# Safer Sleep

## A White Paper on Toxic Chemicals in Bedding and Safer Alternatives for Healthier Sleep

**An evaluation of mattress and bedding materials**
**Final Report - October 29, 2026**

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# Executive Summary

We spend about eight hours a night sleeping, which adds up to almost one-third of our lives in bed. Babies spend almost two-thirds of their time sleeping.[1] While we sleep, our bodies heal, rest, and rejuvenate. But our mattresses and bedding can contain chemicals known to cause negative health effects, which may limit the body's natural ability to protect our health.
At MADEWORKS, we believe products should be made from safe materials: materials that the best available science shows are safe to use, even while we sleep.

A mattress is a complex product composed of multiple materials including foams, fibers, adhesives, and other components that may contribute to its overall chemical profile. While consumers often evaluate mattresses based on comfort, support, and price, these factors provide little insight into the materials used in manufacturing and their potential impact on human health.

Transparency across the conventional mattress industry remains limited. Product labels may use broad material categories or technical terminology without fully disclosing all materials, chemical ingredients, or manufacturing processes involved. This lack of comprehensive disclosure makes it difficult for consumers to fully evaluate the potential health impacts for the products they use for extended periods of time.

Consumers deserve access to clear, comprehensive information about the product they are purchasing. Greater transparency is essential to supporting informed purchasing decisions to choose the right mattress for themselves and their families.

# High-Level Findings

- Flame retardants are a central concern in conventional foam mattresses. Polyurethane foam is made from petroleum-derived ingredients and is highly flammable,[2] so flame retardant chemicals are commonly added to meet federal flammability standards.[3] Studies have linked flame retardants to endocrine disruption,[4-5] lower IQ,[6,7] altered neurodevelopment,[8-9] fertility issues,[10,11] and cancer.[12,13] They have been measured in people's blood,[14] urine,[15,16] and breast milk,[17] and in household dust.[18-19] Their effectiveness in real fires is also debated.[20]
- The foam itself can release chemicals. Residual, unreacted isocyanates have been found in polyurethane foam,[21-22] including in samples up to 31 years old.[23] One of these, TDI, is a known carcinogen.[24] Foam also emits volatile organic compounds (VOCs). It can absorb VOCs from indoor air and release them again later.[25-26]
- Waterproof vinyl crib mattresses can be a constant source of plasticizers for babies.[27] In one study, 17 of 20 crib mattress covers contained at least one plasticizer above 0.1 percent.[28] Additionally, two covers made after the federal phthalate ban still exceeded the limit for DEHP.[29] In chamber tests at 25-55°C, emissions from vinyl crib mattress covers rose significantly with temperature, [30] and the authors' modeling suggests that

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warming from a sleeping infant could make the breathing-zone concentration about four times higher than in the room air.[31] Emissions also don't appear to decline as the mattress ages.[32-33] Because infants breathe approximately twice as much air per body mass as adults, their exposure can be significant.[34,35]

- Many ingredients are hidden from shoppers. Flame retardant formulas,[36] mattress adhesives, antimicrobial treatments, and some latex preservatives[37] are often proprietary trade secrets. That means neither shoppers nor scientists can fully know what's inside, or assess the health risks.
- Bedding labels are useful "chemistry clues." Sheets marketed as "wrinkle-free" or "no iron" may carry a formaldehyde finish,[38] which isn't regulated in US textiles.[39] "Antimicrobial" and "antibacterial" bedding may contain triclosan, triclocarban, or nanosilver.[40,41] "Stain repellent" linens may be treated with per- and polyfluoroalkyl substances (PFAS).[42]
- Safer alternatives exist. Wool is naturally flame resistant, and organic cotton is much less flammable than foam,[43] and when used properly they can meet federal flammability standards without added flame retardant chemicals. Sewn construction avoids chemical adhesives altogether.[44] Studies show that reducing exposure to products with toxic chemicals lowers the levels of those chemicals in the body.[45,46]

In simple terms: the safest mattresses and bedding tend to be made from the simplest materials, with fewer synthetic inputs, fewer chemical finishes, and full transparency about what's inside. With that knowledge, shoppers can make informed choices about what they sleep on.

# Purpose and Scope

This paper looks at the materials that make up conventional mattresses and bedding. It identifies chemicals of concern within them, their potential impacts on human health and ecosystems, and safer alternatives. It is meant to give shoppers clear, evidence-based information so they can choose based on what's inside a product, not just on comfort, cost, or marketing.

Scope includes: (1) conventional polyurethane foam mattresses, including flame retardants, isocyanates, VOCs, other foam additives, polyester ticking, and adhesives; (2) waterproof vinyl baby mattresses and covers, including phthalates and alternative plasticizers; (3) safer mattress materials, including organic cotton, wool, latex, coils, and sewn construction; and (4) linens, including pillows, sheets, mattress pads and comforters, and antimicrobial and stain-repellent treatments. Supporting evidence comes from peer-reviewed literature, biomonitoring studies, and regulatory and public-health sources.

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# How Our Bodies Heal and Detox During Sleep

## Our Brains

One study from the University of Rochester Medical Center conducted on mice suggests that the brain has a mechanism for removing toxic waste that actually ramps up during sleep.[47] They discovered that the space between brain cells expands by about 60 percent during sleep, which allows the glymphatic system (which acts much like the lymphatic system but is unique to the brain) to pump cerebrospinal fluid through the brain and flush the waste from the brain back into the body's circulatory system, where it reaches the liver and is eventually eliminated.[48] This research suggests that humans also have a "garbage removal system" in our brains that removes harmful waste products; this could be a purpose of sleep.

## Our Hormones

When we sleep, our endocrine system is in an anabolic state, which supports energy conservation, repair, and growth.[49] The body produces human growth hormone, which promotes the maintenance and repair of muscles and bones, renewing tissues faster than while we're awake.[50,51]

## Our Skin

The skin is made in part of collagen, a protein abundant in the human body, that gives our skin (and other connective tissues like bone and tendons) strength and structure. As we sleep, our body's immune function is restored, which can positively affect collagen production.[52] Sleep deprivation may also affect our skin's homeostasis, or balanced state, and may impair the skin's natural barrier, which protects us.[53] Sleep deprivation may even cause skin diseases and increase our chances of systemic bacterial infections.[54]

Sleep's abundant benefits for the human body make a healthy sleep environment that much more imperative. By choosing healthier materials, we lower our exposure to toxic chemicals, potentially eliminating interference with healthy, restorative sleep.

# What's Inside the Mattress: Polyurethane Foam

There are many kinds of mattresses. The most common types are made of memory foam (or viscoelastic foam), flexible polyurethane foam, coils, or combinations of these materials. Flexible polyurethane foam and memory foam are both types of polyurethane foam. Each type

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contains different additives at varying amounts to achieve the desired density, firmness, and rate at which the foam returns to its original position.[55]

The polyurethane foam that makes up most mattresses is made by mixing polyols with water and isocyanates, the primary building blocks of foam.[56] The process also uses other chemical catalysts, surfactants, fillers, and flame retardant chemicals.[57] Some manufacturers add auxiliary blowing agents, which influence the foam's softness and density.[58] Most, if not all, of the ingredients used in making polyurethane foam are petroleum products, meaning they are derived from fossil fuels. All of these ingredients are mixed in a mold and react quickly, rising like a loaf of bread.

## Flame Retardants

Flame retardants are a group of chemicals commonly added to polyurethane foam. Because polyurethane foam is made from materials derived from fossil fuels and is therefore highly combustible,[59] some industry officials assert that flame retardant chemicals reduce the risk of flammability. However, these chemicals are of significant concern to our health, and might not actually give us more time to escape in a fire.[60,61]

Some of these toxic flame retardants have been measured in the bloodstream,[62] urine,[63,64] and on people's hands[65] in biomonitoring studies, which measure the actual level of a substance within the body.

Several scientific studies have linked flame retardants to many health impacts, including endocrine disruption,[66,67,68,69] lower IQ,[70,71] hyperactivity,[72] altered sexual development,[73,74] altered neurodevelopment,[75,76,77] other adverse pregnancy outcomes,[78] fertility issues,[79,80] thyroid dysfunction,[81] and cancer.[82,83] Some flame retardants can accumulate in the placenta, which could adversely impact a developing fetus.[84]

Mothers can transfer flame retardants to their babies through breast milk.[85] In fact, breast milk can be one of the largest sources of flame retardants in a person's lifetime.[86] Exposure to toxic substances during critical windows of development can have long-lasting impacts on children's systems. For example, one study that measured certain flame retardant metabolites, the products of metabolizing a substance in the body, in pregnant women found adverse impacts on intelligence and working memory in children when they were assessed at age seven.[87]

Household dust is another common route of exposure to flame retardant chemicals.[88,89,90] Because some flame retardants are not heavily bound to the products they're used in, flame retardants can migrate from a product, like a mattress, and land in household dust.[91] From there, they're inhaled, consumed, and then stored in our bodies.[92] Flame retardant chemicals have been measured in dryer lint; this is likely due to household dust accumulating in clothing[93] or in children's pajamas.

Children are especially at risk of exposure to flame retardant chemicals through contact with household dust. Children play, nap, and sit on the floor, and also handle objects like toys that have touched the floor. Children often place their hands in their mouths; this is a common route

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of exposure to flame retardants.[94] Because their bodies are still developing, children are considered a population vulnerable to chemical exposure that can disrupt various systems.[95] This ongoing development makes children particularly susceptible to flame retardant chemicals.

Not only are some flame retardants harmful to human health, but they also impact animals and the environment. Flame retardants have been found in the tissues of polar bears,[96] sea otters,[97] killer whales,[98] and more.

Because household dust accumulates in clothing, flame retardants have been measured in laundry wastewater effluent. This effluent water can eventually reach natural water sources where aquatic life lives. This is an issue because some flame retardants are known to be toxic to aquatic life.[99] Many flame retardants can be persistent (meaning they stick around) in the environment,[100,101,102,103] can bioaccumulate (accumulate in organisms' tissues),[104,105] and can biomagnify (accumulate progressively in organisms' tissues moving up the food chain).[106,107]

# Polybrominated Diphenyl Ethers

Until 2004, Polybrominated diphenyl ethers (PBDEs) were the most commonly used class of flame retardants,[108] but because of the link between PBDE exposure and hormone disruption,[109] the sole manufacturer in the United States voluntarily and permanently phased them out.[110,111] As a result of the phase-out, researchers found lower levels of PBDEs in people studied.[112,113]

Many older products containing PBDEs from pre-phase-out are still in use by the general public.[114] Regardless of the phase-out, PBDEs are still detected in the blood, albeit at much lower levels.[115] However, in pregnant women, these detected levels may impact thyroid function.[116]

The industry has replaced PBDEs with other flame retardants, but toxicological information on these alternatives—as well as their identities—are not readily available.[117] Flame retardant formulations are often proprietary and considered trade secrets, which means that many major mattress companies will not reveal what flame retardant chemicals they use.[118] Only recently have researchers begun identifying some of the compounds used within flame retardants.[119]

# Organophosphorus and Halogenated Flame Retardants

Although many flame retardant formulations are proprietary, we do know that of the flame retardants currently in use, two types are of primary concern:[120]

- Organophosphorus flame retardants: those containing phosphorus bonded to carbon.[121]
- Halogenated flame retardants:[122] those containing carbon bonded to a halogen (chlorine, bromine, iodine, or fluorine).[123] This class includes flame retardants sometimes referred to as brominated, chlorinated, or organohalogen flame retardants (OFRs).[124] (PBDEs are also halogenated flame retardants.)[125]

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Both categories are suspected to cause adverse effects on human health and the environment.[126]

In July 2015, several petitioners, including medical, consumer, science, fire, and community organizations, submitted a petition to the US Consumer Product Safety Commission (CPSC) to ban halogenated flame retardants (OFRs) in certain consumer products, including some childcare articles, upholstered furniture, mattresses, and mattress pads.[127]

In 2017, the Commission voted to grant the petition; however, it was issued as a non-binding recommendation rather than a legal standard.[128,129,130]

In September 2017, the Commission granted a petition to initiate rulemaking under the Federal Hazardous Substances Act on additive, non-polymeric organohalogen flame retardants (OFRs) as a class and directed a Chronic Hazard Advisory Panel to assess and report on their risks to consumers.[131] Later that month, the Commission issued guidance recommending that manufacturers refrain from intentionally adding OFRs to children's products, upholstered furniture sold for use in residences, mattresses and mattress pads, and plastic casings surrounding electronics.[129,131] CPSC subsequently sponsored the study "A Class Approach to Hazard Assessment of Organohalogen Flame Retardants" and developed a plan to assess the hazards, exposures, and risks of OFRs in consumer products; contractor draft assessment deliverables and staff status reports were issued from 2022 through 2025.[132]

# Firemaster® 550

Firemaster 550, a common replacement for PBDEs,[133] is an organophosphorus and brominated flame retardant mixture.[134,135] The components of Firemaster 550 are commonly found in household dust,[136,137,138] and there are several associated and potential health effects linked to these chemicals.

Perinatal exposure to Firemaster 550 can cause endocrine disruption at levels much lower than previously reported,[139] including those reported by the manufacturer.[140] In animals, Firemaster 550 is a potential obesogen and contributor to metabolic syndrome,[141] may impact growth[142] and neurodevelopment,[143,144] and is associated with early onset puberty in the pups of female rats exposed to it.[145]

Firemaster 550 flame retardant is made up of several compounds:[146,147]

- TBB (2-ethylhexyl-2,3,4,5-tetrabromobenzoate): shown to accumulate in tissues of both the female rats and their pups.[148]
- TBPH (bis(2-ethylhexyl) tetrabromophthalate): linked to potential alterations in fetal testis development, thyroid dysfunction, liver dysfunction, and obesity.[149] TBPH is structurally similar to the phthalate DEHP, which is a male reproductive toxicant in rodents.[150]
- TPP (triphenyl phosphate): While there is little information about the toxicological potential of this individual component, Firemaster 550 as a whole may be an endocrine disruptor, obesogen, and developmental toxin.[151]

- ITPs (isopropylated triphenylphosphate isomers)[152]: linked to adverse health effects in

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zebrafish;[153] several ITPs are trade secrets.[154] Despite widespread exposure to these compounds in the US,[155] there are large data gaps in research.[156] This has been acknowledged by the Environmental Protection Agency (EPA), which prioritized safety evaluations of ITPs in 2016.[157]

- Despite their potential and associated health effects, the chemicals of Firemaster® 550 were commonly detected in baby products purchased between 2000 and 2010.[158] However, the September 2017 CPSC guidance described above recommended that manufacturers refrain from intentionally adding non-polymeric organohalogen flame retardants, including the brominated components of Firemaster 550, to mattresses, mattress pads, and other covered consumer products.[129]

This guidance was a step in the right direction, but did not itself establish a ban. There has been little research to identify the flame retardants used in baby mattresses and products produced after 2011. With new flame retardants continually hitting the market, it's impossible to know which flame retardants might be used in today's baby mattresses without laboratory research or industry disclosure.

## Chlorinated Tris

Chlorinated tris is an organophosphorus flame retardant that was used in children's pajamas until the 1970s, when it was banned due to associated adverse health effects.[159] However, despite the chemical's ban in pajamas, it is still used in mattresses today. Chlorinated tris, a known carcinogen,[160] is used in baby mattresses[161] and is often used as a replacement for PBDEs as a flame retardant. Forms of chlorinated tris include TDCPP, TCEP, and TCPP.[162]

## Other Flame Retardants

In addition to the flame retardants currently in use, companies are continually discovering, synthesizing, and using new ones. However, the chemical structure and formulation are often proprietary, leading to transparency issues and difficulty obtaining toxicological data. Because flame retardant formulations can be considered trade secrets, many major mattress companies will not disclose which chemicals they use. Other flame retardants, some of which are organophosphorus or halogenated, that may be used in polyurethane foam include, but aren't limited to:

- Emerald Innovation NH-1
- Firemaster® 600
- Firemaster® BZ-54
- FR 513
- FR 1410
- Fyrol-2 / Fyrol-38
- Fyrol A300TB
- Fyrol A710
- Fyrol HF-4
- Fyrol HF-5
- Fyrol PCF / Fyrol PCF-LO
- Melamine

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- Reofos NHP
- U_POFR
- V6

Data gaps in proprietary information are exacerbated by the fact that many flame retardant chemicals are used in combination.[163] Not only are the individual chemicals untested, but the combinations are also untested, resulting in even greater gaps in research on human and environmental health.

# Flammability of Foam and Flame Retardants

Mattresses must meet certain flammability standards set by the US federal government; these standards require both a smolder test and an open-flame test. A smolder test is meant to simulate a fire ignited by a cigarette,[164] whereas an open-flame test is meant to simulate a fire ignited by an open flame,[165] such as a candle. Crib mattress flammability is not regulated under a specific federal regulation; the same standards as adult mattresses apply.[166]

The smolder test mandated by 16 C.F.R. § 1632 in 1973 is a mandatory requirement for mattresses and mattress pads. It requires that charring doesn't spread more than two inches from where a faux cigarette is applied to the material.[167]

In 2007, 16 C.F.R. § 1633 was instituted as a complementary requirement to existing § 1632. The new standard requires mattresses, foundations, and mattress-foundation sets to undergo a 30-minute open-flame test,[168] in addition to the existing smolder test.

Open flame tests measure the amount of heat released when a material is ignited. This is called heat release rate. The higher a material's heat release rate, the higher that material's energy content—and propensity to self-propagate a fire.[169] Heat release also measures the size of a fire.[170]

A material's heat release rate also partially determines the likelihood of flashover.[171] Flashover is when a material ignites other materials within the space by the original fire's radiant heat.[172] After flashover occurs, it's essentially impossible to exit a room because it's entirely ignited.[173] The goal of § 1633 is to delay flashover,[174] by capping a material's heat release rate[175] at both 15 and 30 minutes.[176] Flashover is a concern because about two-thirds of fatalities from mattress fires are flashover fires that originate in the mattress.[177]

Because polyurethane foam is highly flammable[178,179] and has a high heat release rate, the addition of flame retardant chemicals is necessary to meet mattress flammability standards.[180] In a fire, polyurethane foam often liquefies, drips, and pools under the product. The pool ignites from the heat of the foam fire, which can cause the fire to grow.[181]

Natural fabrics have a lower heat release and are generally less flammable than polyurethane foam. In a study measuring the time to flashover of foam-based furniture versus cotton batting and cotton fabric-based furniture, foam's flashover occurred at 4 minutes.[182] Cotton-based furniture's flashover did not occur until 34 minutes.[183] The application of flame retardants delayed flashover of foam-based furniture, but cotton flashover was still approximately two

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times longer.[184] Natural fabrics do not often liquify and pool like polyurethane foam.

## Are Flame Retardants Effective?

In addition to the potential adverse health and environmental effects of flame retardants, their efficacy is debated. Flame retardants may not be effective at preventing fire or in providing significantly more time to exit in the event of a fire.[185] However, they're ubiquitous in foam-based products because foam is inherently very flammable.[186,187]

Two studies are often cited regarding flame retardant efficacy. One is misrepresented.[188] The other's conclusions are extrapolated incorrectly.[189,190] Other studies are scarce.
In the first study, researchers used flame retardant chemicals at much higher concentrations than would be used in normal products.[191] The study's author, fire engineer Vytenis Babrauskas, criticized the misuse of his research.[192] The second study's data was extrapolated incorrectly, resulting in the misuse of information.[193] This means that these often-cited studies are not reliable evidence of flame retardant efficacy.

In a fabric-covered foam product, once the underlying foam has ignited through the fabric, flame retardant chemicals are ineffective at mitigating the intensity of the fire's spread.[194,195] In flammability testing, flame retardants applied directly to foam showed no significant difference in flammability safety from foam without flame retardants applied directly.[196]

Beyond their limited effectiveness in suppressing combustion, certain flame retardant formulations may also contribute to increased emissions of carbon monoxide, smoke, and soot during fires.[197] Smoke inhalation is a leading cause of fire-related fatalities.[198]

Furthermore, firefighters experience elevated rates of certain cancers,[199,200,201,202] raising growing concerns about the occupational cancer risks associated with firefighting.[203] Cancer has emerged as a leading cause of mortality among firefighters.[204] Some organizations and researchers attribute exposure to synthetic chemicals in fires as a potential association with occupationally-related cancer in firefighters,[205,206] including flame retardant chemicals specifically.

## Isocyanates

Isocyanates are a primary building block of foam;[207] when they're mixed with water and polyols, a group of surfactants, foam is formed. Toluene diisocyanate (TDI) is the most common isocyanate used in this process; methylene diphenyl diisocyanate (MDI) is also used.[208] Both TDI and MDI are hydrocarbon compounds and are made primarily from crude oil or natural gas.[209]

Exposure can induce asthma attacks, irritate mucous membranes, and cause skin inflammation and chemical sensitization.[210] Isocyanates can also cause respiratory disease, even at low levels of exposure.[211] One isocyanate, TDI, is a known carcinogen.[212] Isocyanates are classified as an occupational chemical of concern.[213]

The polyurethane foam industry maintains that the curing process chemically reacts

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isocyanates during manufacturing, incorporating them into the polymer structure and thereby minimizing the potential for residual isocyanates to migrate or off-gas from the finished product. However, such industry claims often have little supporting evidence.[214]

Excess isocyanates are present during the chemical reaction that produces foam.[215] Not all of the isocyanates are used up in the reaction, resulting in residual, unreacted isocyanates present in polyurethane foam.

The use of excess isocyanates during manufacturing may result in residual unreacted compounds, such as TDI, remaining in finished polyurethane products, including foam bedding, and potentially being released over time, contributing to consumer exposure.[216] Research has identified residual amounts of unreacted isocyanates, such as TDI and MDI, remain in polyurethane products.[217,218] One study found free unreacted isocyanates in samples up to 31 years old.[219] Another found unreacted isocyanates in 13 polyurethane foam samples, likely at greater levels in newer mattresses than in older, used mattresses.[220]

Even though isocyanates can be present in polyurethane foam, the industry maintains that exposure is harmless. One study, conducted primarily by industry scientists, concluded that there is no risk of harmful health effects from sleeping on polyurethane mattresses.[221] But according to the Office of Environmental Health Hazard Assessment (OEHHA), "chronic exposure to TDI may occur via inhalation and dermal contact with polyurethane products"[222] and this "chronic exposure to relatively low levels of TDI may result in allergic sensitization."[223]

While research is inconclusive as to whether isocyanates pose a high risk to consumers of polyurethane foam products, it remains a high occupational risk,[224] and could pose unforeseen health threats.

## Volatile Organic Compounds

Researchers have identified multiple volatile organic compounds (VOCs) that mattresses and mattress covers can emit. VOCs are organic chemicals that readily become gases; these are typically invisible and present in indoor environments, including homes, offices, schools, and childcare facilities.[225] Many VOCs are known to be harmful to human health.[226]

Polyurethane foam is a source of VOC emissions in the home, but it also can absorb VOCs from the surrounding environment.[227] For example, because some paints are high in VOCs, painting a room can result in high levels of VOCs in indoor air; polyurethane foam can absorb the VOCs off-gassing from the paint.[228] This absorption can then be reversed. When VOC concentrations in the room decrease, VOCs can desorb from the polyurethane foam back into the indoor air.[229] This means that polyurethane foam plays a major role in the quality of indoor air.[230]

Because polyurethane foam can absorb VOCs from its surroundings, studies suggest that VOCs emitted from foam samples may originate from either the foam itself or compounds previously absorbed from the surrounding environment.[231]

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One study found that mattress barriers, such as protective baby mattress covers, can act as a partial barrier to VOC emissions from mattresses. However, adult mattresses don't typically have waterproof covers like baby mattresses, which means adults may be more readily exposed to VOCs emitted by polyurethane foam.[232]

Multiple VOC emissions have been identified in mattresses. Researchers have identified the VOCs 1,2-dichlorobenzene and 1,4-dichlorobenzene emissions from polyurethane foam samples.[233] Both of these chemicals are used in the manufacture of isocyanates during the phosgenation process, in which an amine is treated with phosgene,[234] a poisonous gas originally used as a chemical weapon during the First World War that was responsible for the majority of deaths.[235] Phosgene is used widely in chemical manufacturing today.[236] 1-chloro-2-propanol, 2-chloro-1-propanol, and 1,2-dichloropropane also can off-gas from mattress samples.[237] In animal studies, both short-term and long-term exposure at low levels of 1,2-dichloropropane caused damage to the liver, kidneys and the respiratory system.[238] In humans, it can cause eye, skin and respiratory irritation; kidney damage; and liver damage.[239] Phenol, which can be used in the manufacturing process of foam,[240] has been identified in mattress emissions.[241,242] Other identified compounds include: 2-ethyl-hexanoic acid, which can be used in manufacturing;[243] D-limonene, which can be used as a solvent, wetting agent, or fragrance in manufacturing[244]; and linalool, a fragrance ingredient.[245]

In one study, researchers found acetaldehyde and formaldehyde emitted at higher rates than other VOCs.[246] However, because of its small sample size, further research is necessary to determine if these are common emissions in many polyurethane mattresses.

## Other Additives

There are other common additives in polyurethane foam:

- Urethane grade methylene chloride, which can cause skin and eye irritation and is readily absorbed through the lungs.[247,248]
- Acetone, a skin and eye irritant[249] linked to respiratory tract irritation, dizziness, and weakness in workers.[250,251]
- Liquid carbon dioxide, which can pose a risk of frostbite in an occupational setting if not handled properly.[252,253] This additive is gaining popularity in the industry.[254]
- There is limited research available on the potential for these chemicals to off-gas from mattresses or on whether coming into direct contact with a mattress manufactured with these chemicals poses health risks.
- Phthalates and alternative plasticizers, which may be present among the chemical additives used in polyurethane foam manufacturing.[255] Similar to VOCs, phthalates can be absorbed, retained, and subsequently released from foam materials.[256] More on the health effects of these chemicals can be found in the section entitled, "What's Inside the Mattress: Waterproof Baby Mattresses."

# Polyester

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Polyester is often used as ticking, the topmost finely woven protective layer of the mattress. It is also sometimes used to wrap metal coils. The most common fiber used to make polyester fabric is poly(ethylene terephthalate) or PET.[257] This is the same material used for soda bottles.[258]

In the polyester production process, antimony trioxide is commonly used as a catalyst.[259,260] Antimony trioxide is classified as possibly carcinogenic,[261] and some forms are potentially endocrine disrupting chemicals.[262]

Researchers have found detectable levels of antimony in polyester textiles.[263,264,265] The residue could be from petroleum, from which polyester is derived,[266] but is more likely from the catalysts used during manufacturing, the overwhelming majority of which use antimony.[267,268] Researchers have found that even at low temperatures, antimony can migrate from the fabric to saliva[269] and sweat.[270,271] One study concluded that exposure to antimony through polyester could result in health impacts for groups who wear polyester textiles frequently and for prolonged periods.[272] Given that we sleep for approximately eight hours every night, it may be possible that this is prolonged and frequent enough exposure to experience associated health impacts from antimony exposure. However, there is no research on this subject.

In addition to antimony, several researchers have confirmed that estrogenic compounds can migrate from PET water bottles into their contents.[273,274,275] However, there is no research on the capability of endocrine-disrupting compounds to migrate from polyester PET fabrics to the user's skin.

Making polyester is an energy-intensive process, often using far more energy than manufacturing other textiles, such as conventional and organic hemp and cotton.[276] In the production process, emissions can severely contaminate water sources with pollutants, such as dissolved particulate matter, ammonia, and acids.[277] Antimony trioxide can also leach into wastewater, contaminating surrounding waters,[278] potentially inducing toxic effects on aquatic life.[279]

Because we don't yet understand how polyester might be affecting humans in the sleep environment, and because environmental impacts are already documented, MADEWORKS encourages applying the precautionary principle and choosing safer fabrics like organically grown and safely produced wool and cotton.

## Adhesives

The research on adhesives used in mattress construction is limited. Adhesive formulations are often proprietary, and industry information contains few details about what actually goes into mattress glue. Because this information is unavailable, it is difficult to determine which adhesive ingredients people might be exposed to through bedding and what health effects might result. What we do know about adhesives is summarized in this section.

After 1,1,1-trichloroethane (TCA), the primary adhesive solvent used by the polyurethane industry, was banned in the 1990s because it depletes the ozone layer, methylene chloride and

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n-propyl bromide (nPB) took TCA's place.[280] Methylene chloride is a suspected carcinogen,[281] and is implicated in the deaths of dozens of furniture workers.[282]

As methylene chloride was phased out, nPB became a preferred choice for many foam manufacturers,[283] though it is unclear to what extent this dangerous adhesive is used in polyurethane foam mattresses specifically.[284]

nPB irritates mucous membranes, such as the eyes and respiratory tract.[285] The chemical can cause neurological effects like dizziness, confusion, and headaches.[286] The National Toxicology Program found clear evidence of carcinogenicity in female rats and female mice due to exposure to nPB.[287] The body can absorb nPB via contact with the skin and by inhalation.[288] Despite being an occupational hazard, there is no current standard set by the Occupational Safety and Health Administration (OSHA) for nPB exposure.[289]

Other current mattress adhesives are often liquids composed of adhesive solids suspended in a solvent or in water.[290] Hot melt and water-based adhesives are two of the most popular forms of adhesives currently used in the mattress industry.[291] Hot melt adhesives are composed entirely of solids that are heated to high temperatures and then applied to the foam. As the solids cool, the surfaces adhere.[292] As of 2000, the industry favored hot melt adhesives.[293] However, hot melts do not often work well with viscoelastic foams like memory foam.[294]

Water-based adhesives are somewhat misleading, as the term implies that the adhesive's base is water. In these adhesives, water is used instead of solvents, which are traditionally used as adhesive bases. Still, solvents can be undesirable because they readily volatilize, dispersing gaseous molecules that can contaminate the workplace and expose workers.

Just because the adhesive is water-based does not mean it is safe. The suspended adhesive itself can consist of several chemicals or formulations, most of which are proprietary, making it impossible to know what kinds of adhesive compounds we are exposed to through foam mattresses.

In addition to hot melts and water-based adhesives, some companies may use acetone-based adhesives.[295] Several other chemicals have been reported to be used in mattress adhesives, including acrylate resins, chloroform, carbon tetrachloride, cyanide, dioxins, furans, polyvinyl acetate, and more. Formaldehyde, a carcinogen,[296,297] has also been reported as a component of certain adhesives used in mattress manufacturing.[298] However, there is no information available regarding to what extent any of these compounds are currently used in the mattress industry.

# What's Inside the Mattress: Waterproof

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# Baby Mattresses

Babies spend a significantly greater proportion of their time sleeping than adults. This means their sleep environments are particularly important factors in their exposure to gaseous indoor air pollutants, both in the short term and in the long term.[299] Babies also inhale more air than adults relative to body mass,[300] making them more vulnerable to gaseous chemicals. Because infants' developing systems are vulnerable to chemical exposure,[301,302,303] MADEWORKS believes that a healthy sleep environment is crucial for babies.

In addition to the chemicals overviewed in the previous section – flame retardants, isocyanates, and others – waterproof baby mattresses have other specific concerns, including phthalates and additional VOCs.

Crib mattresses commonly feature waterproof covers made from vinyl, or polyvinyl chloride (PVC), which may also be marketed for their antimicrobial properties.[304] The terms "vinyl" and "PVC" are often used interchangeably in this context.

PVC is naturally rigid, so manufacturers often incorporate plasticizers to increase its flexibility and softness. Phthalates, a group of chemicals, are among the most commonly used plasticizers, although alternative plasticizing agents are also available.[305,306]

Waterproof vinyl can off-gas plasticizing phthalates and harmful VOCs. Off-gassing refers to the release of gaseous chemical compounds from materials into the surrounding air. These emissions may be detectable by odor or entirely odorless, potentially contributing to chemical exposure within an infant's immediate sleep environment.

## VOCs

VOCs have been detected off-gassing from polyurethane foam and vinyl mattress covers. Specific to children, exposure to VOCs has been linked to the development or worsening of asthma in some children,[307,308] poor respiratory health in infants,[309] and increased risk of pulmonary infections.[310]

One study found evidence that crib mattress covers may act as a barrier to some VOCs originating in the soft foam layer underneath.[311] However, when the cover cracks, this offers a more direct escape route for VOCs originating in the polyurethane foam. In addition, VOCs don't just come from polyurethane foam; mattress covers are a significant source of VOCs. Despite their ability to block some VOCs, mattress covers may be a more significant source of VOCs than the mattress itself.[312] Mice exposed to waterproof vinyl crib mattress covers experienced acute respiratory tract toxicity.[313] These effects were worsened when exposed a second time.[314]

Researchers found that some mattress covers emitted toluene, xylenes, trichloroethylene, isopropylbenzene, ethylbenzene, and phenol.[315] Other VOCs detected from crib mattresses in studies in which both the cover and polyurethane foam were tested include: phenol, 2-ethyl-hexanoic acid, 3-methyl-1-heptanol, D-limonene, neodecanoic acid, and linalool.[316]

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For more information on chemicals that can off-gas from polyurethane foam, see the "Volatile Organic Compounds" section earlier in this report.

## Phthalates

Plasticizing phthalates, which are semi-volatile organic compounds (SVOCs), can also off-gas from polyurethane foam and vinyl mattress covers. Mattress covers are a source of SVOCs, such as phthalates.[317] Because phthalates are not tightly bound within the vinyl, they can migrate out of the product into the sleep environment.[318,319] Phthalates are "ubiquitous and among the most abundant SVOCs in indoor environments," as a result of off-gassing from consumer products.[320]

In 2009, because of their documented negative health impacts and widespread use, some phthalates were banned for use in "childcare articles,"[321] which include products that are intended to facilitate sleep or feeding in infants.[322] The banned phthalates include: bis(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), and butylbenzyl phthalate (BBP) in quantities greater than 0.1 percent.[323] Five more phthalates were banned in 2017 for use in childcare articles and toys (DINP, DIBP, DPENP, DHEXP, DCHP).[324]

Because of health concerns about some phthalates, alternative plasticizers, including new phthalates and plasticizers from other chemical groups, are being researched and developed.[325] These include: di(2-ethylhexyl) adipate (DEHA), di(2-ethylhexyl) terephthalate (DEHT),[326] and diisononyl cyclohexane-1,2-dicarboxylate (DINCH).[327,328] These new plasticizers do not have sufficient toxicological data.[329,330] However, because these alternative plasticizers share similar physicochemical properties with phthalates, they may exhibit comparable emission patterns and environmental behavior.[331]

Researchers found that 17 of 20 crib mattress covers tested for plasticizers contained at least one plasticizer greater than 0.1 percent.[332] In new mattress covers tested, DINCH was the most commonly detected plasticizer; in used mattress covers, DINP was the most commonly detected.[333] Overall, the most commonly detected plasticizer was DINP,[334] one of the phthalates prohibited in children's toys and child care articles under a final CPSC rule (16 CFR Part 1307).[335,336]

In approximately one-fourth of the covers, DEHP and DINP were both detected.[337] DEHA was also detected, but always with another plasticizer. This suggests that plasticizer combinations may be used in mattress covers.[338]

In the study, mattress covers manufactured after the US Consumer Product Safety Commission's ban of select phthalates most commonly contained DINCH and iso-DEHP.[339] This suggests that these two plasticizers are being used as alternatives to the banned phthalates. Two of the mattresses containing DEHP, a phthalate banned at concentrations greater than 0.1 percent, exceeded the standard, despite being manufactured after the ban took effect.[340]

Plasticizers emit from soft vinyl at a slow rate.[341] These findings suggest that crib mattresses may serve as a continuous source of plasticizer exposure within an infant’s immediate sleep

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environment.[342] Researchers point out the gravity of this: crib mattresses often last around 10 years, are passed down through families and friends, and are donated or purchased second-hand.[343] Unlike many VOCs, the gases of which decrease as a product ages, SVOCs from phthalates do not appear to readily decrease over time.[344,345] In fact, mattress covers might "behave as a permanent source of phthalates and other SVOC additives during the lifetime of the covers."[346]

Mattress temperature also influences phthalate emissions from mattress covers.[347] Some phthalates more readily off-gas as temperature increases. In chamber tests at 25-55°C, phthalate emissions from vinyl crib covers increased with temperature, and the authors' model estimates that, in an infant's sleep environment, a warmer mattress could make breathing-zone concentrations four times higher than in the room air[348] According to researchers, this "suggests that, due to their close contact with the mattress, infants are likely to be exposed to higher phthalate concentrations than other occupants of the room."[349] However, it is important to note that this study was conducted in a research laboratory and real sleep environments are complicated by other environmental factors that influence phthalate emissions.[350]

Despite these limitations, researchers emphasized the potential significance of phthalate exposure from mattress covers, noting that infants inhale substantially more air relative to their body weight than adults, which may result in greater inhalation exposure to phthalates emitted from these materials.[351,352] This means that while researchers are not yet certain of the extent to which phthalates may impact infants in real sleep environments, there is reason to suspect that phthalates pose a potential problem to infant health.

SVOCs, such as plasticizers, can also adsorb onto bed sheets.[353] With temperature increases from a sleeping infant, the plasticizers can be released, coming into direct contact with the baby.[354] Because some plasticizers can be dermally absorbed, a sleeping baby may absorb the chemicals through the skin.[355] Inhalation is also a significant source of exposure to phthalates.[356]

Numerous adverse health impacts are associated with phthalates. Multiple have endocrine disrupting properties, and thereby may impact any function mediated by hormones. Because hormones exert biological effects at very low concentrations, some endocrine disruptors can impact our bodies at levels of parts per billion.

A 2012 report by the World Health Organization and the United Nations Environment Programme documents evidence of phthalate endocrine disruptors and their effects in humans and animals. These effects in males include: decreased testis weight, reduced anogenital distance,[357] reduced accessory sex organ weights, modifications in sex organs and cells, reduced fertility, and more.[358] In females, endocrine disrupting effects include: uterine abnormalities, reduced fertility, and problems with thyroid function.[359] These effects are observed from one or more of the phthalates DEHP, BBP, DINP, and DBP.[360]

## Flame Retardants

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Vinyl may also contain flame retardant chemicals. This includes TBPH, an analog of the phthalate DEHP, a reproductive toxicant,[361] used in PVC.[362] For more information on flame retardants that are used specifically in polyurethane foam, see the section entitled, "Flame Retardants" earlier in this report.

# Safer Mattress Materials

Many studies show that reducing exposure to products with toxic chemicals reduces the levels of those chemicals in the body.[363,364] This also applies to mattresses and bedding products. Choosing mattresses and bedding made from minimally processed materials, without chemical additives of concern, can help reduce exposure to potentially harmful substances and minimize long-term exposure to chemical emissions during sleep.

## Cotton

Organic cotton is a nontoxic alternative to foam. It provides cushion and softness to mattresses without dangerous chemical inputs. Cotton can be used as batting to replace foam in the bulk of a mattress, as batting in a pillowtop, as the mattress cover, to wrap coils, and more.

Cotton, a natural material, is also inherently much less flammable than foam, which is made from petrochemicals. When properly used in conjunction with other naturally flame-retardant materials, cotton mattresses can meet federal flammability standards without adding flame retardant chemicals.

Although cotton is a preferred alternative to polyurethane foam, organically grown cotton is recommended to minimize potential exposure to chemicals of concern. Conventional cotton often uses heavy doses of pesticides.[365,366,367,368] Growing cotton can also be a water-intensive process, requiring 20,000 liters of water to produce one kilogram of cotton,[369] which is the equivalent of one outfit.[370] Cotton is also one of the world's most common genetically modified crops. In the US, the majority of cotton is genetically modified.[371]

Compared with conventionally grown cotton, organic cotton is produced without genetically modified seeds or most synthetic pesticides. When responsibly sourced and minimally processed, organic cotton can serve as a lower-concern bedding material by reducing potential exposure to certain chemical residues and additives. However, cotton is inherently combustible and should not be considered naturally flame resistant.

## Wool

Wool can be used in multiple mattress components. Some mattresses are made of 100 percent wool, both externally and internally. Other mattresses have pillow tops filled with wool, coils wrapped with wool textiles, supportive wool filling in the bulk of the mattresses, as part of the mattress cover, and more.

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Wool is naturally flame resistant.[372] When used properly, wool can provide fire resistance that meets federal flammability standards.

Polyurethane mattresses tend to harbor heat, which results in a hotter sleep environment. Wool helps to naturally regulate body temperature, in both warmer and cooler months, by effectively circulating air within the material. It also wicks moisture away from the body.

Wool should be processed using chemical inputs of low toxicological concern, including surfactants and other processing treatments. Responsible sourcing is also important, as animal welfare concerns may arise throughout wool production. Consumers should seek information from mattress manufacturers regarding their wool sourcing practices and adherence to established animal welfare standards.

# Latex

Latex is used in many different components of mattresses. It can make up the entire bulk of the mattress, serve as a top layer on coil mattresses, comprise a middle layer between the coils and a cotton or wool topper, or be added in small amounts to foam. Because of its utility, latex is a versatile substitute for foam.

There are three types of latex used in mattresses: natural, synthetic, and natural/synthetic blends. Natural latex is a milky fluid found in a wide range of plants. Latex also forms the basis of natural rubber.[373] Natural latex is tapped from trees, a process similar to collecting maple syrup.

Synthetic latex is made from refined oil, coal, or other hydrocarbons.[374] More specifically, synthetic latex is most often styrene-butadiene rubber (SBR).[375]

In this process, butadiene and styrene are mixed together with other ingredients, which may include di-isopropyl benzene hydroperoxide, ferrous sulfate,[376] and others.[377] Butadiene is an occupational chemical of concern, which can cause mucous membrane irritation at low doses and central nervous system depression at high doses.[378]

Blends are composed of both natural latex and synthetic SBR latex.

Despite being labeled as "natural," some natural latex mattresses can still contain chemicals of concern. This is because latex must be preserved before it undergoes processing, which is required to achieve a desired shape. Preservation occurs at multiple points in the process. The preservative can be dictated by the type of processing used. Multiple chemicals are known to be used as preservatives, including:[379]

- Ammonia
- Ammonium borate
- Ethylene diamine tetraacetic acid (EDTA)
- Formaldehyde
- Sodium pentachlorophenate
- Patented preservatives with undisclosed formulations

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There are two types of processes used to create latex mattresses: Dunlop and Talalay. Dunlop is a simpler process which involves whipping the latex, pouring it into a mold, baking it, washing it, and then drying.[380] Talalay is a more complex process; the latex is poured into a mold and a vacuum is formed to distribute the latex. It is then frozen, heated, washed, and dried for curing.[381]

While mattresses made with both methods can be touted as "natural" and "green," other additives can be used in the process, such as gelling agents, emulsifiers, and ingredients that add structure. Nanoparticle silver can also be incorporated into natural latex—and potentially synthetic latex—to impart antimicrobial properties.[382] Nanoparticle silver is toxic to some wildlife,[383] and is potentially toxic to people, but the full scale of its effects is unknown.[384]

Because products marketed as “natural” latex may still contain synthetic additives, transparency regarding material composition and manufacturing processes is essential. Natural latex that is responsibly sourced and processed without additives of concern can provide a preferable alternative to polyurethane foam.

While latex has many uses, it can be highly allergenic, and approximately 1 to 6 percent of the general population[385,386] and 8 to 12 percent of healthcare workers[387] are allergic to the material. A latex allergy can cause itching, sneezing, and coughing.[388] In serious cases, the allergy can cause anaphylaxis,[389] a severe, life-threatening reaction.

While adults with known latex allergies can avoid mattresses containing the material, latex sensitivities in infants may not yet be identified. As a precautionary measure, choosing latex-free crib mattresses may help minimize potential allergic reactions.

## Coils

A 2010 guest blog post published in Scientific American discussed a study suggesting that metal coils in mattresses may amplify electromagnetic fields (EMFs) associated with radio and television broadcasts, potentially raising concerns about cancer risk.[390] Although these claims attracted attention from health bloggers, the original study's findings were inaccurately represented in the blog post.[391,392]

In actuality, the study concluded that metal-containing mattresses attenuate—or reduce—electromagnetic waves immediately above the surface of the mattress.[393] According to the study, beds containing metal components may reduce EMF exposure on the side of the body closest to the mattress, while the opposite side may remain exposed to electromagnetic fields.[394] However, the proposed association between metal mattress coils and cancer risk remains unsubstantiated due to a lack of direct scientific evidence. Some citizen-scientists and mattress companies have measured EMF near mattresses but have generally reported acceptable levels.[395,396]

The researchers point to mattresses and box springs containing "helically wound springs," which are coils bound and connected with a long spiral wire.[397] The hypothesis is that coils made in this fashion are connected, and therefore waves can be transferred.[398] But there is no

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substantive science supporting this claim, and not all mattress coils are made in this fashion.

There are four common types of mattress coils: continuous, offset, Bonnell, and pocket.[399,400] Continuous, which are formed with a single piece of wire; offset, which are hinged together with helical wires; and Bonnell, which are the most common and are connected with helical lacing that binds the rows and borders the entire unit, are all "connected" types. Pocket coils—also called wrapped coils, encased coils, and pocketed springs—function independently of one another because they are individually enclosed. These coils are wrapped in fabric, often cotton, wool, polypropylene, or polyester. Pocket coils are not connected by metal. Contemporary foundations (formerly called box springs) are typically made without metal springs.

In addition to the findings of this topic's primary study being inaccurately portrayed, there is insufficient evidence to state that coil mattresses can interfere with electromagnetic fields.

## Adhesives

Avoiding chemical adhesives in mattress construction can help minimize potential exposure to substances of concern. Some manufacturers instead use stitching, including hand-sewing techniques, to secure mattress components together.[401] Choosing mattresses constructed without chemical adhesives can help reduce potential exposure to adhesive-related chemical emissions. Also see Adhesives section.

# Linens

## Pillows

Pillows made with polyurethane foam do not require additional flame retardant chemicals under federal flammability laws. Nevertheless, flame retardants continue to be used in some pillow formulations, potentially as a precautionary measure to reduce fire-related liability associated with the flammability of polyurethane foam.

Foam pillows are made from the same materials as polyurethane mattresses, meaning that they may pose similar risk of toxicity. For more on foam, see the section entitled, "What's Inside the Mattress: Polyurethane Foam."

Other synthetic pillows can also be made with flame retardant chemicals, phthalates, or alternative plasticizers. As these off-gas from polyurethane crib mattresses, it can reasonably be assumed that these products might carry the same risks, though this is unstudied. Studies suggest a possible connection between childhood allergies or adult rhinitis and synthetic pillows.[402,403]

## Sheets

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Sheets, especially cotton, labeled "wrinkle-free," "no wrinkle," "no iron," and similar terms may contain a formaldehyde finish.[404] Levels of up to 2,000 parts per million or two parts per thousand of formaldehyde have been detected in textiles.[405] Formaldehyde is capable of off-gassing under certain conditions, like high temperatures and humidity.[406] In textiles, it has been reported as associated with allergic contact dermatitis.[407] The US has no regulations on formaldehyde in textiles.[408]

Polyester, acrylic, and nylon are petroleum products. These variations of plastic often require additives to manufacture, process, soften, and condition the materials. Some of these additives are considered harmful to human health.[409,410,411] For more on polyester, see the section entitled "Polyester."

While some evidence indicates that some pesticides can be washed out of cotton,[412,413,414] because the crop is so heavily sprayed with pesticides,[415,416,417,418] it is best to choose organic cotton, as this protects field workers and prevents pesticide run-off.[419]

## Mattress Pads and Comforters

Mattress pads and comforters are often made of polyester, acrylic, and nylon. For more information on these textiles, see the section above, "Sheets."

Some waterproof mattress pads are made of vinyl, which may contain endocrine-disrupting phthalates. For more information on vinyl, see "What's Inside the Mattress: Waterproof Baby Mattresses."

## Antibacterial and Antimicrobial Linens

Many antibacterial and antimicrobial compounds can be added to bedding, including sheets, mattress pads, and mattress toppers.[420] These compounds include silver nanoparticles, triclosan, triclocarban, and many proprietary formulas under trade names.

Triclosan, which can be found in antimicrobial bedding,[421] is a known endocrine-disrupting chemical.[422,423,424,425,426,427,428] It is also recognized as toxic to the aquatic environment.[429,430] The FDA banned triclosan in hand soaps effective in 2017,[431] but the chemical is still allowed for use in other products, including bedding.

Antimicrobial treatments marketed under trade names such as Microban, Biofresh, Ultra-Fresh, and Sure Check may be applied to bedding to inhibit microbial growth, with certain formulations designed to remain effective after repeated laundering.[432] Some trade name formulations may contain triclocarban, an endocrine-disrupting chemical[433,434,435,436] that is toxic to aquatic life;[437] triclocarban, like triclosan, was banned by the FDA in hand soaps.[438]

Because many antimicrobial and antibacterial treatments are considered proprietary, scientists cannot know what chemical ingredients these products contain, making it impossible to determine health risks.

Silver nanoparticles can be embedded in bedding and mattresses.[439] Nanoparticle silver is

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toxic to some wildlife, and is suspected to be harmful to people, but the full scale of its effects is unknown.[440] Due to limited research on the long-term health effects associated with nanoparticle exposure, MADEWORKS and other organizations[441] recommend a precautionary approach with nanoparticle technology. It is best to avoid nanoparticles until extensive testing can be conducted.

To avoid harmful silver nanoparticles, endocrine disrupting triclosan, and undisclosed antimicrobial compounds, avoid bedding labeled as "antibacterial" and "antimicrobial."

## Stain Repellents

Stain repellents can be made of poly- and perfluoralkyl substances (PFAS), which include thousands of unique chemicals, including PFOA, PFOS, PFHxS, and PFHxA.[442]

Many PFAS are persistent and/or bioaccumulative in the environment[443,444,445] PFAS have several toxic effects,[446] including endocrine disrupting capabilities,[447] cancer,[448] immunotoxicity,[449] and developmental and reproductive toxicity.[450,451,452]

## Spotting Safer Bedding

Avoid linens labeled with these terms, as they indicate the fabric may be treated with a harmful chemical:

- Antibacterial
- Antimicrobial
- Easy care
- No iron
- No ironing needed
- No wrinkle
- Shrink resistant
- Soft finish
- Stain repellent
- Stain resistant
- Wrinkle-free

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# Conclusion

The sleep environment plays an important role in overall health and well-being, making the materials used in mattresses and bedding an important consideration for reducing potential chemical exposures. Mattresses and bedding made from certified organic cotton, wool, and responsibly processed natural latex, particularly those manufactured without chemical adhesives or added chemical finishes, may help minimize exposure to substances of concern. When selecting conventional products, avoiding polyurethane foam, vinyl mattress covers, and textiles marketed as “wrinkle-free,” “antimicrobial,” or “stain repellent” may further reduce exposure to potentially harmful chemicals in the sleep environment.

These considerations are particularly important for infants and young children, who spend a substantial proportion of their time sleeping, breathe more air relative to their body weight than adults, and undergo critical stages of physiological development.[453] As a result, prolonged and close contact with crib mattresses and bedding may represent a significant source of chemical exposure during early life.

Although eliminating all sources of chemical exposure is not feasible, informed purchasing decisions can help reduce exposure to potentially harmful substances. Research has demonstrated that reducing contact with certain chemical-containing consumer products can decrease the concentrations of associated chemicals or their metabolites in the body.[454,455]

Prioritizing products made from simpler materials, with transparent ingredient disclosures and minimal chemical treatments, represents a practical approach to reducing unnecessary exposures and supporting a healthier sleep environment.

# About MADEWORKS Intelligence™

MADEWORKS Intelligence™ (formerly MadeSafe.org) has been driving marketplace change since 2015. We are building a bridge to a safer, more sustainable future for all. Using the MADE Ecosystem Approach, MADEWORKS Intelligence™ generates insights that support better product development and advance systemic change. By bringing together science, industry leadership, and informed consumer choice, we help turn meaningful information into action, transforming the marketplace for a healthier world.

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