, including Home Depot, Sherwin-Williams, and Lowe's, announced that they were phasing out or banning sale of Methylene Chloride paint strippers by the end of 2018. These chains also would not sell or were phasing out the sale of paint removers with NMP.

Chart P10 contains a list of least-toxic chemical paint removers reviewed by the South Coast Air Quality Management District in California. The District recommends against Methylene Chloride and NMP as ingredients.



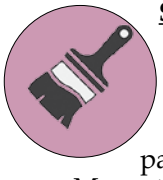
Low-VOC Paints: VOC emissions have plummeted since they first became a concern in the 1980s. Today, almost all major paint manufacturers offer products with low- or zero-emissions. However, the reduced emissions are often for the base and not the tints. The products in Chart P11 include paints with rated emissions generally between 0 and 10 grams per liter *inclusive* of VOCs emitted from colorants. *Consumers should verify this with the manufacturer or dealer at time of purchase.*



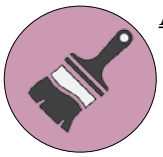
Recycled Paints: Americans generate between 50 and 130 million gallons of leftover paint each year. Many cities and several private companies collect unused but still usable paint and reblend it with virgin paint or factory seconds to sell as an inexpensive primer.

Many brands have limited color palettes, though some companies have expanded color palettes for more general use. While recycling prevents resources from being disposed, recycled paints can emit VOCs several times higher than most new products on the market today, and still retain toxic additives that newer products have reduced or eliminated. Chart 12 contains a list of some of these products.

Not Recommended



Specialty Paints: Some paints that target niche markets contain ingredients that are more toxic than common paint. Chlorinated paraffins, which are possible carcinogens, are used to create fire resistance. "Dry-Erase" paints contain isocyanates, which are asthmagens. Magnetic paint can contain solvents that damage the central nervous system. These and other specialty paints with high chemical risks should be avoided.



Antimicrobial Paints: Another kind of specialty paint adds extra levels of biocides. Many consumers infer that this will kill more disease causing pathogens. In fact, it is possible that pathogens will actually mutate and become resistant to biocides and antibiotics from this wanton chemical use. Meanwhile, people themselves may be vulnerable to the effects of these biocides, and pay a monetary premium for the privilege.

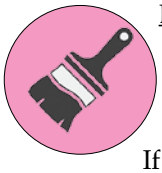
Chart P10 – Least-Toxic Paint Remover Manufacturers

Product Name	Manufacturer	Phone	Web Site
PREFERRED			
Crown Paint Strip Next	Packaging Service Company	(281) 485-1458	packserv.com
Hi-Speed Ready-Strip	Sunnyside Corporation	(847) 541-5700	sunnysidecorp.com
Motsenbocker's Lift Off Paint and Varnish Remover	Motsenbocker	(800) 346-1633	liftoffinc.com
Piranha NexStrip Pro	Fiberlock Technologies	(800) 342-3755	fiberlock.com
Safest Stripper™ Paint and Varnish Remover	3M	(866) 556-5712	3m.com
Smart Strip	Dumond Chemicals	(800) 245-1191	dumondchemicals.com
ZipStrip Premium Green Paint and Finish Remover	Absolute Coatings	(800) 432-4333	absolutecoatings.com
These products contain chemicals that can irritate the skin, eyes, nose, and throat. Gloves and chemical safety goggles and/or face shield should be worn. People with asthma should avoid using these products.			
USE WITH CAUTION			
Piranha 8	Fiberlock Technologies	(800) 342-3755	fiberlock.com
Peel Away 1	Dumond Chemicals	(800) 245-1191	dumondchemicals.com
These products can produce serious skin and eye injuries if not used safely. They should be used only while wearing chemical safety goggles and face shield to protect against splash, and gloves are recommended for caustics.			

Chart P11 – Low-VOC Paint Coating Manufacturers With No-VOC Colorants
(Generally 0 to 10 grams/liter)

Manufacturer	Product Name	Phone	Web Site
AFM Safecoat	Zero VOC in Flat; Eggshell; Pearl; Semi-Gloss	(619) 239-0321	afmsafecoat.com
Benjamin Moore & Co	Aura® Bath & Spa; Aura® Interior; ben®; Eco Spec WB®; Eco Spec WB® Silver; Natura®; Regal Select®; Ultra Spec 500®; Waterborne Ceiling Paint	(201) 573-9600	benjaminmoore.com
Colorhouse	Interior Multi-Purpose; Inspired	(503) 493-8275	colorhousepaint.com
Dunn Edwards	ACRI-WALL®; EVEREST®; INTER-KOTE® Primer; SPARTAZERO®; ULTRAGRIP® Select; VINYLASTIC® Premium; VINYLASTIC® Select	(888) 337-2468	dunnedwards.com
Kelly-Moore	AcryPlex®; Kel-Pro®; Premium Professional®	(916) 921-0165	kellymoore.com
Sherwin-Williams Company	Eco Select®; Emerald® Interior; Emerald® Designer Interior; Harmony®; ProMar® 200 Zero VOC; ProMar® 400 Zero VOC	(800) 474-3794	sherwin-williams.com

Chart P12 – Recycled Paint	
Product/Company	**Web Site**
Acrylatex	acrylatex.com
Amazon Environmental	amazonpaint.com
Austin Habitat for Humanity	austinhabitat.org
Austin Reblend (free to indiv.)	austintexas.gov/department/austin-reblend
GDB International	gdbpaint.com
Legacy Paints and Coatings	legacypaints.com
Visions Paint Recycling	visionsqualitycoatings.com



Legacy Paints with Lead: Unlike other undesirable products listed in this article, one cannot buy lead paint today. Rather, it is embedded in significant doses in the structures of about 16% of residences in the U.S. If the building was constructed before 1978, there is a risk that it could be contaminated with lead paint. While this can potentially be dangerous to anyone, in the particular cases of pregnant mothers and small children, it could cause health problems if action is ignored.

There are 4 techniques for lead abatement in homes.

• *Encapsulation* covers lead-coated surfaces with another coating that acts as a barrier to hold the lead in place; it keeps it from migrating to the indoor or outdoor environment.

• *Encasement* covers lead-coated surfaces with uncontaminated building materials such as new wallboard.

• *Removal of building materials* replaces house parts contaminated with lead paint.

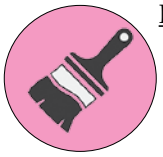
• *Removal of lead paint on existing building materials* extracts lead from inside the building.

These various techniques have advantages and disadvantages, and may not be suitable in all situations. Removal of lead paint inside buildings is expensive, requiring isolation of the affected area, along with workers that don HazMat suits who are equipped with gloves and respirators. As a rule, encapsulation is the least expensive strategy.

As well as chemical hazards, people using oil paints and paint solvents (including plant-based formulas) should be aware of the hazards of auto-oxidation. Rags and paint application materials soaked in these liquids can literally autocombust under certain situations. One way to mitigate this is to soak these materials in water, and then place them in a sealed plastic bag for disposal.

Chart P13 contains a list of encapsulation products and paints that act as a lead-paint barrier. In general, they are best applied by trained specialists. Note that some building materials that have constant wear are not appropriate for encapsulation. For instance, windows and doors generate friction when they are opened and closed, which will wear away encapsulants and re-expose the old lead coatings. These materials are often candidates for removal.

Also, encapsulants must be periodically inspected and maintained if the barrier is marred or damaged.



Fluoropolymer (Teflon™-like) Paint: Fortunately, these products are not widely used in the residential market, but when encountered, they should be rejected because of their adverse health and environmental effects.

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Chart P13 – Lead Encapsulant Manufacturers			
Product Name	**Manufacturer**	**Phone**	**Web Site**
Barrier Coat II	Fiberlock Technologies	(800) 342-3755	fiberlock.com
BTN Exterior Encapsulant	Sunnyside Corp	(800) 323-8611	sunnysidecorp.com
ChildGuard	Fiberlock Technologies	(800) 342-3755	fiberlock.com
Ecobond® LeadDefender® *	Ecobond	(888) 520-7132	ecobondlbp.com
L-B-C Lead Barrier Compound	Fiberlock Technologies	(800) 342-3755	fiberlock.com
Lead Block®	Insul-X	(855) 724-6802	insl-x.com
Lead Stop®	Dumond Chemicals	(609) 655-7700	dumondchemicals.com
LeadLock™	Global Encasement	(800) 266-3982	encasement.com
LeadX™	Synavax	(800) 858-3176	synavax.com
Protect-A-Coat Lead Encapsulant	Sunnyside Corp	(800) 323-8611	sunnysidecorp.com
SE-110-MS Penetrating-Stabilizer	SAFE Encasement Systems	(888) 277- 8834	safeencasement.com
SE-120 Protective-Skin	SAFE Encasement Systems	(888) 277- 8834	safeencasement.com
**This product is a paint and not a true encapsulant*			

Environmental/Health Ratings for Paint

In addition to the ranking of generic products and listing of specific products in this article, various agencies and institutions have created rating systems to judge paints and coatings. Below is a short list. Their Web sites give information on specific products that meet their criteria.

Biopreferred
biopreferred.gov
Hosted by the U.S. Department of Agriculture, this program lists products, including paints and coatings, that contain a minimum percentage of biobased ingredients.

Cradle to Cradle Products Innovation Institute
c2ccertified.org/products/registry
This non-profit organization manages a comprehensive rating system for building materials. Cradle to Cradle rates on 5 criteria: Material Health; Material Utilization; Renewable Energy and Carbon Management; Water Stewardship; and Social Fairness. These separate ratings are then combined into an overall score. Unfortunately, few paint products sold in the U.S. were rated for this standard at the time of publication.

GREENGUARD
spot.ul.com/main-app/products/catalog/?keywords=
This certification system administered by Underwriters Laboratories measures for VOCs emitted from many product categories, including paint. It has two tiers: its standard GREENGUARD rating; and its premium GREENGUARD Gold rating. As of the date of this publication, there were almost 1,200 products rated by this higher standard.

GreenSeal
greenseal.org/certified-products-services
This rating system administered by a non-profit organization has a comprehensive evaluation for environmental paints and coatings. Its "GS-11" standard strictly limits VOCs in both the base paint and tints, restricts the use of various dangerous chemicals as ingredients, mandates packaging that has a certain percentage of recycled content or is recyclable, and requires that key information be disclosed on the product label. Unfortunately, only one U.S. paint brand had even some of its products rated for this standard at the time of publication (Benjamin Moore).

GreenSeal also has its "GS-43" recycled paint standard that requires minimum percentages of post-consumer content, proof of origin for the recycled paint sources, and a maximum VOC limit. Again, only one U.S. paint brand was rated for this standard at the time of publication (GDB International).

Indoor Advantage
scsglobalservices.com/certified-green-products-guide
Scientific Certification Systems, Inc. is a private company now operating as SCS Global Services. It certifies third-party verifications of environmental claims. It has two tiers of VOC ratings for the paint that it rates, the Indoor Advantage program and the premium Indoor Advantage Gold program. Over 100 U.S. paint products were rated for this higher standard at the time of publication.

South Coast Air Quality Management District (SCAQMD)

In parts of Southern California, stagnating air pollution hazards are particularly acute. SCAQMD contains the greater Los Angeles area and an area to the east that almost reaches to the state's eastern border. It has a population of almost 15 million and a territory of almost 11,000 square miles.

The District has great latitude to regulate air emissions, including standards for VOCs from paints. SCAQMD maintains two databases on these products.

1. Architectural Coatings Database
aqmd.gov/home/rules-compliance/compliance/vocs/architectural-coatings/pub-db
This is a searchable database of coatings sold in the District that comply with its VOC standards (Rule 1113). Information is updated annually and comes from the annual reports submitted by the manufacturers. The data can be sorted by the level of VOCs, making it one way to find low-emission products. Consumers outside SCAQMD would need to make sure that the same products they are seeking are sold in their own region.

2. Super Compliant Coatings Manufacturers List
aqmd.gov/home/rules-compliance/compliance/vocs/architectural-coatings/super-compliant-coatings
This list contains products sold by manufacturers/suppliers that have informed the District that they meet its "super-compliant" VOC standard of less than 10 gram per liter. This listing is strictly voluntary and does not require third-party verification of compliance. Again, consumers outside SCAQMD would need to make sure that the same products they are seeking are sold in their own region.

Safety Data Sheets (SDS)
These legally required summaries of potential product hazards are usually found on manufacturers' Web sites. There are shortcomings for SDS information. Due to trade secrets, percentages of ingredients listed are often in vague ranges. And SDS rules only require listing of hazardous ingredients if they make up more than 1% of a product, and carcinogenic ingredients if they make up more than 0.1% of the product.

Health Product Declaration Collaborative
hpd-collaborative.org/hpd-public-repository/
This non-profit member association creates Health Product Declarations (HPDs). HPDs allow product manufacturers to disclose information about the chemical ingredients of their products and associated health information that is more detailed than Safety Data Sheets. By promoting ingredient transparency and disclosure, HPDs enable consumers to make more informed decisions and motivate manufacturers to adopt healthier chemical ingredients.

HPDs of specific products can be accessed at its Web site.

CAULKING AND SEALANTS
Not an Airtight Case

Skull: Park Ji Sun /Shutterstock.com Tubes: brakeandexit/Shutterstock.com

In 2017, the Adhesive & Sealant Council estimated that 446 million pounds of caulking and sealant was sold to the U.S. construction and retail consumer market. This is roughly equivalent to about 900 million tubes of caulking a year.

Caulking is rarely noticed in the context of a home. However, it has at least two important environmental attributes. First, it saves a great deal of energy. Though homes built today are much more efficient than new homes built in the 1970s, in that era, the average dwelling had about one square yard of cumulative cracks and openings where energy used to heat and cool the home was lost. Caulking and weatherstripping prevent a noticeable percentage of this lost energy, along with the harmful environmental effects from this energy's production and consumption. Second, these materials create barriers to keep bugs out, protecting health while also preventing the greater use of conventional pesticides, which are harmful to people as well as insects.

However, less attention has generally been paid to the environmental effects of the material itself. Unlike other building materials such as paints, which have improved over time or that allow the use of more benign product alternatives, relative environmental progress in caulking and sealing products is not as advanced.

Environmental Sticking Points

Various caulking and sealant products in the U.S. employ a number of chemistries. Almost all of them are based on petrochemicals. This author was not able to find any caulking products on the market at the time this article was published that were even partially plant-based. The more benign products on the market either use minerals or least-toxic acrylic polymers as their main ingredients. (This contrasts to other building product categories such as paints and flooring, where a number of alternative products are partially or totally petrochemical free.)

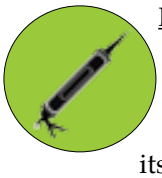
In addition to the chemical base, many caulking products contain a number of additives that can adversely affect health: toxic solvents that emit VOCs (Volatile Organic Compounds); biocides; phthalates; organotin catalysts; isocyanates; antifreeze; and flame retardants.

CAULKING RATINGS FOR THE INDOOR ENVIRONMENT (From Best/Green to Worst/Red)
Non-Combustible Sodium Silicate Caulking
Least-Toxic Caulking
Expanding Polyurethane Foam Sealant Tape
Acrylic Latex Caulking
Siliconized Acrylic Caulking
Intumescent Acrylic Firestop Caulking
One-Component Silicone Caulking
Modified Polymer Sealant (STPE Caulking)
One-Part Polyurethane Spray-Foam Caulking
One-Component Polyurethane Caulking

This article will first discuss the generic types of caulking and sealants, ranked by their relative health effects.

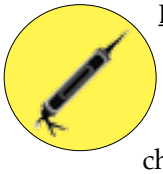
Following this, there will be a chart of least-toxic products. Most of them cannot be labeled "green," but at least they can be considered "gray" (as opposed to "black"). Additives in these products will also be discussed. *Not all products will have all of these additives, and while sometimes these additives will make up noticeable percentages of the products, other times they will only be present in small amounts. So look for the products that are the least contaminated.*

Cutting Open the Tube – Generic Caulks

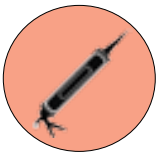


Non-Combustible Sodium Silicate Caulking – This water-based product, also known as "fire caulk," is largely mineral based. Common ingredients include various kinds of silica, kaolin clay, and ferric oxide. While its health effects are relatively benign, its utility is limited. It is a mortar caulk used for fireblocking by sealing penetrations around ducting, and electric and plumbing penetrations. It is also not recommended for areas that come in contact with water.

Least-Toxic Caulking – This uses more benign polymers such as acrylic latex, but leaves out most or all of the toxic additives. These products are usually more tolerated by people who are chemically sensitive.

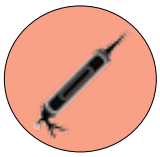


Expanding Polyurethane Foam Sealant Tape – Strips of pre-cut expandable polyurethane foam are manufactured with a self-adhesive back. While polyurethane uses isocyanates, a potent asthmagen, in the case of tape, the chemical is reacted off-site in the manufacturing process. Again though, this type of sealant has very limited applications, and is often used to seal around windows and doors.

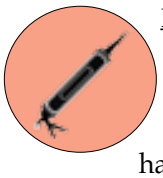


Acrylic Latex Caulking – This caulk is based on a water-based chemistry using relatively benign synthetic polymers, though most conventional products have toxic additives that can be injurious to health. Often mineral fillers make up the majority of it.

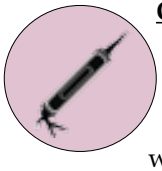
Higher quality products can last up to 10 years, can be sanded and painted, and smoothed and formed with a moist finger. It has little flexibility however, and needs to be painted if used outdoors. Most acrylic caulks will not adhere to metal.



Siliconized Acrylic Caulking – This class of product is a hybrid that mixes a small amount of silicone caulking chemicals with acrylic caulk to enhance adhesion to wet surfaces. It is also water-based and paintable.



Intumescent Acrylic Firestop Caulking – Unlike silicate fire caulk, this product used in fire-rated assemblies has an acrylic base with filler materials that expand when exposed to high temperatures. Like silicate fire caulk, it has limited utility outside of this niche.

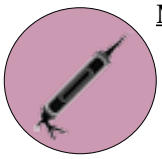


One-Component Silicone Caulking – Silicone sealants are generally made of an inorganic base of silicon and oxygen. They also include mineral fillers such as silica. However, a small percentage of silane chemicals with hydrocarbons are used as curing agents. These have an unpleasant smell until it dissipates, and can contain reproductive toxins and endocrine disruptors.

Silicone is considered a higher quality product, valued for its flexibility and its endurance to extreme weather, UV radiation, mold, and mildew. This also makes it valuable in humid indoor locations such as bathrooms. However, many silicone products are unpaintable, and they are not water-based, so they require solvents to clean after application.

Silicone caulks cure quickly and can withstand rain almost immediately. They adhere well to glass, metal, tile, and porcelain. They do not, however, adhere to wood or (ironically) damaged, previously applied silicone caulk.

One-Part Polyurethane Spray-Foam Caulking – Canned spray-foam products are typically used to seal around building-shell penetrations such as window and doors. All polyurethane products contain isocyanates, which are potent asthmagens and allergens, particularly for workers and chemically sensitive people. These also include blowing agents, some of which are toxic. And some can include toxic flame retardants. They also require solvents for clean up after application.



Modified Polymer Sealant (STPE Caulking or MS-Polymers) – This product class, also known as "hybrid sealants," uses modified polypropylene oxide as its base, combining the positive characteristics of silicon or polyurethane caulks without many of their problems.

It is: water-based (solvent-free); paintable; stain and dirt resistant; flexible; cures quickly; can be applied in low temperatures; is easily stored; and incredibly weather-resistant. It avoids isocyanates (potent asthmagens) needed in polyurethanes for curing. It can be used with most construction materials, though it should be avoided on glass.

One-Component Polyurethane Caulking – As stated previously, one of the main chemical families that makes up polyurethane is isocyanates, potent asthmagens. This solvent-based class of caulk is the more potent than can spray caulk. The product is more dense than foam polyurethane and contains more isocyanates by volume, so it is considered a poorer environmental choice.

Polyurethane caulk, like silicone, is also considered a higher quality product because of its ability to withstand extreme weather, flexibility, and (unlike silicone) paintability. Moreover, it also has the salient quality of being abrasion resistant, which is important for places such as floor joints. It is difficult to install in cold weather.

Environmental/Health Ratings for Caulking

Most products on the following page have been rated as Underwriters Laboratories' GREENGUARD Gold or Scientific Certification Systems' Indoor Advantage Gold for VOC emissions at the time of publication. AFM and Chem Link products are listed because they have a reputation for tolerance by the chemically sensitive. However, they were not graded by ratings organizations.

Ingredients this author thought were of particular concern, found in Safety Data Sheets (SDS), were listed along with their hazards. Some theoretically dangerous ingredients were not listed here. For instance, crystalline silica, contained in some caulking materials, is considered a carcinogen if inhaled, but unless one breathes the dried dust frequently (e.g., occupationally), it will usually not be a major health concern.

Safety Data Sheets have shortcomings. Due to trade secrets, ingredient percentages are often vague. SDS only require listing of hazardous ingredients if they make up more than 1% of a product, and carcinogenic ingredients if they make up more than 0.1% of the product.

The Health Product Declaration Collaborative is a non-profit that creates Health Product Declarations (HPDs). HPDs disclose more chemical information than Safety Data Sheets. HPDs of specific products can be accessed at: hpd-collaborative.org/hpd-public-repository/

Hazardous ingredients listed here are of concern to the author, but readers are encouraged to consult SDS and other information themselves if they are more cautious. Chemical hazards are relative to many situations such as the degree of outgassing that has taken place, the percentage of ingredient in the product, and personal contact with the chemical over time.

Least-Toxic Caulking/Sealant Products

Manufacturer and Products	Web Site	VOCs *Grams/ Liter*	Codes for Ingredients of Major Concern
Firestop	**firestop.com**	**SCS Gold Rated**	
3600EX		37.1	1
4800DW		32.5	1
Prosoco	**prosoco.com**	**SCS Gold Rated**	
FastFlash®		30	21, 35
AirDam®		30	21, 35
Grabber Products	**grabberman.com**	**GREENGUARD Gold Rated**	
GrabberGard EFC		32.5	1
GrabberGard IFC		37.1	16
Henkel – LePage	**lepage.ca**	**GREENGUARD Gold Rated**	
LePage® No More Nails® Paneling and Moulding		37	25
LePage® No More Nails® Wet Grab		48	27,34
LePage® Greenseries™ Draft & Sound		45	13
Henkel – Loctite	**loctiteproducts.com**	**GREENGUARD Gold Rated**	
PL Premium® PU Construction		45	3, 10, 11
PL Premium® Fast Grab Construction		22	10, 11, 29
Power Grab® Express All Purpose		14	25
Power Grab® Express All Purpose Acrylic		27	25
Power Grab® Express All Purpose Pressure		14	1
Power Grab® Express Heavy Duty		27	25
Power Grab® Express Paneling/Moulding		27	2, 25
Power Grab® Ultimate Construction		48	27, 34
Power Grab® Tub Surrounds		27	25
Stik'n Seal® No Mess Adhesive		NA	1
Henkel – OSI	**ositough.com**	**GREENGUARD Gold Rated**	
H2U® High Performance Sealant		42	13
GreenSeries™ F-38 Drywall & Panel		49	13
GreenSeries™ SC-175 Draft & Acoustical		45	13
GreenSeries™ SF-450 Heavy Duty		<8	17, 22
Holdrite	**holdrite.com**	**GREENGUARD Gold Rated**	
HydroFlame™ 50 Smoke & Acoustic		<10	1
HydroFlame™ 100 Firestop Sealant		<10	1
HydroFlame™ 200 Firestop Sealant		<10	1
Inpro Corporation	**inprocorp.com**	**GREENGUARD Gold Rated**	
Fastfill™ Caulk		<25	9 ,21, 28
Liquid Nails	**liquidnails.com**	**GREENGUARD Gold Rated**	
Liquid Nails® Foamboard Adhesive N-604		32	1
PPG	**ppgpaints.com**	**GREENGUARD Gold Rated**	
TOP GUN® 200		20	7
NUCO	**nucoinc.com**	**GREENGUARD Gold Rated**	
Self Seal® SL-100 Silicone Firestop		25	1
Self Seal® GG-200 Silicone Firestop		25	1
Self Seal® GG-266 Intumescent Silicone Firestop		25	15
Nuflex® 302 Bath & Kitchen		30	31
Nuflex® 302 General Purpose		30	31
Nuflex® 309 Metal & Vinyl		NA	31
Nuflex® 311 Self-Leveling Silicone Joint		NA	1
Nuflex® 319 Glazing Silicone Sealant		NA	9, 31
Nuflex® 331 Exterior Siding & Trim Silicone		NA	9, 31
Sherwin-Williams	**sherwin.com**	**GREENGUARD Gold Rated**	
950A Siliconized Acrylic Latex Caulk		46	25
Loxon™ S1 One Component Polyurethane		30	8, 12, 14, 36, 38
Powerhouse® 1100A Siliconized Acrylic		34	13, 25
White Lightning® Silicone Ultra Kitchen/Bath		27	18, 20, 31
White Lightning® Speed Grip Construction		2	1
White Lightning® 3006 Quick Dry™ White		46	25
White Lightning® 3006 Ultra®		39	25
White Lightning® 3006™ Advanced Formula		46	25
White Lightning® All Purpose Silicone		31	9, 23, 30, 31, 33
Tremco	**tremco.com**	**GREENGUARD Gold Rated**	
Dymonic® FC		6	8, 24, 26, 35, 34
Fyre-Caulk		10	5, 6, 40
Proglaze® SSG		8	9, 32, 34, 35
Proglaze®		36	19, 30
Spectrem® 1		1	3, 35
Spectrem® 2		34	32
Spectrem® 3		13	8, 24, 26, 34, 35, 39
Tremflex® 834		13	5
TremGlaze® SA1100		14	3, 5, 6
TremPro® 644		0	23, 30
TremPro® 644 RTV		0	23, 30
TremPro® 645		0	1
Tremsil® 200 w/o Fungicide		0	4, 23, 30
TREMstop® IA+		26	5, 6, 37
TREMstop® Fyre-Sil		26	1
USG Sheetrock®	**usg.com**	**GREENGUARD Gold Rated**	
Firecode® Smoke-Sound Sealant		<15	13
Acoustical Sealant		15	13
AFM	**afmsafecoat.com**	***Listed By Reputation***	
Safecoat® Caulking Compound		14.5	1
Chem Link	**chemlink.com**	***Listed By Reputation***	
M-1® Universal Adhesive & Sealant		17	1
M-1® CR Clean Room		14	1
NovaLink® 35		14	1
ChemLink Clear		14	1

Codes and Dangers for Hazardous Ingredients in Caulking
Blue = Highest Hazard
Purple = High Hazard
Orange = Medium Hazard

Hazards from Healthy Building Network Pharos database.

	Carcinogenic	Gene Mutation	Bioaccumulative Toxin	Developmental Toxin	Reproductive Toxin	Endocrine Disruptor	Respiratory Toxin	Organ Toxicant
1 No Major Concerns								
2 Acetone				P	O	O		P
3 Aluminum oxide							P	P
4 Ammonia				O		O	P	B
5 Ammonium hydroxide							P	B
6 Biocide – Chlorothalonil	P				O	O	P	O
7 Biocide – Proxel								P
8 Calcium Oxide	P			O				B
9 Carbon Black	P							P
10 Diisocyanate – Diphenylmethane	O			O			P	O
11 Diisocyanate – Methylenediphenyl	O						O	O
12 Diisocyanate – Tolylene	P						P	O
13 Ethylene Glycol				P		O		B
14 Ethylhexanoic acid				O	O	O		P
15 Melamine Resin	P					O		
16 Methacrylic acid							P	
17 Methyl acetate				O				B
18 Methyl Ethyl Ketoxime	P							P
19 Organotin – Dibutyltin Diacetate	O			P	P			O
20 Organotin – Dibutyltin Dilaurate	O	O		P	P	O		P
21 Organotin – Tin, Dibutylbis	O			P				
22 Petroleum – Resins	P							
23 Petroleum – Middle Distillates	P		B					
24 Petroleum – Heavy Naphthenic	P		B	O				
25 Petroleum – Light Aliphatic	O		B	O				
26 Phthalate – Butyl Benzyl	O		B		P	P		O
27 Phthalate – Diisodecyl	O			P		O	O	
28 Phthalate – Diisononyl	P			O		O		
29 Polymeric MDI	O			O			P	B
30 Silane – Ethyltriacetoxy								P
31 Silane – Octamethylcyclotetra (D4)			B		O	O		
32 Silane – Hexamethyldisilazane								B
33 Silane – Methyl Triacetoxy								P
34 Silane – Vinyltrimethoxy								P
35 Stearic Acid						O		
36 Stoddard Solvent	P	P	B					P
37 Sulfuric Acid	O			O			P	B
38 Talc	O							B
39 Tosylisocyanate							O	O
40 Zinc Oxide					O	O	P	B

FLOORING MATERIALS & THE ENVIRONMENT
The Underlying Hazards

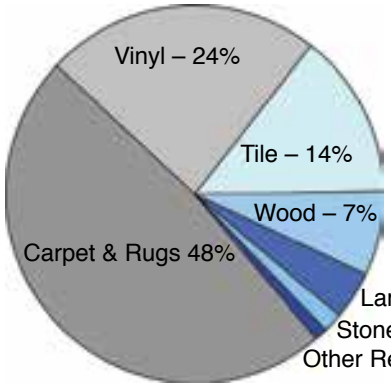
Graphic Art by Scott Van Osdol using Cotton Grass by Norikazu and Bedroom by Antoha713 from Shutterstock.com

According to a 2018 survey printed in *Floor Covering Weekly*, 854 square miles of flooring material was sold in America. Floors rate among the worst building materials for the potential to cause environmental problems linked to indoor air quality and direct exposure to embedded toxins.

As a class, carpets and rugs had 48% of the floor market, followed by PVC vinyl with a 24% share. These two generic materials host a number of health and environmental concerns. Even more benign materials such as tile, wood, and laminate, can be problematic under certain conditions.

There are thousands of different floor products, and each has its own environmental impact. However, as generic class floor types, the chart on the right rates each product for its relative health effects inside buildings.

2018 U.S. Market Share of Flooring Types



"The Statistical Report 2018," *Floor Covering Weekly*, July 22, 2019

FLOOR RATINGS FOR THE INDOOR ENVIRONMENT (From Best/Green to Worst/Red)
Linoleum
Cork (pre-finished)
Solid Wood Floors (pre-finished)
Ceramic Tiles and Stone (made in the USA/lead-free with no CRT-glass content)
Engineered Wood Floors (pre-finished)
Carpet (natural)
Cork (finished on site)
Laminate (non-vinyl)
Resilient Biobased Floors
Rubber or Rubber/Cork Floors (without crumb rubber)
Solid Wood Floors (finished on site)
Engineered Wood Floors (finished on site)
Resilient Petrochemical Non-Vinyl Floor
Carpet (with no fly ash, no vinyl or polyurethane backing, and no Teflon™ chemicals)
New Formulations of Vinyl Floors (with least-toxic chemicals)
New Formulations of Vinyl Floors (with least-toxic chemicals and very low percentage of PVC)
New Formulations of Vinyl Floors (with no post-consumer recycled content)
Ceramic Tiles (not made in the USA with presence of lead unknown)
Carpet (containing fly ash, vinyl or polyurethane backing, and Teflon™ chemicals)
Conventional Vinyl Floors (with post-consumer recycled content)
Rubber or Rubber/Cork Floors (made with recycled-tire rubber)
Traditional Vinyl Floors

CARPET

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Carpet (including rugs) is the most popular, and problematic of all domestic flooring materials. About 410 square miles of it was installed in the U.S. in 2018, and it represents about 48% by area of the total U.S. flooring market.

On the positive side, its acoustic qualities create quieter buildings, its soft surface makes walking and standing less stressful, and it cushions falls, a big plus for small children.

However, these good attributes are outweighed by the material's many detriments. To begin with, most carpet is derived from petrochemicals. It is very difficult to keep clean for any length of time due to the astounding number of permutations in each strand of fiber. It often absorbs or contains dust, dust mites, allergens, mold, mildew, and chemicals tracked in from the outdoors. To remove these, carpet sometimes requires special cleaning beyond what a vacuum cleaner can accomplish, and this cleaning is often enhanced with toxic chemicals.

Many brands of carpet also have short service lives compared to more durable floor surfaces. While the low cost of installation may seem attractive in the near term, other flooring materials that are long lived will save time and money in the long run.

If these reasons are not enough to avoid carpet, consider that most products on the market today are manufactured with highly toxic chemicals, literally from top to bottom. And since babies and small children spend much of their time on the floor or closer to the floor than adults, they are more likely to be exposed by direct contact and respiration.

Conventional Carpet Chemicals

Stain resisters in carpet fibers are typically part of the perfluorocarbon or "Teflon™" family, which can cause cancer, thyroid disease, and weakened immunity.

Antimicrobials such as formaldehyde, a carcinogen and asthmagen, or triclosan, an endocrine disruptor and environmental toxin, are employed to keep both the fibers and carpet backing from breaking down. Some products use nano-silver as a biocide, whose safety is largely untested.

"*Fly ash*" from coal combustion is used as a filler or bulking agent in carpet backing, which contains the toxic mineral asbestos and the toxic heavy metals cadmium, lead, and mercury. These can collectively contribute to a number of adverse health problems including cancer, childhood development problems, and neurotoxicty. (Ironically, as coal-plant scrubbers improve their ability to clean the air, they collect more toxics that are often recycled into carpet.)

Flame retardants are found in carpet fibers, backing, and cushioning. While flame retardants can be mineral-based and without major health affects, some can be toxic. These include halogenated chemicals and antimony trioxide, which are carcinogenic, developmental and reproductive toxins, and endocrine disruptors.

Carpet backing is usually toxic in its own right. Backing materials include polyvinyl chloride (PVC), polyurethane, and styrene butadiene (SB).

• *Polyvinyl Chloride* (PVC) is the most toxic of common plastics. It is an organochlorine, in the same carcinogenic chemical family as dioxin, DDT and PCB. Organochlorines are released in its manufacture, as well as in accidental building fires, landfill fires, and during waste incineration. The production process also releases considerable amounts of asbestos.

• *Polyurethane* is partially made up of isocyanates, a very potent asthmagen.

• *SB backing* contains styrene (carcinogen and asthmagen), and butadiene (carcinogen and developmental toxin). To produce styrene, ethylbenzene, another carcinogen, is released.

Organotins are organometallic substances used as stabilizers and catalysts in the manufacture of carpet backing. Their dangers include reproductive toxins, endocrine disruptors, mutagenicity, eye and skin irritation, and organ toxicity.

Phthalates are used as plasticizers in backing to make carpet flexible. While their danger depends on the specific chemical used, some of them can cause asthma, cancer, and reproductive and developmental harm. While phthalate chemicals are being phased out of many new products due to consumer demand for safer materials, carpet backings in products sold prior to 2015 could well include them.

Carpet cushioning is also problematic. Since it is usually made with recycled furniture cushioning, the flame retardants in it are transferred to the new cushion.

Carpet adhesives, most commonly used on broadloom carpet found in residences, can contain carcinogens, endocrine disruptors, and developmental toxins.

TOXINS IN CARPET

The chart below details toxins in various carpet products. Not all of these toxins occur in the same brands, and just because one is exposed to these in relatively small amounts does not necessarily portend acute hazard or immediate harm. Still, it is prudent to remove as many toxins as possible from the indoor environment.

Fiber	
Stain Resisters (e.g.,Teflon™)	Carcinogen, Developmental and Reproductive Toxin, Endocrine Disruptor
Flame Retardants	
Halogenated	Carcinogen, Developmental and Reproductive Toxin, Endocrine Disruptor, Environmental Toxin, Mutagen, Neurotoxin
Organophosphate	Carcinogen, Developmental and Reproductive Toxin, Endocrine Disruptor, Environmental Toxin, Mutagen, Neurotoxin
Antimicrobials	
Formaldyhyde	Asthmagen, Carcinogen
Triclosan	Endocrine Disruptor, Environmental Toxin
Backing	
Material	
PVC	Asthmagen, Carcinogen (during combustion and manufacturing), Developmental Toxin
Polyurethane	Asthmagen
Styrene Butadiene	Asthmagen, Carcinogen, Developmental Toxin
Flame Retardants	
Antimony Trioxide	Carcinogen, Developmental and Reproductive Toxin
Halogenated	Carcinogen, Developmental and Reproductive Toxin, Endocrine Disruptor, Environmental Toxin, Mutagen, Neurotoxin
Organophosphate	Carcinogen, Developmental and Reproductive Toxin, Endocrine Disruptor, Environmental Toxin, Mutagen, Neurotoxin
Coal Ash Filler	
Asbestos	Lung Cancer, Mesothelioma
Cadmium	Birth Defects, Carcinogen, Endocrine Disruptor, Neurotoxin, Reproductive Toxin, Respiratory Toxin
Lead	Carcinogen, Cardiovascular and Kidney Problems, Childhood Developmental Problems, Premature Birth, Neurotoxin, Reproductive Toxin
Mercury	Acrodynia, Kidney Dysfunction, Neurotoxin
Padding	Carcinogen, Developmental and Reproductive Toxin, Endocrine Disruptor, Environmental Toxin, Mutagen, Neurotoxin
Adhesives	
Bisphenol A	Endocrine Disruptor, Developmental and Reproductive Toxin
Epichlorohydrin	Carcinogen, Developmental Toxin
Nonylphenol ethoxylate	Aquatic Toxicity, Developmental and Reproductive Toxin, Endocrine Disrupting Chemical
Cleaners	
1,4-Dioxane	Asthmagen, Carcinogen, Neurotoxin, Respiratory Toxin
Ammonium Hydroxide	Acutely Toxic, Asthmagen, Respiratory Toxin
Ethylene Oxide	Carcinogen, Reproductive Toxicity, Respiratory Toxin
Napthalene	Acutely Toxic
Petroleum Gases	Acutely Toxic, Carcinogen
Perchloroethylene	Acutely Toxic, Carcinogen, Damage to Kidney, Liver, and Immune System, Developmental and Reproductive Toxin, Neurotoxin
Volatile Organic Compound Emissions (VOCs)	
4-phenylcyclohexane (4-PC)	Allergic Reactions, Respiratory Irritation
Acetaldehyde	Birth Defects, Carcinogen, Mutagen, Neurotoxin, Respiratory Toxin
Benzene	Acutely Toxic, Carcinogen, Mutagen
Formaldehyde	Asthmagen, Carcinogen
Perchloroethylene	Acutely Toxic, Carcinogen, Damage to Kidney, Liver, and Immune System, Developmental and Reproductive Toxin, Neurotoxin
Toluene	Birth Defects at High Levels, Developmental Toxin, Liver and Kidney Damage, Neurotoxin, Respiratory Damage
Phthalates	Carcinogen, Developmental and Reproductive Toxin, Endocrine Disruptor, Environmental Toxin
Organotins	Endodrine Disruptor, Environmental Toxin, Genetic Mutation, Reproductive Toxin

Volatile Organic Compounds (VOCs) are offgassed chemicals from carpet materials that adversely affect indoor air quality. Short-term effects can be severe enough to cause allergic reactions, dizziness, nausea, and headaches. Long-term exposures can be linked to cancer, organ toxicity, and even birth defects at high levels. While most VOCs from new carpet are discharged within a few weeks after installation, low-levels of emissions can continue for years.

And do not forget the chemicals in these *carpet shampoos*. Though it is possible to find commercial and home made products that are relatively benign, many cleaners today have ingredients that are acutely toxic, asthmagenic, toxic to the respiratory tract, carcinogenic, and developmental/reproductive toxins.

There are numerous ways that these toxins are released or shaken from the original carpet and introduced into the indoor and even outdoor environment. Some are emitted as Volatile Organic Compounds. Others are quickly or slowly broken loose through the force of installations, foot traffic, and cleaning. Over time, carpet can also degrade from oxidation, biodegradation, photolysis, and hydrolysis. The toxic molecules appear in house dust, and even in water used for carpet shampoos, which is eventually discharged to the sewer system into the environment.

Andrey_Popov/Shutterstock.com

Health-Conscious Carpets

Carpet manufacturers have adapted new materials and chemical ingredients to reduce or eliminate toxic chemicals for the various parts of the carpet. It is quite possible to buy carpets with several of these more benign materials and technologies in the same product. It may, however, take some shopping to find carpets that include most of them. Below are a few alternatives.

Carpet Fiber: Safer stain resistors are in various brands including Aquafil Econyl StayClean, United Fibers sulfonated nylon copolymers, and Invision Fluorine Free repellent.

Carpet Backings: Various companies now make products with less hazardous backing materials.

- Shaw Direct's Ecoworx®, Mannington Commercial's rEvolve™, and Mohawk Group's EcoFlex NXT™, use polyolefin backing.
- J+J/Invision's eKo® Modular backing uses polyethylene.
- Tandus Flooring's ethos® modular uses polyvinyl butyral (a distinctly different chemical than polyvinyl chloride).

Fire retardants: Alumina trihydrate (ATH) is mineral-based and fairly benign, and is often used instead of toxic halogenated fire retardants. Mineral-based fire suppressors are actually more common than halogenated ones, so they should not be difficult to find.

Recycled Glass Filler: Shaw carpet now uses post-consumer glass as a filler instead of fly ash in carpet backing.

Carpet Padding: Alternative padding includes rubber, flexible polyurethane foam, felt, wool, and cotton. Foam with recycled content might contain halogenated fire retardants and should be avoided.

Adhesives: A few adhesive products are biobased. Many more are manufactured to low-VOC emission standards. Adhesives can be eliminated altogether by laying carpet on tacking strips. See the Floor Adhesives pages (112-113) in this section for more on this subject.

Even if all toxic chemicals are removed though, carpet will still be difficult to clean, and still harbor pollutants tracked in from the outside.

Organic Carpet Materials

Natural materials can replace petrochemical-based carpet. Again though, carpet of any kind will still be more difficult to clean than smooth flooring, and can still harbor pollutants, dust mites, and allergens tracked in from the outside to some degree.

Wool is the most common organic carpet material, making up about 2% of all carpet sales nationwide. In addition to being organic, soft, and biodegradable, it is resistant to mold and mildew, naturally stain resistant, naturally flame resistant, and can trap allergens until the carpet is cleaned. While highly durable, it is often treated with moth-repellent, which can cause reactions to people who are chemically sensitive.

Seagrass is harvested from reeds grown in saltwater paddies in China, and woven into comfortable durable carpets or rugs. Its nearly impermeable surface makes it resistant to dirt, stains, and discoloration, but it is also resistant to dyes, instead having an earth-color appearance.

Sisal is made from the interior fiber of agave plants from Brazil, Africa, and other tropical climates. It can be dyed and woven into a wide variety of textures.

Jute is derived from an Asian plant, and is one of the softest, but least durable, of natural carpet fibers. This makes it more suited to low-traffic uses such as bedrooms.

HQuality/Shutterstock.com

VINYL

There were 207 square miles of vinyl flooring sold in the U.S. in 2018, representing 24% of the U.S. floor market. While vinyl is smooth and does not have the same cleaning problems as carpet, it is still far from an environmentally preferable alternative. It is also derived from petrochemicals, and as stated previously, polyvinyl chloride (PVC) is the most toxic of common plastics. It is one of a family of "organochlorine" chemicals that combine chlorine and carbon. These are rarely found in nature by themselves, and can take hundreds of years to biodegrade.

The manufacture of PVC is highly polluting to the surrounding environment. The most dangerous contaminant emitted is dioxin, a carcinogen, neurotoxin, reproductive toxin, and endocrine disruptor. Dioxin is also released from the material in the event of accidental house fires, as well as from unintended landfill fires and waste incinerators after disposal.

PVC factories often use toxic mercury or asbestos as part of their process.

About 70% of all PVC in the U.S. and Canada is used in buildings, and can cause potential harm to occupants. Some PVC building products are more stable than others. For instance, modern vinyl windows (as distinguished from older vinyl windows) may emit small amounts of VOCs, but are not considered nearly as unstable and toxic as PVC flooring.

As much as 50% of vinyl flooring is made up of plasticizers. Until recently, most of these were *orthophthalates*. While their danger depends on the specific chemical used, some of them can cause asthma, cancer, and developmental and reproductive harm.

Phthalates have been associated with increased asthma and allergies in children, as well as long-term chronic disease.

A Swedish study showed increased levels of phthalates in children living in homes with vinyl floors, leading to assumptions that they had been ingested through breathing and contact with skin. (*Indoor Air*, June 18, 2012, pp. 32-9.) Another Swedish study linked increased incidence of autism to vinyl flooring. (*Neurotoxicology*, September 2009, pp. 822-831.)

These chemicals are often being replaced with less toxic plasticizers, some made from plant materials. However, the replacement is not universal, and not all replacement plasticizers are completely benign or thoroughly tested for their effects on people and the environment.

Organotins are organometallic substances used as stabilizers in vinyl floors. While less toxic than the lead and cadmium they replace in legacy products, their dangers include reproductive toxins, endocrine disruptors, mutagenicity, eye and skin irritation, and organ toxicity.

Vinyl floors can also include flame retardants and antimicrobial chemicals similar to those in carpet. While vinyl floors are not a preferred alternative, there are ways that their hazards can be reduced.

Vinyl Floors with Recycled Content: While recycling vinyl floors may sound like it yields environmental benefits, it is actually something to be avoided given the dangerous ingredients in legacy products. Older vinyl can include lead and cadmium stabilizers, PCB (another dangerous organochlorine), antimony trioxide flame retardants, and antimicrobials such as triclosan and OBPA. The trade-off of one environmental problem for another is not worth it.

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Vinyl Floors With Less Vinyl: Though a huge number of products contain vinyl, total content can range from less than 1% to as much as 75%. Obviously, less is more from an environmental standpoint. Much of the balance of ingredients in products with low percentages of vinyl is from minerals such as limestone dust (calcium carbonate).

Vinyl Floors with Least-Toxic Chemicals: Seeking out products without orthophthalate plasticizers, organotin stabilizers, toxic flame retardants, and antimicrobials will limit their exposure to the indoor environment. Look for specific preferable phthalate replacements that are better for the environment and healthy building environments: Ecolibrium (Dow); Grindsted Soft-n-Safe (Danisco/DuPont); and Polysorb ID37 (Roquette).

OTHER RESILIENT FLOORING

RESILIENT: NATURAL LINOLEUM

The term linoleum is commonly confused with vinyl. But before there was vinyl flooring (made popular after W.W.II), there was natural linoleum (invented in about 1860). It is a smooth-surface flooring material made with renewable or abundant materials such as linseed oil, tall oil rosin, pine-gum rosin, wood flour, cork and limestone powder, and jute backing.

Linoleum is generally higher cost than most vinyl products, but long lasting, and often requires less maintenance than vinyl flooring, thus reducing maintenance costs. It comes in a wide variety of colors, and the pigments go through the entire material, so that damage from scratches is not as apparent.

It is also naturally antimicrobial because the oxidation of linseed oil and pine rosin continues for the life of the flooring, starving microbes of oxygen. Because of this, linoleum is particularly valued in the healthcare industry.

RESILIENT: CORK

Cork is similar to wood; in fact, it is made of the bark of cork oak trees harvested every 7 to 10 years, and that typically live for 250 years. It is rapidly renewable and highly durable. Since it has 200 million closed air pockets per cubic inch, it is prized for its acoustic ability to render a room quieter while insulating temperatures. In a sense, it also allows people to "walk on air," making it comfortable for adults to stand on while soft for children to fall on.

Cork can be grown in the U.S., but currently most/all cork flooring is imported from Portugal and Spain.

Within this floor class, two main environmental considerations have indoor air quality ramifications.

Cork That is Prefinished: Some cork products come prefinished. Cork with no onsite finish has very low VOCs. Depending on the finish, some cork products are extremely resilient, and the color goes through the material, making scratches less detectable.

Cork Finished Onsite: Just like wood, adding chemicals onsite can cause VOCs to offgas, though they will diminish over time. However, many cork products require another topcoat floor finish or wax for more protection, or to make sure that spilled liquids do not creep into the cracks in cork floating-floor planks.

RESILIENT: BIOBASED AND NON-VINYL SMOOTH FLOORING

Similar to linoleum, there are smooth flooring products that are made of other renewable biobased materials and abundant mineral materials.

However, the biobased products sometimes also use petrochemicals that are toxic. Therefore, it is difficult to rate these products as a class. On the whole though, these are probably less toxic than vinyl smooth flooring.

One example is Armstrong's product line – Migration™, Biobased Tile™, and Striations™ – with Biostride™ polyester derived from corn to bind limestone powder together into tile. It appears that the small percentage of the product that is made up of petrochemicals is biodegradable and relatively harmless to people.

Another example is Mannington's Enlighten, a rubber composite with some biobased content, though a greater percentage (non-vinyl) petroleum content.

Non-Vinyl Petrochemical Smooth Flooring: There is also another option that is less environmental than biobased floors but safer than vinyl, which is smooth flooring made with less-toxic petrochemicals. While preferable to vinyl, some products still contain toxic chemicals that make them regrettable substitutes.

RESILIENT: RUBBER

Rubber flooring is a very niche market at this time. The rubber can be natural or synthetic.

Its advantages include a comfortable surface for people to walk on (and children to fall on), ease of cleaning, slip-resistance in wet areas, stain-resistance, high durability, and in the case of rubber tiles, their natural tackiness can sometimes eliminate the need for adhesive installations. Unlike most other types of smooth flooring, it has sound-calming characteristics.

As with other generic classes of floors, there are various options that are more environmental than others.

Natural Rubber: Tiles made entirely of natural rubber and minerals are preferable to synthetic rubber. "Au natural" by Allstate Rubber is one such product. Note that about 4% of the general population is allergic to natural (latex) rubber. ("Current prevalence rate of latex allergy," *Journal of Occupational Health*, March 20, 2016, pp. 138-144.)

Synthetic Rubber With Few Other Hazardous Products: Other products use synthetic rubber, but emit very low VOCs and have few or no hazardous chemicals combined with it.

Rubber Flooring With Recycled Material: The dark side of recycling tires is that toxins in them, such as lead, hydrocarbon processing oils, and carbon black, show up in floor materials and playscapes that use their "crumb rubber" feedstock. This flooring option is highly discouraged both indoors and outdoors.

WOOD

Wood is a smooth, easily cleaned floor from renewable resources. Though minimal amounts of VOCs can be emitted from the wood or adhesives used to install it, wood can often be installed with non-adhesive methods (e.g., nailed and floating).

There are several categories of wood-flooring products that rank in order of environmental preference.

Solid Wood That is Prefinished: Solid wood floors have no chemical binders that offgas VOCs, so they are the environmentally preferred choice for wood. Wood floors generally need to be finished. If this is applied at the factory, most of the chemical offgassing will have taken place before it is even installed.

Engineered Wood That is Prefinished: Engineered floors can also be finished offsite, though many engineered products use chemical binders to hold wood layers or cellulose powder together, which offgas over time even if the floor finish does not.

In choosing engineered wood, the first preference is products that use resins that are soy-based or that contain no formaldehyde in the binders. Products with low formaldehyde and its attendant VOCs fall next in line. Numerous products are rated for this quality by the California Air Resource Board and the Composite Surfaces Association. (See the Sidebar on the Composite Lumber page (114) of this section for Web addresses.) Lowest ranking are floors with standard formaldehyde content and emissions.

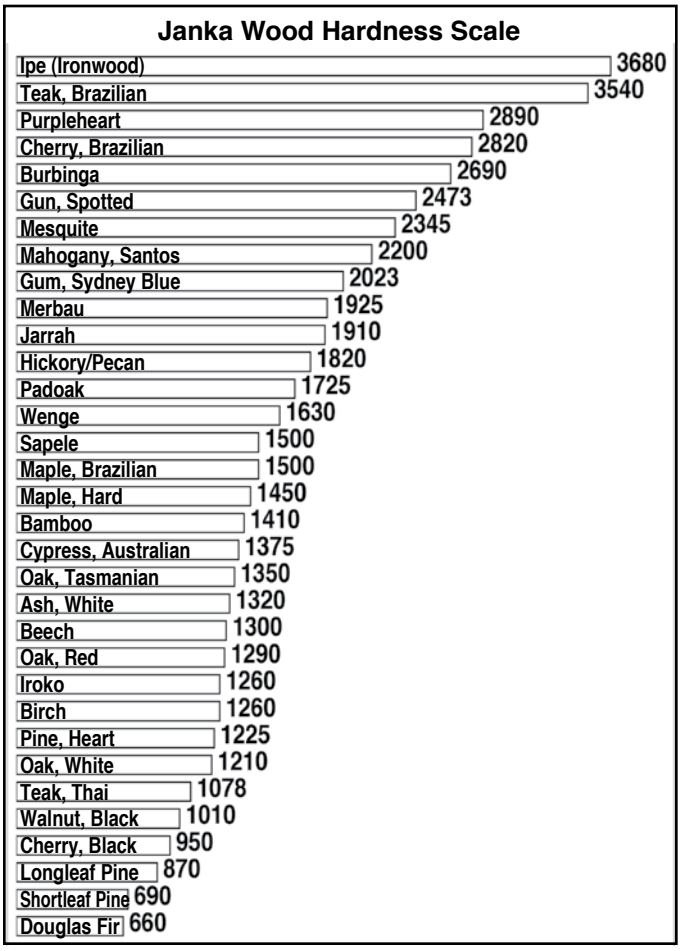
Solid Wood Finished on Site: This choice requires onsite use of offgassing floor sealants, though their VOC emissions will diminish over time.

Engineered Wood Finished on Site: This choice requires onsite use of offgassing floor sealants, and it will also offgas VOCs in the chemical binders. It is the least-preferable option for wood floors. If this option is chosen though, choosing finishes with no- or low-VOC emissions and flooring with no- or low-formaldehyde binders is preferable.

Other Environmental Concerns for Wood Floors

While floor life and the use of threatened resources do not generally impact exposure to toxins in buildings, they do affect sustainability and should be considered.

Wood Rated for Hardness: Different species of wood have different levels of hardness, and are thus more or less resilient to foot traffic, dents, and other kinds of wear. Different species are rated by the Janka hardness scale, with imported iron wood at the top and pine and cherry at the bottom. Quality is one factor that should be considered during purchase. The chart shows the Janka scale for some popular wood species. It does not include "fossilized" flooring with compressed wood, which can be rated as high as 5500 on the scale.



Wood That is Sustainably Harvested: Though wood is a renewable resource, abusive forestry practices such as clearcutting, overharvesting, harvesting too close to watersheds, and incursions into old-growth forests all cause unacceptable levels of environmental harm. Since the 1990s, wood building products have been certified for environmental harvesting standards by various third-party companies or organizations.

One of the more highly respected is the Forest Stewardship Council, which maintains lists of both companies that manufacture building materials with sustainable wood and U.S. suppliers of these companies' products. These can be downloaded at the organization's Web site: **us.fsc.org**

There are also species of trees (most of them tropical and from other continents than North America) that are endangered from over-harvesting and should be avoided. Several non-profit organizations have compiled lists of endangered tree species whose sales should be, or are, banned or controlled.

One of these is the Convention on International Trade of Endangered Species (CRITES), an organization based on international agreement between most of the world's countries to regulate sales of wood from these species.

Banned or regulated species that CRITES has determined are threatened with extinction or whose trade must be regulated to ensure survival include: 24 species of rosewood; 5 species of Asian yew; 3 species of mahogany; 3 species of agarwood; and 3 species of bubinga. A complete list can be found at the U.S. Fish and Wildlife Web site: **fws.gov/international/plants/current-cites-listings-of-tree-species.html#2**

CERAMIC TILE & STONE

Common tile is typically derived from abundant and relatively safe minerals such as clay, calcium carbonate, feldspar, quartz, silica, and talc. Its kilning process renders the ingredients inert. The smooth surfaces are easy to clean. Tile emits no VOCs, though some grout/adhesives that are used to install it can. Cut stone also has these traits.

On the negative side, tile and stone can be slippery when wet; it is rated on a slip-resistance scale of 1 to 10, with 10 being the least slippery. Products used for slip resistance may introduce unwanted chemicals into the building. Tile is also hard to fall on, cold to walk on in winter months, and its smooth surface sometimes causes sound echo.

Most tile is relatively inexpensive, but as in most building materials, you get what you pay for.

All glazed tile is typically ranked on the PEI (Porcelain Enamel Institute) wear-rating scale of 1 through 5, with 5 being the best quality.

Porcelain tile is higher quality than ceramic tile, but also generally more expensive. It is harder and denser, and absorbs less moisture, allowing exterior use in cold climates because it can better tolerate freeze-thaw cycles without cracking. Glazed porcelain tile is more stain resistant.

Color body porcelain in glazed porcelain matches the color of the glaze to the color of the minerals underneath, so that if the glaze is chipped, it will be less noticeable. *Through body porcelain* in unglazed tiles not only incorporates the color throughout the body of the tile, but also the pattern, making chips and scratches even harder to detect. It does not have a PEI rating because of its high durability. However, it is more susceptible to stains.

Ceramic tiles are usually less expensive than porcelain, and easier to cut (important in DIY installations). Ceramic products usually (but not always) have a lower PEI rating than porcelain.

In addition to longevity concerns, there are two general environmental considerations when choosing tile.

Tile Manufactured in the U.S.: Tile made in this country is typically free of lead in its glazings. However, about 80% of tile in America is imported. If imported tile is purchased, it is important that it is sourced.

Tile With Recycled Content: While the use of recycled glass and ceramics in tile is usually a good thing environmentally, do not install products whose material sources are not disclosed. In particular, avoid products with recycled lead-glass from Cathode Ray Tube TVs.

LAMINATE

Laminate flooring is usually made with a non-vinyl plastic surface that can resemble wood or vinyl patterns built on top of a wooden base. The wood is usually derived from ground up waste wood adhered with a binder.

As long as the binder emits low amounts of formaldehyde and other VOCs, non-vinyl laminate is environmentally superior to carpet and vinyl since it is a smooth floor that can be cleaned easily and does not contain PVC or other hazardous chemicals. Laminates are also intentionally designed as floating floors, so they often avoid adhesives used in installation.

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Environmental/Health Ratings for Flooring

In addition to the ranking of generic products in this article, various agencies and institutions have created rating systems to judge flooring products. Below is a short list of them. Their Web sites give information on specific products that meet their criteria.

Cradle to Cradle Products Innovation Institute
c2ccertified.org/products/registry
This non-profit organization manages a comprehensive rating system for many products, including flooring materials. Cradle to Cradle rates on 5 criteria: Material Health; Material Utilization; Renewable Energy and Carbon Management; Water Stewardship; and Social Fairness. These separate ratings are then combined into an overall score.

FloorScore®
scsglobalservices.com/certified-green-products-guide
This is SCS Global Services' certification program for most smooth flooring types that limit VOC emissions. (These include: cementitious; ceramic, cork; engineered bamboo; engineered hardwood; laminate; linoleum; polymeric; porcelain, raised; rubber; vinyl composite tile (VCT); vinyl sheet; vinyl tile; and luxury vinyl tile (LVT). The certification also include floor accessories such as: adhesives; stair treads, underlayments; and wall bases.

As of the time of publication, about 7,200 products had been rated and listed on its Web site.

Green Label Plus
spot.ulprospector.com/en/na/BuiltEnvironment
This standard, administered by the Carpet and Rug Institute, certifies carpet products if they do not exceed a minimum level of VOC emissions. At the time of publication, almost 500 carpet products rated by this label could be found at the Underwriters Laboratories' Web site.

Green Squared
greensquaredcertified.com/find-certified/
This certification is for ceramic and tile products, as well as products related to them such as grout, mortar, backer boards, and sheet membranes.

The certification is a point-based system that relies on: 1) the tile's characteristics; and 2) materials extraction and the manufacturing process. Standards for characteristics include: the percentage of recycled content or recyclability of packaging; VOC levels; and the amount of indigenous raw materials (which limits energy and emissions from transportation). Meeting optional criteria for Solar Reflectance Index and acoustic standards also count for points.

Standards and optional points for materials extraction and the manufacturing process include: prohibition of visible particulate emissions; use of relatively clean process heating fuels such as natural gas; the use of low-NOx burners; written sustainable material procurement practices; and good practices for waste minimization, lighting efficiency, heating fuel usage, electricity consumption, water conservation, water discharge limits, utilization of renewable energy, cogeneration, and incorporating heat recovery or combined heat and power systems.

GREENGUARD Gold
spot.ul.com/main-app/products/catalog/?keywords=

This certification system administered by Underwriters Laboratories measures for VOCs emitted from many product categories, including flooring. It has two tiers: its standard GREENGUARD rating; and its premium GREENGUARD Gold rating. As of the time of publication, there were over 11,200 products rated by the higher standard.

Safety Data Sheets (SDS)
These legally required summaries of potential product hazards are usually found on manufacturers' Web sites. There are shortcomings for SDS information. Due to trade secrets, percentages of ingredients listed are often in vague ranges. And SDS rules only require listing of hazardous ingredients if they make up more than 1% of a product, and carcinogenic ingredients if they make up more than 0.1% of the product.

Health Product Declaration Collaborative
hpd-collaborative.org/hpd-public-repository/
This non-profit member association creates Health Product Declarations (HPDs). HPDs allow product manufacturers to disclose information about the chemical ingredients of their products and associated health information that is more detailed than Safety Data Sheets. By promoting ingredient transparency and disclosure, HPDs enable consumers to make more informed decisions and motivate manufacturers to adopt healthier chemical ingredients.

HPDs of specific products can be accessed at its Web site.

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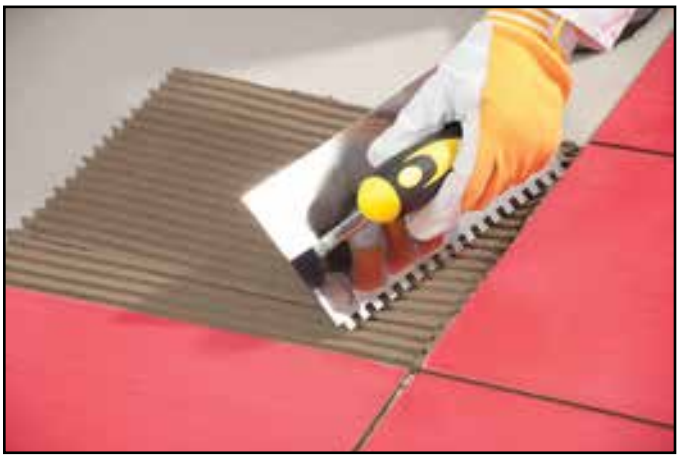

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Similar to other products with petrochemical bases, floor adhesives can offgas VOCs (Volatile Organic Compounds). Other chemicals in the product can directly harm workers and building occupants who are exposed to them. Over time, they can degrade, exposing building occupants to their dangers. (The particles attach to dust motes, and become breathable in the indoor air.)

The Chart below depicts the effect that various floor adhesive product classes have on the indoor environment.

FLOOR ADHESIVE RATINGS FOR THE INDOOR ENVIRONMENT (From Best/Green to Worst/Red)
Mechanical Installation
Plant-based
Peel and Stick
Acrylic
MS Polymers
Polyurethane
Epoxy

Mechanical Installation – Often floors can be installed without any use of chemical adhesives. Nails, staples, and carpet tacks are alternatives. "Floating floors," interlocking panels or squares held firmly in place by shoe molding at the baseboards, are also quite common.

Plant-Based – A few alternative products exist whose adhesive qualities are derived from plant-based materials. These products are preferred by people who are chemically sensitive, and they usually carry a price premium.

Peel and Stick – These solid (often acrylic) adhesives, in squares or strips, can either be factory applied to floor products or applied onsite. As a class, VOC emissions and toxic qualities are low or negligible.

Acrylic – This is the least toxic class of common liquid adhesive products. It is water-based, generally has low- or no-VOC emissions, and with exceptions, does not contain dangerous chemicals in large percentages. However, many acrylic products contain biocides in small amounts, and some specialty products contain flame retardants and antifreeze.

MS Polymers – Modified silicon polymers can adhere to flooring while creating a barrier for porous concrete surfaces, preventing wood floors or the adhesive itself from being affected by moisture. Like polyurethane, it allows wood flooring flexibility to move with changing humidity. However, it is free of dangerous isocyanate chemicals. Some MS products do contain organotin catalysts and biocides in small percentages.

Polyurethane – These adhesives are often used with wood floors because they form a moisture barrier on porous concrete while allowing wood to expand and contract with humidity. However, they contain isocyanates, which are potent asthmagens. They also often contain petroleum solvents and organotin catalysts. Though some products have low-VOC emissions, this class generally has higher emissions than other adhesive classes.

Epoxy – This class of adhesives contains a two-part formula that must be mixed onsite. It includes a BPA-based catalyst, a chemical reviled as an endocrine disruptor, which is also a developmental and reproductive toxin. These adhesives also contain nonylphenols (NPEs), with many of the same chemical dangers as BPA. In addition, NPEs are Persistent Bioaccumulative Toxins. And epoxy products contain amines, which are asthmagens.

Codes and Dangers for Hazardous Ingredients in Floor Adhesives Blue = Highest Hazard Purple = High Hazard Orange = Medium Hazard *Hazards from Healthy Building Network Pharos database.*	Carcinogenic	Gene Mutation	Bioaccumulative Toxin	Developmental Toxin	Reproductive Toxin	Endocrine Disruption	Respiratory Toxin	Organ Toxicant
Polyurethane Floor Adhesives								
Calcium Oxide								
Distillate Fuel Oils, Light								
Hydrotreated Middle Distillates								
Isocyanates (Various)								
Napthalene and Naptha Solvents								
Organotins (Various)								
Stoddard Solvent								
Epoxy Floor Adhesives								
Amines								
Bisphenol A (BPA)								
Diethylene Triamine								
Diisopropyl Naphthalene								
Nonylphenols (NPEs)								
Triethylenetretramine								
Trimethylolpropane Triacrylate								

Environmental/Health Ratings for Floor Adhesives

In addition to the ranking of generic products, various agencies and institutions have created rating systems to judge floor adhesives. Below is a short list. Only a few were rated with these standards at the time of publication.

GREENGUARD
spot.ul.com/main-app/products/catalog/?keywords=
This rating system administered by Underwriters Laboratories measures for VOCs emitted from many product categories, including floor adhesives. It has two tiers: its standard GREENGUARD rating; and its premium GREENGUARD Gold rating.

SCS FloorScore®
scsglobalservices.com/certified-green-products-guide
Scientific Certification Systems, Inc. is a private company now operating as SCS Global Services. It certifies third-party verifications of environmental claims. Its FloorScore® rating program sets limits for VOC emissions.

Safety Data Sheets (SDS)
These legally required summaries of potential product hazards are usually found on manufacturers' Web sites. There are shortcomings for SDS information. Due to trade secrets, percentages of ingredients listed are often in vague ranges. And SDS rules only require listing of hazardous ingredients if they make up more than 1% of a product, and carcinogenic ingredients if they make up more than 0.1% of the product.

South Coast Air Quality Management District (SCAQMD)

Compliant and Super Compliant Adhesive Products List
aqmd.gov/home/rules-compliance/compliance/vocs/adhesive-and-sealants/rule-1168-compliant-products
SCAQMD regulates air emissions in the greater Los Angeles area, including "Rule 1168" standards for VOCs from adhesives. This list of products, including floor adhesives, have exceptionally low emissions.

Other Least Toxic Adhesives

The products in the chart are considered least toxic acrylic adhesives, though they are not rated by third party organizations. They are listed because they have a long-established reputation as materials tolerated by the chemically sensitive.

Least-Toxic Floor Adhesive Manufacturers

Manufacturer	Phone	Web Site	VOC (Grams/L)	Address	Material
AFM Safecoat	(619) 239-0321	afmsafecoat.com		3251 Third Avenue, San Diego, CA 92103	
3 In 1 Adhesive			3		Acrylic
Almighty Adhesive			<35		Acrylic
Auro USA	(541) 733-8204	aurousa.com		NA	
Universal Adhesive No. 380			NA		Plant-based Acrylic
Floor covering adhesive No. 382			NA		Plant-based Acrylic
Natural Latex Fixative No. 388			NA		Plant-based Acrylic
Ecos Paint	(864) 946-9104	ecospaints.net		P.O. Box 489, Fairforest, SC 29336-0489	
Wood glue			0		Acrylic

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COMPOSITE LUMBER
A Veneer of Safety?

Composite, non-structural, wood is used in the manufacture of cabinets, countertops, doors, flooring, flooring underlayment, furniture, moldings, and shelving. While structural lumber such as studs and sheathing is essential to most homes, it is usually not directly exposed to the indoor air.

These composites use chemical binders to mold wood particles and chips into functional boards, and these binders often contain formaldehyde. This chemical is carcinogenic, a developmental toxin, an endocrine disruptor and organ toxicant, and can cause respiratory problems. Its symptoms include dizziness and sinus inflammation linked to multiple chemical sensitivity. There is no safe threshold of exposure.

Responding to public health concerns, the lumber industry has complied with regulatory standards limiting formaldehyde emissions. Voluntary standards lower emissions even more. Below is a ranking of wood products reflecting their effect on the indoor environment.

Note that there is a secondary ranking within each class that contains formaldehyde. Composite hardboard has lower emissions than particle board, which in turn has lower emissions than medum density fiberboard due to the percentage of chemical binders used in each product. Also worth noting is that there is no such thing as formaldehyde-*free* wood. Wood generally has a small amount of the chemical that is naturally occurring.

WOOD PRODUCT RATINGS FOR THE INDOOR ENVIRONMENT (From Best/Green to Worst/Red)	
Solid Wood	
No Added Formaldehyde (NAF) & Soy-Based Resins	
Ultra-Low Emitting Formaldehyde (ULEF)	
National (CARB 2) Standard	
Wood Material	Hardboard (3.5% binder)
	Particleboard (10% binder)
	Medium Density Fiberboard (12.4% binder)
	Thin Medium Density Fiberboard (12.4% binder)

Solid Wood – Solid wood, where feasible, is a preferred option to composites of any kind. If this class of materials is used, it is preferable that finishes or coatings be applied during manufacturing to limit VOC offgassing onsite.

No Added Formaldehyde (NAF) & Soy-Based Resins – Some composite lumber products use formaldehyde-free binders. These include methylene diisocyanate and soy-flour mixed with petrochemicals. While environmentally preferable, isocyanates are asthmagens, and some petrochemicals are inherently toxic in their own right.

Moreover, some retail composite products are so complicated that one part of the product can be labeled NAF while another part still contains the chemical.

Ultra-Low Emitting Formaldehyde (ULEF) – This is a voluntary standard that goes above minimum national standards. The ULEF standard results in an emissions reduction of at least 11% in particleboard, 18% in medium density fiberboard, and 15% in thin medium density fiberboard.

National Formaldehyde Emissions Standard – Beginning in 2009, the California Air Resources Board (CARB) required that all composite lumber products sold in the state limit formaldehyde emissions to standards verified by third parties. Between 2010 and 2012, stricter Phase 2 ("CARB 2") standards were put into effect. CARB 2 products became a default rating for green building programs around the country attempting to improve indoor air quality. These standards were estimated to have lowered Califonia formaldehyde emissions from composite lumber by 58%.

In June of 2018, the U.S. Environmental Protection Agency adopted (with minor revisions) CARB 2 standards for the entire U.S.

Environmental/Health Ratings for Composite Wood Products

Various agencies and organizations rate composite wood product emissions differently. Some analyze them as assembly materials; others certify retail products.

California Air Resources Board
ww3.arb.ca.gov/toxics/compwood/listofnaf_ulef.htm
The Board certifies composite material and product manufacturers that meet the more rigorous NAF and ULEF standards for sale in the state.

Composite Panel Association
compositepanel.org/sustainability/ecc/naf-ulef.html
The Association lists composite wood product manufacturers that comply with NAF and ULEF standards.

Eco-Certified Composite (ECC) Sustainability Standard
decorativesurfaces.org/cpa-green/ecc-certified-companies.html
This is another green product initiative sponsored by the Composite Panel Association. In addition to not exceeding national formaldehyde emission standards, products must meet at least 3 of 5 other environmental criteria: a net-zero carbon footprint; use of local and renewable resources; recycled content; efficient use of raw materials; and sustainable wood sourcing.

GREENGUARD Gold
https://spot.ul.com/main-app/products/catalog
This certification system administered by Underwriters Laboratories measures for VOCs emitted from many product categories, including cabinets, countertops, and doors (wood, agrifiber, and metal). It has two tiers: its standard GREENGUARD rating; and its premium GREENGUARD Gold certification.

Indoor Advantage Gold
scsglobalservices.com/certified-green-products-guide
Scientific Certification Systems, Inc. is a private company now operating as SCS Global Services. It certifies third-party verifications of environmental claims. It has rated several composite-wood molding products for low air emissions.

KITCHEN & BATHROOM SURFACES
In-Countered Toxins

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Countertops have both direct and indirect effects on the indoor environment. Products manufactured with certain chemicals can offgas VOCs into the air, and toxins coating them or embedded in them can sluff off over time through wear and washing. Most stone surfaces are treated with protective sealants, which can be toxic. Poor quality products (that are not easily repairable) also need replacement or refurbishment; such construction creates a different kind of indoor air quality problem.

According to a market share report by the Freedonia Group, in 2019, 97% of the 27 square miles of countertops installed in the U.S. were made from 5 generic materials: tile; engineered stone; natural stone; acrylic solid surfaces; and laminate. The remainder are specialty products that are purchased for the style, or because they are low-cost.

This article attempts to rate generic classes of countertop surfaces. There are many different products and sub-classes, so these ratings should be considered a general guide. For example, while most quartzite and granite surfaces are expensive, buying small amounts from "remnant" retailers can greatly lower the price. And while most quartzite and granite require sealing, some types are denser and less porous, so sealing is not as critical.

However, with the exception of soapstone, most stone surfaces are porous and very prone to staining. For this reason, most people apply sealants, and many of these have toxic ingredients, including Teflon™-like fluoropolymers.

So stone as well as certain other surfaces in this chart are usually rated both green and red. *They are green since they do not emit VOCs and if they use safer sealants. However, they are red if the sealants have dangerous chemicals.* And like so many other chemical dangers in our home, the chemicals appear transparent, and you will never see the hazards.

Acrylic Plastic and Engineered Quartz and Marble surfaces also have a dual rating. *They are green because of their low onsite air emissions and toxin exposure. However, they are yellow because of noticeable quantities of toxins used in their manufacture.*

Another class of chemicals to avoid is synthetic antimicrobials. Many consumers believe countertops with these pesticides (some of which are dangerous to people in their own right) kill food-borne bacteria. But some of the bacteria will survive and mutate to resist these very chemicals.

COMMON COUNTERTOPS

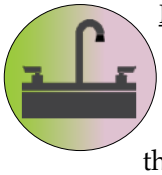
U.S.-Made Ceramic Tiles – Domestic tile is one of the safest countertop materials. Most U.S. products do not have lead in the glazing or ceramic body. However, by one estimate, 80% of tile sold in the U.S. is imported. So looking for the country of origin cannot be taken for granted. Unglazed tiles are even better. An extra precaution in avoiding lead in tile is to avoid products containing recycled glass from old televisions (Cathode Ray Tubes, or CRTs).

COUNTERTOP RATINGS FOR THE INDOOR ENVIRONMENT
(From Best/Green to Worst/Red)

	Stain Resistance	Scratch Resistance	Heat Resistance	Cost
COMMON COUNTER MATERIALS				
U.S.-Made Ceramic Tiles (lead-free/No CRT Glass)	Best	Best	Best	$$
Sintered Stone	Best	Best	Best	$$$$
Natural Stone				
Soap Stone	Very Good	Poor	Best	$$$$
Granite	Poor; Needs sealant	Very Good	Best	$$$
Marble	Poor; Needs sealant	Poor-Medium	None	$$$$
Quartzite	Fair; sealant advised	Best	Best	$$$$
Travertine/Limestone	Poor; Needs sealant	Fair	Good	$$
Acrylic Plastic Solid Surface	Very Good	Very Good	Poor	$$$
Engineered Quartz / Cultured Marble	Best	Best	Best	$$$$
Plastic Laminate	Best	Good	None	$$
Imported Ceramic Tiles (uknown content/CRT Glass)	Best	Best	Best	$$
Countertops Treated With Antimicrobials	NA	NA	NA	NA
Vinyl Film	Good	Poor	None	$
OTHER COUNTER SURFACES				
Linoleum	Fair	Poor	None	$
Stainless Steel	Best	Fair	Best	$$$$
Concrete	Poor; Needs sealant	Very Good	Best	$$$
Recycled Glass	Fair; sealant advised	Good-Best	Good	$$$$
Wood	Good	Fair	None	$-$$$$

Other considerations are abrasion and scratch resistance. Using higher quality products (glazed tiles with high Porcelain Enamel Institute, or PEI, rating or through-body porcelain tiles) will generally require less maintenance and replacement. Unglazed tiles may require sealing to make them more stain resistant.

Sintered Stone – This unique class of surface material began to be marketed in the early part of the 2010 decade. It is a synthetic counter made of natural minerals such as quartz, porcelain, and glass fused under high heat and pressure. Safe to the indoor environment, it is light and thin, yet can be as hard as quartz or granite. This material is highly resilient to common kitchen hazards such as staining, scratching, and heat. Brand names include Dekton and Neolith.

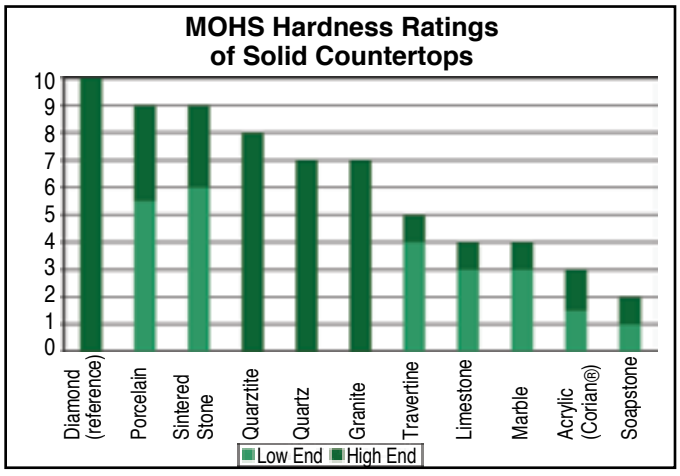


Natural Stone – Many stone countertops are stunningly beautiful. As a class, they do not emit noticeable amounts of VOCs, nor does their wear generally contribute toxic dust to the indoor environment. Surprisingly, though, some of these literally rock-hard surfaces are not that durable, being prone to stains, acid etching from certain foods and cleaners, scratches, heat damage, and surface wear. Some products are protected with toxic sealants. (Hence the simultaneous green and red rating.)

Stones are rated on the MOHS hardness scale. *Quartzite* and *granite* are on the high end, and are difficult to scratch. (They can be chipped though.)

Quartzite is the hardest natural stone surface available, making it slightly more durable than granite. It looks similar to certain other, less durable, materials. Given its expense, it is essential to conduct scratch and etching tests to confirm the material's identity.

Both quartzite and granite, despite their hardness, are susceptible to stains unless sealed, especially lighter colors. Granite counters can also emit low levels of radon gas. While there is technically no safe level of radiation, the amount emitted to indoor air is extremely small. This author has never seen a health advisory specific to granite. However, in regions of the country where natural geology sometime creates noticeable amounts of radon in buildings, countertop emissions can add to the health burden.

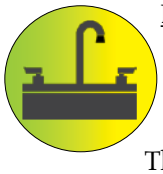


Least-Toxic Fluoropolymer-Free Stone Sealants		
Manufacturer	**Phone**	**Web Site**
AFM Safecoat	**(541) 733-8204**	**afmsafecoat.com**
Mexeseal Satin, Mexeseal Semi Gloss, Mexeseal Grout Sealer		
DryTreat	**(866) 667-5119**	**drytreat.com**
STAIN-PROOF®: Waterbased Penetrating Sealer; Dense Stone		
Hope Company	**(512) 245-2420**	**dtep.com**
100% Pure Tung Oil		
Livos USA	**(208) 317-3545**	**livosusa.com**
Alisa Stone Oil #202		
Real Milk Paint	**(800) 339-9748**	**realmilkpaint.com**
Pure Tung Oil		

Marble, *limestone*, and *travertine* (a variation of limestone) are all surfaces whose beauty outshines their durability. They are all relatively soft, so are prone to scratching. They are extremely vulnerable to stains and acid etching, including foods such as vinegar, citrus, and tomato sauce. They are more suited to bathroom counters than kitchens.

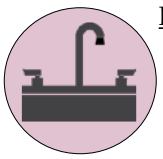
Soapstone is generally the only natural stone counter surface that does not need sealing to protect from stains. However, since it colors unevenly overtime, some owners of these counters prefer to periodically cover it with mineral oil to create a uniform appearance. It is much softer than many other surfaces, and quite prone to scratching.

Acrylic Solid Surface – Counters made of acrylic or polymethyl methacrylate are solid sheets of non-stainable plastic. They are impervious, so no sealant is required. While containing toxic chemicals, they are embedded in the material or emitted at the factory. They are generally not released into the indoor environment.



Engineered Quartz / Cultured Marble – Engineered quartz counters (differing from quartzite) employ quartz and other minerals pressed under high heat and vacuum. Minerals make up the vast majority of the product. The toxic resin typically makes up only about 6% of the material. Cultured marble is largely made up of ground limestone molded together with polyester resin and decorated with swirled pigment to resemble marble. The resin typically makes up about 20% of the material.

Like acrylics, the chemicals are embedded in the materials or emitted at the factory. Their impervious quality makes them stain resistant, eliminating the need for sealants.

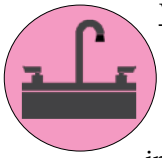


High Pressure Laminate – This class of counters employs resin-coated paper pressed under high heat to form a solid surface. Melamine resins are used in the decorative top coat, and phenol resins are used in the underlying base. The material sometimes has aluminum oxide added to it for extra wear and impact

endurance. Laminate surfaces are applied on top of a (usually wood-based) substrate.

The resins can emit formaldehyde and other VOCs, though many laminate counter products are rated for low emissions. An added concern is that laminate sheets applied in buildings must be glued down, and these glues can also emit VOCs. This concern can be mitigated by purchasing laminate counters pre-glued at the factory, where some of these VOCs are discharged.

Ceramic Tiles/Imported or With Recycled CRT Glass – Imported tile is more likely to be glazed with heavy-metal pigments such as lead, which can eventually wear away and get into the indoor environment. The same problem can exist in tile where recycled lead glass from CRTs is used. Do not use imported tile or tile made with recycled glass unless the ingredients can be sourced.

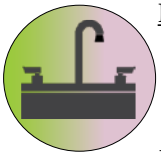


Vinyl Film – Adhesive-backed vinyl is sometimes pasted over existing counters to mask damage or to get a new appearance at a low price. As with other vinyl products, the material is toxic to manufacture, and may include hazardous phthalates and catalysts.

Other Counter Surfaces

Linoleum – This is the same wear-resistant material used for floors. It comes in hundreds of colors and patterns, and is inexpensive compared to most other counter materials. It is also naturally antimicrobial (without the use of biocides). However, it is vulnerable to scratches and heat.

Stainless Steel – This counter material casts a cold look, but some people want this for a modern style. While it has a positive effect on the indoor environment, many steel counters do not hold up well to scratches.

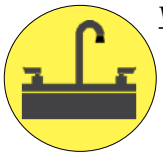


Recycled Glass – Counters made of recycled glass make a strong statement about sustainability by preventing use of virgin material. Brightly colored glass from beverage containers, stop lights, auto glass, and even stained glass are mixed in a counter slab held together with cement or epoxy resin.

Some resins contain BPA, a potent endrocrine disruptor. And even though recycled counters are relatively healthy for indoor air quality, they need to be sealed once a year to prevent staining, again raising concern about toxins in the sealant. If cement binders are used, check to assure that coal fly ash that might contain heavy metals is avoided.

Concrete – This counter class is always custom-crafted onsite. The raw materials are obviously heavy. Unless Do-It-Yourselfers have experience working with concrete, it would be best to have these created by professionals (which can add to expense). Cement containing coal fly ash with heavy metals should be avoided.

While some concrete countertops become unique art forms that cannot be duplicated with other materials, they are vulnerable to stains and must be sealed like stone surfaces. They can also chip, and develop hairline cracks.



Wood – Wooden plank and "butcher-block" countertops are made from renewable resources, and give kitchens a warm appearance. The surface can be sealed to retain moisture and protect it from stains, scratches, and heat, though some of these finishes can offgas VOCs. Further contributing to longevity, these materials are fairly easy to repair; this often is accomplished through oiling and waxing, or light sanding and resealing. Bamboo counter products are also naturally antimicrobial.

Prices range from low-cost for some domestic species to extremely expensive for exotic imports. Though finishes can make wood more resilient to water, some experts recommend its use for counters away from sink areas that are frequently moist. Flammability of wood also makes it difficult to locate near stoves. Wood hardness is not rated on the MOHS scale, but the Janka scale. (See p. 109.)

Environmental/Health Ratings for Countertops

In addition to the ranking of generic products at the beginning of this article, a few agencies and institutions have created rating systems to certify countertops.

GREENGUARD
spot.ul.com/main-app/products/catalog/?keywords=
This rating system administered by Underwriters Laboratories measures for VOCs emitted from many product categories, including counter surfaces. It has two tiers: its standard GREENGUARD rating; and its premium GREENGUARD Gold rating.

Indoor Advantage
scsglobalservices.com/certified-green-products-guide
Scientific Certification Systems, Inc. is a private company now operating as SCS Global Services. It certifies third-party verifications of environmental claims, including VOC emissions from counter surfaces under its Indoor Advantage Gold program.

Safety Data Sheets (SDS)
These legally required summaries of potential product hazards are usually found on manufacturers' Web sites. Safety Data Sheets have shortcomings. Due to trade secrets, ingredient percentages are often vague. SDS only require listing of hazardous ingredients if they make up more than 1% of a product, and carcinogenic ingredients if they make up more than 0.1% of the product.

OTHER CONSIDERATIONS & BUILDING MATERIALS

Antimicrobials

Antimicrobial chemicals have become common in building products. Most consumers believe they kill germs and viruses that cause illness. They are frequently found in carpets, concrete, countertops, door handles, light switches and covers, paints, tile, toilets and toilet seats, wall paper, and wood products. However, while antimicrobials are effective as biocide preservatives in products such as paint, there is no evidence antimicrobials are effective in creating better health. There is, rather, evidence that they can cause harm. (Perkins+Will, *Understanding Antimicrobial Ingredients in Building Materials*, March 2017.)

These chemicals are overtly toxic to people in sufficient doses, and even in small quantities can sometimes contribute to chemical sensitivity. When they leach from the material they are applied to through cleaning water, antimicrobials find their way to the wastewater supply and eventually the environment when treated sewage effluent is returned to waterways. This adversely affects aquatic life, and also people downstream who drink the treated water. Both triclosan and silver nanoparticles are appearing in increasing amounts in waterways and in human tissue samples, in part because they are commonly used in household products and building materials. Antimicrobials can also become airborne and harm indoor air quality.

Most worrisome is that antimicrobials are believed to contribute to antibiotic resistance in the very microbes they are designed to kill. Since these chemicals are not lethal to every single germ, germs that survive develop resistance and pass this trait on to their progeny.

Consumers should avoid these chemicals to the greatest extent possible by avoiding the purchase of building materials boasting antimicrobials as a selling point. People will pay dearly with cost premiums and environmental and health risks while getting no real added health benefits.

Insulation

Though common insulation materials are not usually installed in the interior of a building, VOCs in them can offgas and adversely affect indoor air quality. Chemicals used in their manufacture can also harm workers exposed to them during installation.

Fiberglass and *rockwool* are mineral-based materials. Most residential fiberglass ceiling and wall insulation is relatively benign now that formaldehyde binders have been eliminated. There are some fiberglass-board duct liner products that are formaldehyde-free as well. Formaldehyde-free rockwool products are also entering the market.

Some people prefer *cellulose* and *cotton* insulation because they are renewable and biodegradable, However, both are treated with boric acid as a fire retardant. While less toxic than most other flame retardants on the market, in sufficient dosages, it is a developmental and reproductive toxin, endocrine disruptor, and organ toxicant.

Rigid-board or plastic-board insulation is typically used in new buildings as opposed to retrofit situations. Polyisocyanurate and polystyrene (expanded and extruded) are manufactured with fire retardants more toxic than boric acid. Expanded polystyrene also has pesticides in it to deter termites.

Spray foam insulation (SPF) combines an onsite two-part chemical combination of isocyanates and polyols with additives. *It is the most hazardous of all insulation types.* The implications of the chemical hazards contrast the material's contribution to energy efficiency, since the use of SPF in wall cavities and under roof decks can turn homes into veritable thermoses that dramatically reduce heating and cooling needs.

But there is no getting around the chemical risks in SPF. Isocyanates and amine are potent asthmagens. Toxic flame retardants and organotin catalysts are also ingredients in spray foam. To add to these chemical concerns, a particular type of spray foam, "closed cell," uses blowing agents manufactured with carbon tetrachloride, a fiendishly potent ozone depleting chemical.

Environmental/Health Ratings for Insulation

A few agencies and institutions have created rating systems to certify insulation products.

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spot.ul.com/main-app/products/catalog/?keywords=
This rating system administered by Underwriters Laboratories measures for VOCs emitted from many product categories, including insulation. It has two tiers: its standard GREENGUARD rating; and its premium GREENGUARD Gold rating.

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There are SPF products that are third-party rated for their low-VOC and formaldehyde emissions. However, unexpected air emissions are more likely from this product class because the products are installed onsite and not factory controlled. (These installations may not all be made in accordance with specifications.)

Polyvinyl Chloride Plastic (PVC)

Of all common plastics, polyvinyl chloride, or PVC, is generally considered the most dangerous. It is in the same chemical family as the banned pesticide DDT, banned chemical PCBs, and dioxins, and is considered highly toxic to manufacture.

PVC manufacturing creates substantial amounts of dangerous air and water emissions, as well as hazardous waste. Chemical additives used in PVC products, such as phthalates that allow the material to be flexible, and organotin catalysts that render the material stable, are themselves toxic, and over time they can break down to harm indoor air quality or be absorbed through the skin.

In the event of fire, hydrogen chloride and heavy metals are released, and dioxins are created through the combustion process. In addition to these hazards, PVC takes as long as 200 years to biodegrade, and toxins in it bioaccumulate in the food chain.

For all these reasons, environmentally conscious consumers should avoid PVC products whenever possible. Yet they are ubiquitous in the average building. With the appropriate chemical engineering, this plastic can be made either rigid or flexible, and its versatility and relatively low cost has made it adaptable to many uses.

PVC building products include windows and doors, weatherstripping for windows and doors, blinds and shades for windows and (glass) doors, siding, plastic lumber for fences and decks, flooring, plumbing (particularly wastewater), shower curtains, wall paper, and electric-wire sheathing.

For the majority of these building products, non-PVC alternatives are available and relatively affordable, and should be chosen to make buildings as PVC-free as possible.

Wallboard

Gypsum wallboard is ubiquitous in buildings. Green building programs around the country have encouraged the use of pre-consumer recycled content in this product, which almost always means synthetic gypsum derived from the Flue-Gas Desulfurization (FGD) in coal power plants. Though it seems counterintuitive to say recycled content is not green, FGD gypsum contains toxic minerals and heavy metals such as asbestos, cadmium, lead, and mercury.

It is caustically ironic that mercury emissions around coal plants have fallen because of efficient pollution control devices while mercury emissions around drywall manufacturing plants have soared since 2000 because of widespread use of FGD gypsum.

These toxins can also be exposed to workers that install the product, and can, at least initially, get into house dust until installation clean-up occurs. The toxins can also leach into groundwater near landfills if dry wall scrap or old material is discarded there. *Consumers that purchase new dry wall are encouraged to buy products with as little pre-consumer recycled content as possible.*

Another variation of wallboard to avoid is products laminated with PVC film. These carry the same environmental problems as other materials made from PVC, with the added problem of low vapor permeability. Buildings need to breathe, and PVC coatings on walls lying on a building's exterior or bordering a humid room may lead to condensation that can contribute to mold.

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Austin's Central Library is an Experience in Orchestrated Delight

Kathy Zarsky

The City of Austin is a proud member of the Biophilic Cities Network, which connects us to new research, tools, and ideas from around the globe that advance integrating nature into the city. We envision Austin as a community where nature is integrated seamlessly into the city's legal, planning, and design process; development and redevelopment that prioritizes vegetation, ecosystem function, and human experience; and access for all Austinites to a healthy dose of daily nature. The following article is sponsored by the City of Austin's Office of Sustainability.

The 198,000 square foot library, which has achieved LEED Platinum certification, is considered the best daylit library in the country. Over 61% of the outdoor site area is dedicated open space, and the site captures stormwater runoff and condensation to reduce potable water by 100% for irrigation needs and sewage conveyance. The building conserves over 87% potable water for internal use. The design has resulted in an energy cost savings of 33% with 10% on-site renewable energy.

Wonder in Architecture

Austin's Central Library is a highly anticipated public structure sited along Shoal Creek and Lady Bird Lake on the western edge of downtown. Its climatic responsive design and use of local materials lend a timeless and iconic fit to its place amongst the many towering giants that are commonplace in the urban core. It's a place that visitors relish and dream of frequenting, coining it "Austin's living room." The building's atrium captivates and signals an irresistible invitation the moment you walk inside, and gravity is no match for the stairs that bait feet to Escher-like stairs in an upward, spiraling ascent. Whether arrival takes place on foot, bicycle or car, the library is a destination that connects visitors to nature inside and out in ways that are immediately sensed if not easily articulated. The building siting and design arouse delight and well-being through experiences of connection, activity, mindfulness, learning and curiosity.

Local to Global Benefits of Integrating Nature

Paul Hawken, in his book *Drawdown*, outlines an extensive variety of technological and ecological solutions to the urgent predicament of climate change. *Drawdown's* research emphasizes many of the same solutions recommended by Biophilic Cities, namely the protection and promotion of nature within cities. Austin's Central Library includes five "drawdown" design elements worth emulating elsewhere within the city.

The first biophilic solution is design that promotes walkable cities. If anything, the Central Library is a destination that is enjoyable to access on foot. The most popular way to approach the building is along the Shoal Creek Trail or across the new Butterfly Bridge. This path introduces visitors to a vital link to the pulse of one of Austin's primary watersheds. The Shoal Creek Trail will include 10 miles of connections to neighborhoods, schools, parks and employment centers when completed. Walkability correlates with livability, and the desire to walk carries into the circulation design within the building. Trails that meander along riparian edges and stairs that twist and turn in midair indoors are powerful design accomplices. Walking becomes the favored choice when feelings of discovery, curiosity, risk and play are evoked.

Austin is also investing more in bike infrastructure within the Seaholm EcoDistrict and beyond, and the library serves as the primary catalyst for more biking surfaces, maintenance stations and parking for the general public. Employees of the library enjoy gracious biking accommodations and changing facilities, making the commute a viable means of transportation all year long. The public has access to one of the most extensive and protected bike corrals in the city, making the library a likely staging area for a variety of nearby attractions. The health, energy and nature connection through bike infrastructure is the second biophilic solution.

Once settled in, it doesn't take visitors long to discover the library's green roof on the sixth floor, which is the third biophilic drawdown solution. It is by far one of the most cherished design features. It offers expansive views of Lady Bird Lake, Shoal Creek and the always changing downtown skyline. The native vegetation is diverse and

lush with a variety of textures and massing to attract people, pollinators and wildlife. The dappled light under the photovoltaic canopy is similar to sitting under the shade of a tree, with soft slits of light slowly shifting across the wood decking as the sun travels across the sky. It is exactly the kind of design element sorely needed with a population craving more ways to work and recreate in comfortable, nature inspired outdoor settings. Buildings with integrated vegetation, if scaled across contiguous transects, can turn cities into life-supporting systems.

What may not be readily apparent to infrequent visitors is the way in which the library is creating community. Metaphorically, it draws a diverse group of individuals and groups and creates opportunities for intersection and interaction. Quite literally, however, it is reintroducing a community of trees that together will moderate the extremes of heat and cold, erosion, water quality, evaporation and more. The ecosystem services of trees are hidden yet well studied, and this represents the fourth biophilic drawdown for cities. While these beneficial tree community traits often get taken for granted, the qualities that trees bring to the environments we inhabit are understood from early childhood. We enjoy their shady protection, the habitat they offer, the sound of wind through their leaves, and the seasonal changes they display.

There are many lessons and experiences to be gleaned from these statuesque wonders, not least of which is that every tree is a valuable member of their ecological community. Biophilia can also inspire reciprocity, the fifth drawdown concept that looks to human behavior to play a mutualistic role. The library site has left ample space to restore a once thriving, functional ecological corridor in the heart of the city that we can enjoy as amenity, but the opportunity for the city is to encourage robust extensions of similar natural corridors that link with other life-supporting systems in three dimensions. These biologically diverse and connected nature networks support more effective ecosystem services and also create more ways for people to connect to, learn from, and nurture as symbiotic partners.

Scales of Biophilic Design

The design of the library as a building is widely reported, but lesser known is the influence that the library's designs play across scales of block, street, neighborhood and community. The building prominently incorporates natural, local materials like limestone and mesquite, and it offers a variety of views and vistas in all directions from every level. The quality of the extensive daylighting is undeniable. The perimeter window seating goes fast because the natural light and views are so calming and restorative. The use of color, spatial gradients and volume have maximized the degree to which daylight is employed throughout the building. There's truly not a bad seat in the house.

The central focus of the library is the atrium with grackles serving as the motif for a giant cuckoo clock rising as tall as the maze-like stair ascends. The entire library is filled with spatial variability and transitions to indoors and outdoors. The design lends to experiences of prospect, refuge, mystery and risk. All of these elements and experiences are translations of sensations that are typical in the natural settings that we are hardwired to seek out.

The place-based biophilic design becomes more apparent with jumps in scale. The building opens up to the east to create areas for congregating and circulation along Shoal Creek. The vegetation transitions from maintained to wild, signaling both habitat and watershed edges. The creek connects to the largest water body in Austin, Lady Bird Lake, less than 200 meters away. The surrounding neighborhood is contained within the Seaholm EcoDistrict, a historically and culturally significant part of downtown Austin due to its industrial relationship with water. The new developments within the EcoDistrict have shifted their relationship to water to one of reverence and attraction.

The primary limestone building materials are reflected in similarly scaled office and civic structures nearby, paying homage to the character of place. More than any other downtown site, the library feels integrally linked with pedestrian and cycling infrastructure. Boundaries are soft and blurred, allowing for interpretation for a variety of community uses outdoors. The outdoor spaces meander and traverse elevation changes that nudge curious visitors to explore. This act of discovery quickly connects visitors to the site, street, neighborhood and eventually community as time and distance allow. It is nature and the qualities it offers with breezes, sounds, daylight and glimpses of wildlife and watercourses that make these linkages so attractive. The library offers a new vision: that buildings in Austin can and should enhance the quality of day-to-day life through integrating nature at multiple scales, bridging building to place and place to community.

Kathy Zarsky is an architect in Austin, LEED®AP, BD+C, a Certified Biomimicry Specialist, and founder of BiomimicryTX.
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