

Textiles

Chemicals of Concern in Textile Fibers, Treatments, Dyes, Performance, and Finishes. Including Practical Strategies for Reducing Unnecessary Chemical Exposure.

By MADEWORKS™ Intelligence

August 2026

© 2026 MADEWORKS Intelligence - All rights reserved

Executive Summary

Textiles move through complex global supply chains before reaching consumers. Pesticides may be used while natural fibers are grown or processed; chemical inputs are used to manufacture synthetic and regenerated fibers; and dyes, flame retardants, water- and stain-resistant treatments, and other finishes may be applied during manufacturing. Because textile labels generally do not disclose the full chemical composition of fibers, consumers often have limited visibility into these inputs.

The major concerns differ by fiber and treatment. Natural fibers raise questions about pesticide use and residues. Synthetic fibers can involve hazardous manufacturing chemicals, leachable contaminants, slow degradation, and microfiber release. Regenerated cellulose can offer advantages, especially when closed-loop solvent recovery is used, but environmental risks depend primarily on the production system, chemical inputs, and applied dyes and finishes. Across all fiber types, performance treatments and colorants can introduce additional hazards.

Purpose and Scope

This report examines common chemical and environmental concerns associated with textiles, including clothing, bedding, and upholstered furniture. It considers impacts across the textile lifecycle, from fiber production and pesticide use to manufacturing, dyeing, finishing, consumer exposure, laundering, and disposal.

The report focuses on natural, synthetic, and regenerated cellulose fibers, as well as frequently used textile treatments, dyes, and performance finishes, including Per- and polyfluoroalkyl substances (PFAS), flame retardants, formaldehyde, heavy metals, and synthetic dyes. It also provides practical

guidance for identifying potentially concerning product claims and selecting textile materials with a lower chemical and environmental burden.

The Hidden Chemical Load in Textiles

Textiles, which include clothing, bedding, and upholstered furniture, typically are the product of a complex global supply chain that involves numerous steps before reaching the finished product. The process begins in the fields, where pesticides are typically used, and continues through manufacturing where dyes and treatments are applied. As a result, these materials often carry a hidden chemical burden. Because our skin is our largest and most absorbent organ, it represents a significant pathway for chronic, low-level exposure. A lack of supply chain transparency and ingredient disclosure on a textile product's tag means that it can be nearly impossible for consumers to know exactly what their clothing and other textiles contain. This report identifies the most common chemical hazards found in modern textiles and provides guidance on recognizing red-flag marketing claims and choosing better materials.

Fibers and Materials

The chemical profile of a textile begins with the raw fiber. Natural, synthetic, and regenerated cellulose fibers each present distinct concerns related to cultivation, manufacturing, use, and disposal.

Natural Fibers

A primary concern for natural fibers is the exposure to pesticides. The term “pesticides” encompasses any herbicide, insecticide, or fungicide used in the growing or processing of a crop. Exposure to

pesticides is associated with a multitude of health concerns including endocrine disruption, neurological disorders, and cancer.¹ Additionally, pesticide usage has detrimental effects on land and water habitats, which exacerbates the world's already declining biodiversity. This is troubling because biodiversity is a major indicator of ecosystem health and strength. One landmark 2025 study analyzed over 1,700 existing lab and field studies on the impacts of 471 different pesticides in agricultural and household use. The study found negative effects on nearly every aspect of behavior and lifecycle for more than 800 plant, animal, and microorganism species.²

Cotton and Pesticide Intensity

Cotton remains one of the most pesticide-intensive crops per acre in the US, and ranks fifth among the most heavily sprayed crops grown globally.³ Research on farmers and workers exposed to pesticides used in the production of cotton in international contexts point to a gamut of both acute and chronic concerns such as neurological problems, respiratory illnesses, cancer, and more.^{4,5,6}

Survey data from 2021 collected by the US Department of Agriculture (USDA)'s National Agricultural Statistics Service (NASS) found that for conventional cotton crops grown in the US, herbicides were applied to 96% of planted acres, insecticides were applied to 39% of planted acres, and other chemicals (referring to chemicals intended for all other pests) were applied to 68% of planted acres. The top herbicides applied were glyphosate isopropylamine salt, glyphosate potassium salt, and paraquat.⁷

Glyphosate

Despite continued pushback, the US Environmental Protection Agency (EPA) maintains that there are no risks to human health when glyphosate is used in accordance with its current label and that it is unlikely to be a human carcinogen.⁸ This decision was echoed by the European Commission when, in 2023, they reviewed data from the European Food Safety Authority (EFSA) and subsequently renewed the approval for the use of glyphosate on crops in the EU until 2033 due to insufficient evidence to meet the criteria for a ban.⁹ This herbicide continues to be a topic of contention, with a stark divide between independent academic literature and regulatory findings. Academic research has raised concerns over the repercussions of glyphosate exposure including harm to the nervous system¹⁰ and the microbiome,^{11,12} as well as detrimental epigenetic effects.¹³ Researchers have also advocated against glyphosate due to its negative impacts on bees.^{14,15} This only touches on the many concerns raised by researchers and consumers regarding the safety of glyphosate and glyphosate-based herbicides. In 2015, the World Health Organization's International Agency for Research on Cancer (IARC) classified glyphosate as probably carcinogenic to humans (Group 2A) after reviewing published literature.¹⁶ In January 2026, a 2000 cornerstone study establishing glyphosate's safety was retracted from the Regulatory Toxicology and Pharmacology journal after ethical concerns emerged revealing undisclosed industry influence on the study.¹⁷ This development comes at a pivotal time, as the EPA is expected to issue a new, comprehensive review on glyphosate sometime in 2026.

Paraquat

Paraquat also raises a number of environmental and human health concerns. Research has linked paraquat exposure with Parkinson's Disease,^{18,19} other neurotoxic effects,²⁰ and cancer.²¹ In April 2026,

the US House of Representatives voted to remove preemption language from the Farm Bill to preserve each state's right to issue their own health warnings and restrictions, garnering support from the Parkinson's advocacy community.²² As of 2026, multiple US states have proposed bills to ban the use of paraquat.

Residues and Supply-Chain Complexity

Pesticide residues lingering from the growing process are a known issue, prompting researchers to search for a reliable method to test for these residues.^{23,24,25,26} One 2025 study aimed at developing a precise, extensive testing method for 115 pesticide residues simultaneously, found that many of the materials tested had low concentrations of multiple residues, which raises concerns regarding the cumulative risk to human health.²⁷ As global trade increases, it becomes harder to track what chemicals are used in different countries throughout the growing and manufacturing processes. For example, raw materials may be grown in one country using a number of herbicides and insecticides, and then transported to or stored in another country where fungicides are applied to prevent mold and mildew. The result is a cumulative chemical exposure that compounds and often persists in the finished product.

Other Natural Fibers

Other natural fiber options include linen, hemp, jute, silk, and wool. Due to the superior hardiness of linen, hemp, and jute crops, they tend to be less heavily sprayed than cotton, but even smaller amounts of pesticides are still cause for concern. Pesticides are also a concern in silk production, posing significant risks to silk quality and silkworm health.²⁸ Lastly, when it comes to wool, the primary

pesticide concern is the use of insecticides to prevent lice, ticks, and other pests. These chemicals are highly toxic to the workers applying them, and residues often linger in the finished product.²⁹

Synthetic Fibers

Synthetic fibers are man-made textile fibers produced entirely from chemical substances, such as petrochemicals. Common synthetic fibers found in textiles include polyester, nylon, acrylic, and spandex. When it comes to synthetic fibers, the key concerns are exposure to harmful chemicals and environmental impact.

Potential Chemical Exposure

The manufacturing process for synthetic fibers often utilizes harmful chemicals that can remain in the fibers and eventually become a source of exposure for the consumer. For example, antimony, which is a heavy metal associated with negative effects on the respiratory and cardiovascular systems (as well as skin irritation and possibly cancer^{30,31}) may potentially leach from polyester fibers when in contact with sweat. A 2021 study tested this assertion using artificial sweat, confirming that antimony leaches from polyester in measurable amounts, particularly during the initial stages of wear and in acidic, sweat-inducing conditions.³² Added concern is layered on top of this finding when we consider that a vast majority of workout clothing is composed primarily of polyester.

Similarly, acrylic fiber is made using a volatile liquid called acrylonitrile, some of which can remain trapped in the fabric during the manufacturing process. The EPA classifies acrylonitrile as a probable human carcinogen (Group B1),³³ and IARC categorizes it as carcinogenic to humans (Group 1).³⁴ An additional concern for synthetic fabrics is that they are frequently paired with performance finishes.

Lifecycle Pollution and Persistence

From an environmental standpoint, synthetic fibers raise issues due to their contributions to pollution throughout their entire lifecycle. Nitrous oxide, which is a byproduct of the production of adipic acid (a critical component for making nylon), accounted for 6% of all US greenhouse gas emissions in 2022.³⁵ While the manufacturing of nylon is only one of many industrial sources of this gas, nitrous oxide is nearly 300 times more potent than carbon dioxide, making even the relatively small amount linked to synthetic fiber production a meaningful contributor to pollution. At the end of their lifecycle, synthetic fibers incite further environmental concerns due to their lack of biodegradability,³⁶ with one 2023 study finding virtually no signs of degradation after more than 400 days in seawater (for both pure synthetic and cellulose/synthetic blends).³⁷ Synthetic fibers are also known for their microplastic release during laundering.^{38,39}

Regenerated Cellulose

Regenerated cellulose fibers are a category of semi-synthetic materials that are produced by taking natural cellulose (from wood, bamboo, or eucalyptus) and using a chemical process to dissolve and regenerate it into a spinnable fiber. Popular types of regenerated cellulose materials are rayon/viscose, bamboo viscose, modal, and lyocell (also known by the brand name Tencel). The primary difference between these fibers is the solvent used in the fiber's production and the method of production. The most common viscose production process, used for rayon, modal, and bamboo viscose, typically operates as an open-loop system and often utilizes carbon disulfide. Lyocell, by

contrast, usually involves a closed-loop system that utilizes N-Methylmorpholine N-oxide (NMMO), an organic solvent. Exposure to carbon disulfide is associated with neurological, cardiovascular, and developmental effects.⁴⁰ Furthermore, research has indicated a connection between carbon disulfide exposure in female factory workers and negative effects on their reproductive health.^{41,42} A benefit of a closed-loop system like that used in the production of lyocell is that there is a high recovery rate for the solvents used, meaning that there is less waste leaked into the environment.⁴³ A closed-loop solvent recovery system can decrease toxicity-related concerns, with one study finding a 35% reduction in freshwater ecotoxicity and a 62% reduction in non-carcinogenic human toxicity.⁴⁴

Biodegradability and the Influence of Dyes and Finishes

The conclusion of the fiber lifecycle raises the question of biodegradability for regenerated cellulose.

Recent findings from a 2025 study indicate that although lyocell can degrade by 20% in just one month (vastly outperforming polyester), certain dyes and finishes significantly delay this process.⁴⁵

Preliminary findings from a 2025 study found that native cellulose (cotton, linen) and regenerated cellulose (viscose, modal, lyocell) biodegrade at similar rates.⁴⁶

Ultimately, the methods and inputs used to create regenerated cellulose fibers can influence the degree of concern for human and environmental health. For this reason, transparency around the production process is essential.

Common Textile Fibers

Fiber Category	Primary Concerns Highlighted in This Report
Natural fibers	Pesticide exposure during growing and processing, including potential residues in finished textiles.
Synthetic fibers	Leaching of harmful chemicals, lack of biodegradability, and contribution to microplastic pollution.
Regenerated cellulose	Wastewater contamination risks and transparency concerns; impacts vary by solvent and manufacturing process.

Table 1: Textile fiber types

Treatments, Dyes, and Performance Finishes

Chemical treatments can add water repellency, stain resistance, wrinkle resistance, flame resistance, color, antimicrobial performance, and other properties. These functions may be useful in certain instances, but they can also introduce hazards that consumers may struggle to identify based on the product label.

PFAS

PFAS, also known as “forever chemicals,” can be used in textiles for their water-repellent and stain-resistant properties. They are used as treatments in textiles such as outdoor gear, performance apparel, furniture, carpets, mattress protectors, bedding, and more. Though their presence is often not readily disclosed by the company, consumers can look for red flags in the form of performance

claims. For example, “water-repellent,” “stain-resistant,” and “easy-care” are telltale signs of a PFAS treatment. PFAS have been linked to harmful effects including endocrine disruption,^{47,48,49,50,51} bioaccumulation,^{52,53,54} and cancer.^{55,56,57} In 2023, IARC upgraded the classification of perfluorooctanoic acid (PFOA) to Group 1 (“Carcinogenic to humans”) and of perfluorooctanesulfonic acid (PFOS) to Group 2B (“Possibly carcinogenic to humans”).^{58,59} Increasing awareness of the harmful effects of these chemicals is a vital development for consumers, but concerns remain because manufacturers tend to replace PFOA and PFOS with other PFAS, often possessing similar properties. This means they likely have comparable negative effects.⁶⁰

PFAS raise multiple environmental concerns as well, as they are both water soluble and highly persistent in the environment. The result is that their presence in the world is widespread and nearly irreversible.⁶⁰ Due to their lack of biodegradability, both terrestrially and aquatically, they persist in the environment and can create long-term ecosystem concerns.^{61,62,63,64}

Growing awareness of the harms associated with PFAS has led to multiple legislative actions at the state level in the past few years. States like California, New York, Maine, and Minnesota are leading the way in prohibiting the use of PFAS in textiles. With the combination of new legislative protections and consumer demand for safer products, many companies are phasing out the use of PFAS. However, it is still important to continue reading labels and be mindful of undesirable substitutions (such as merely swapping one PFAS chemical for another). One pioneering 2024 study on dermal absorption found that short-chain PFAS, which have become a popular replacement for the common long-chain PFAS (such as PFOA), are more easily absorbed into the skin,⁶⁵ which raises questions about whether they might be considered an undesirable substitution.

Flame Retardants

Flame retardants are added to textiles to slow the ignition and spread of fire. They can be found in children's sleepwear, upholstered furniture, mattresses and bedding, carpets, protective workwear (such as firefighter uniforms), and seats in automobiles or public transportation. The two main classes of flame retardants are halogenated flame retardants and organophosphorus flame retardants.

Halogenated flame-retardant chemicals contain chlorine, bromine, iodine, or fluorine, and include flame retardants sometimes referred to as brominated or chlorinated flame retardants.^{66,67,68}

Organophosphorus flame retardants, on the other hand, contain phosphorus bonded to carbon.⁶⁶

Flame retardants have been associated with many negative effects, though the exact health concerns depend on the type used. Studies have linked flame retardants to negative effects such as endocrine disruption,⁶⁹ learning difficulties,^{70,71} hyperactivity,⁷² fertility issues,^{73,74} and cancer.⁷⁵ Many flame-retardant chemicals are also persistent in the environment^{66,76,77,78} and some are known to be toxic to aquatic life.⁷⁹

Many US states have taken action, with states like California, New York, Maine, Massachusetts, and Nevada restricting the usage of flame retardants in various consumer goods such as apparel, upholstered furniture, and carpeting.

Formaldehyde

Formaldehyde is used as a finishing agent to give fibers a crisp look and to support properties such as wrinkle resistance, color fastness, and shrink resistance. Signs that a textile may have been treated with a formaldehyde-containing substance are claims like "wrinkle-free," "easy care," or "permanent

press.” Common textiles that have been treated with formaldehyde include business attire, school and military uniforms, bedding, pre-distressed jeans, and imported cotton or linen (to function as an antimicrobial agent in shipping).

IARC has classified formaldehyde as a Group 1 carcinogen with sufficient evidence of carcinogenicity in humans (and animals) to justify this categorization.⁸⁰ The EPA⁸¹ and the European Chemicals Agency (ECHA)⁸² further endorse this concern for formaldehyde’s carcinogenic effects. Formaldehyde exposure is furthermore suspected of mutagenicity (causing genetic defects).^{82,83}

Heavy Metals

Heavy metals like lead, cadmium, and chromium can be used in the dyeing process to create vivid, long-lasting colors or to help dyes stick to the fibers. While the disclosure of their usage is rarely found on a product tag, certain kinds of goods have a higher likelihood of being treated than others. Brightly colored fast-fashion (especially oranges, reds, and yellows) and plasticized screen prints on apparel are high-risk when it comes to heavy metals. The growth in the fast-fashion industry over the past decade has given rise to an increased chemical risk to consumers, with many products containing heavy metals and other harmful substances. In the US there are significant regulatory gaps specifically related to apparel. While the US Consumer Product Safety Commission (CPSC) requires that children’s clothing must not contain more than 100 ppm lead,⁸⁴ it has very few rules pertaining to adult clothing. The Federal Trade Commission (FTC) has regulations, but they focus more on labeling the fiber content of the fabrics rather than the chemicals used in the processing of the fabric.⁸⁵

Despite the CPSC regulations on lead in children’s clothing, emerging research indicates a lack of compliance in children’s clothing. Preliminary results from researchers at Marian University in 2026

found the presence of lead exceeding the 100 ppm limit in 11 different children's shirts, encompassing the full rainbow of color.⁸⁶

Lead isn't the only heavy metal lingering in clothing. One 2025 study assessing heavy metals and dermal exposure found that 80% of the 33 textile samples tested exceeded the safety limits set by OEKO-TEX Class I. The heavy metals present included cadmium, chromium, and arsenic. The presence of heavy metals raises significant concerns regarding dermal absorption; a concern that is compounded in regards to clothing for infants, who have thinner, more absorbent skin and smaller body mass compared to adults.⁸⁷

Some US states such as California, Washington, and New York have state-specific regulations regarding heavy metals in clothing.

Synthetic Dyes

Synthetic dyes dominate the global textile industry due to their cost-effectiveness, vibrant color range, and their high color fastness, meaning that colors remain stable during washing and exposure to light. Azo dyes are the most widely used, accounting for approximately 60–70% of all dyes used in the industry.⁸⁸

A major concern with azo dyes is the formation of aromatic amines, which are highly toxic degradation by-products released through the breakdown of azo bonds. Aromatic amines have been linked to multiple types of cancers.⁸⁹ IARC Monograph No. 100F, *Chemical Agents and Related Occupations*, categorized multiple aromatic amines as carcinogenic to humans (Group 1).⁹⁰ IARC Monograph No. 127, *Some Aromatic Amines and Related Compounds*, identified aromatic amines

believed to be possibly and probably carcinogenic to humans.⁹¹ In light of the evidence of carcinogenicity, some governmental bodies have sought to regulate azo dyes via the aromatic amines they release. One such example is the EU, which lists 22 regulated aromatic amines and prohibits the use of azo dyes that can release them in concentrations above 30 mg/kg for textiles and leather.⁹²

There are also a number of environmental health concerns associated with azo dyes as well, with a major one being that they are toxic to aquatic systems.^{93,94} One 2025 literature review found that the presence of azo dyes resulted in a 70% reduction in photosynthesis in aquatic plants and caused DNA damage and liver necrosis in fish, and contributed massively to terrestrial contamination (irrigation with dye-contaminated wastewater leads to the accumulation of aromatic amines in crops).⁹⁵ Azo dyes are resistant to natural degradation and are known to bioaccumulate, which are both major environmental and human health concerns.⁹⁶ This is significant because, as one 2023 study demonstrated, even though a fabric may be made from biodegradable materials, any synthetic dyes or finishes applied to the fabric may remain in the water supply.³⁷ Due to the environmental persistence of azo dyes, wastewater management and contamination prevention are of essential.

Azo dyes are linked to a multitude of human health concerns as well. Acute exposure to aromatic amines is linked to blindness, skin irritation, vertigo, vomiting, and more.⁹⁵ Chronic exposure to azo dyes and their derivatives has been associated with cancer and mutagenicity.^{95,97,98}

Common Chemical Treatments

Chemical Category	Key Human, Environmental, or Transparency Concerns
PFAS	Endocrine disruption, bioaccumulation, cancer, and high environmental toxicity and persistence.
Flame retardants	Endocrine disruption, learning difficulties, hyperactivity, fertility concerns, cancer, environmental persistence, and aquatic toxicity.
Formaldehyde	Cancer and mutagenicity concerns.
Heavy metals	Data gaps, limited transparency, and evidence that limits are commonly exceeded in textile samples.
Synthetic dyes	Cancer, mutagenicity, aquatic toxicity, wastewater contamination, bioaccumulation, and environmental persistence.

Table 2: Treatments, dyes, and finishes

Essential Guidance for Choosing Better Textiles

The following strategies can help reduce unnecessary chemical exposure and support more transparent, lower-impact textile choices.

Material Selection

- Look for credible third-party certifications that identify safer fibers and fabrics such as GOTS (Global Organic Textile Standard) and OEKO-TEX Standard 100. Prioritize buying organic items

that have the most prolonged contact with your skin and sweat (underwear, base layers, bedding etc.).

- To minimize chemical burden, opt for organic, natural textile materials where possible. This includes cotton, linen, wool, hemp, silk, and jute.
- Favor regenerated cellulose fibers from closed-loop systems, such as lyocell.

Washing, Wear, and Children's Sleepwear

- Wash clothes and bedding before using them to rinse off surface finishes. Washing new fabrics multiple times before wearing or buying secondhand can reduce the chemical load.
- To avoid chemical flame retardants in children's clothing that lacks organic certification, look for tight-fitting pajamas, as this style can meet the CPSC flammability standards without the need for flame retardants. Some children's pajamas may disclose on the tag if the product has been chemically treated, but not always.

Performance Claims and Colorants

- For outdoor gear or other performance apparel where water-resistance is necessary, search for fluorine-free Durable Water Repellent (DWR) treatments as alternatives to PFAS.
- Avoid performance claims such as "wrinkle-free," "stain-resistant," "easy-care," "permanent press," and "odor-resistant." These indicate that treatments containing PFAS or formaldehyde may have been used.
- Avoid brightly colored fast-fashion items and plasticized prints to minimize risk of heavy metal exposure and azo dye-associated concerns.

Furniture, Mattresses, and Foam

- Bypass mattresses, rugs/rug pads, and furniture made with polyurethane foam or memory foam when possible (polyurethane foam is often treated with flame retardants due to its high flammability). Look for options that use alternatives such as pure, natural latex or natural fibers as the filling.
- When buying second-hand, it's important to remember that some older furniture might be treated with phased-out, more toxic flame retardant chemicals.

Visit MADEWORKS.com for textiles without harmful chemicals.

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.

MADEWORKS Intelligence is a project of Nontoxic Certified Inc., a registered 501(c)(3) nonprofit organization.

References

1. Shekhar C, Khosya R, Thakur K, et al. A systematic review of pesticide exposure, associated risks, and long-term human health impacts. *Toxicol Rep.* 2024;13:101840. doi:10.1016/j.toxrep.2024.101840
2. Wan NF, Fu L, Dainese M, et al. Pesticides have negative effects on non-target organisms. *Nat Commun.* 2025;16(1):1360. doi:10.1038/s41467-025-56732-x
3. Organic Trade Association. Pesticides, Fertilizers, and GMOs in Conventional Cotton Fact Sheet. Published online 2025. <https://ota.com/sites/default/files/docs/Pesticides%2C%20Fertilizers%2C%20and%20GMOs%20in%20Conventional%20Cotton%20Fact%20Sheet%20.pdf>
4. Kapeleka JA, Ngowi AV, Mng'anya S, et al. Assessment of Unintentional Acute Pesticide Poisoning (UAPP) Amongst Cotton Farmers in Tanzania. *Toxics.* 2025;13(4):300. doi:10.3390/toxics13040300
5. (PDF) Occupational Health Risks Among Cotton Farmers: Associations with Pesticide Reduction under Sustainable Cotton Initiatives. ResearchGate. December 3, 2025. Accessed July 28, 2026. https://www.researchgate.net/publication/398155000_Occupational_Health_Risks_Among_Cotton_Farmers_Associations_with_Pesticide_Reduction_under_Sustainable_Cotton_Initiatives
6. Koussé JND, Ilboudo S, Ouédraogo JCRP, et al. Self-reported health effects of pesticides among cotton farmers from the Central-West region in Burkina Faso. *Toxicol Rep.* 2023;11:273-282. doi:10.1016/j.toxrep.2023.09.011
7. National Agricultural Statistics Service. 2021 Agricultural Chemical Use Survey. United States Department of Agriculture; 2022.

https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/2021_Field_Crops/chemhighlights-cotton.pdf

8. EPA. Glyphosate. September 18, 2014. Accessed July 28, 2026.
<https://www.epa.gov/ingredients-used-pesticide-products/glyphosate>
9. Glyphosate | EFSA. March 26, 2026. Accessed July 28, 2026.
<https://www.efsa.europa.eu/en/topics/topic/glyphosate>
10. Costas-Ferreira C, Durán R, Faro LRF. Toxic Effects of Glyphosate on the Nervous System: A Systematic Review. *Int J Mol Sci.* 2022;23(9):4605. doi:10.3390/ijms23094605
11. Walsh L, Hill C, Ross RP. Impact of glyphosate (Roundup™) on the composition and functionality of the gut microbiome. *Gut Microbes.* 15(2):2263935. doi:10.1080/19490976.2023.2263935
12. Lehman PC, Cady N, Ghimire S, et al. Low-dose glyphosate exposure alters gut microbiota composition and modulates gut homeostasis. *Environ Toxicol Pharmacol.* 2023;100:104149. doi:10.1016/j.etap.2023.104149
13. Rossetti MF, Canesini G, Lorenz V, Milesi MM, Varayoud J, Ramos JG. Epigenetic Changes Associated With Exposure to Glyphosate-Based Herbicides in Mammals. *Front Endocrinol (Lausanne).* 2021;12:671991. doi:10.3389/fendo.2021.671991
14. Muñoz JP, Soto-Jiménez D, Brito A, Quezada-Romegialli C. Glyphosate-Based Herbicides and Their Potential Impact on the Microbiota of Social Bees. *Toxics.* 2025;13(7):551. doi:10.3390/toxics13070551
15. McHenry LC, Schürch R, Council-Troche M, et al. Sublethal glyphosate exposure reduces honey bee foraging and alters the balance of biogenic amines in the brain. *J Exp Biol.* 2025;228(9):jeb250124. doi:10.1242/jeb.250124
16. IARC. Some Organophosphate Insecticides and Herbicides. Vol 112. International Agency for Research on Cancer; 2017. Accessed July 28, 2026.

<https://publications.iarc.who.int/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Some-Organophosphate-Insecticides-And-Herbicides-2017>

17. Tabuchi H. A Study Is Retracted, Renewing Concerns About the Weedkiller Roundup. The New York Times. January 2, 2026. Accessed July 28, 2026.
<https://www.nytimes.com/2026/01/02/climate/glyphosate-roundup-retracted-study.html>
18. Tanner CM, Kamel F, Ross GW, et al. Rotenone, Paraquat, and Parkinson's Disease. Environ Health Perspect. 2011;119(6):866-872. doi:10.1289/ehp.1002839
19. Paul KC, Cockburn M, Gong Y, Bronstein J, Ritz B. Agricultural paraquat dichloride use and Parkinson's disease in California's Central Valley. Int J Epidemiol. 2024;53(1):dyae004. doi:10.1093/ije/dyae004
20. Silva R, Sobral AF, Dinis-Oliveira RJ, Barbosa DJ. The Link Between Paraquat and Demyelination: A Review of Current Evidence. Antioxidants (Basel). 2024;13(11):1354. doi:10.3390/antiox13111354
21. Park SK, Kang D, Beane-Freeman L, et al. Cancer incidence among paraquat-exposed pesticide applicators in the Agricultural Health Study. Int J Occup Environ Health. 2009;15(3):274-281. doi:10.1179/oe.2009.15.3.274
22. APDA. Victory for state control over banning paraquat. American Parkinson Disease Association. May 1, 2026. Accessed July 28, 2026.
<https://www.apdaparkinson.org/article/victory-for-state-control-over-banning-paraquat/>
23. Eclou IB, Glèlè Kakaï R. Contamination and pesticide multiresidue analysis in cotton production systems in Benin. Discov Environ. 2024;2(1):54. doi:10.1007/s44274-024-00087-5

24. Mitran EC, Sandulache I, Secareanu L, et al. Assessing the presence of pesticides in modern and contemporary textile artifacts using advanced analysis techniques. *Industria Textila*. 2021;72:138-143. doi:10.35530/IT.072.02.1828
25. Hrouzková S, Szarka A. Development of a Modified QuEChERS Procedure for the Isolation of Pesticide Residues from Textile Samples, Followed by GC–MS Determination. *Separations*. 2021;8(8):106. doi:10.3390/separations8080106
26. Hu TT, Lu CM, Li H, Zhang ZX, Zhao YH, Li J. Determination of Eleven Organophosphorus Pesticide Residues in Textiles by Using HPLC-HRMS. *ANAL SCI*. 2017;33(9):1027-1032. doi:10.2116/analsci.33.1027
27. Li Y, Ye X, Luo X, Zhu W, Tang Z, Niu Z. Determination of 115 Pesticide Residues in Textiles by Liquid Chromatography-Tandem Mass Spectrometry. *Rapid Commun Mass Spectrom*. 2025;39(9):e9992. doi:10.1002/rcm.9992
28. S A, BM B, Bharathi B K, et al. Insecticide use in mulberry pest management and its combined effects on silk productivity. *International Journal of Advanced Biochemistry Research*. 2024;8:840-844. doi:10.33545/26174693.2024.v8.i8SI.1939
29. Coggon D. Work with pesticides and organophosphate sheep dips. *Occup Med (Lond)*. 2002;52(8):467-470. doi:10.1093/occmed/52.8.467
30. Agency for Toxic Substances and Disease Registry. Antimony | Toxic Substances | Toxic Substance Portal | ATSDR. Toxic Substances Portal. 2021. Accessed July 28, 2026. <https://wwwn.cdc.gov/TSP/substances/ToxSubstance.aspx?toxid=58>
31. National Center for Environmental Assessment. Antimony; CASRN 7440-36-0. US Environmental Protection Agency. https://iris.epa.gov/static/pdfs/0006_summary.pdf
32. Biver M, Turner A, Filella M. Antimony release from polyester textiles by artificial sweat solutions: A call for a standardized procedure. *Regulatory Toxicology and Pharmacology*. 2021;119. doi:10.1016/j.yrtph.2020.104824

33. US Environmental Protection Agency. Acrylonitrile. EPA; 2000.
34. IARC. Talc and Acrylonitrile. Vol 136. International Agency for Research on Cancer; 2025.
Accessed July 28, 2026.
<https://publications.iarc.who.int/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Talc-And-Acrylonitrile-2025>
35. Nitrous Oxide Emissions. January 7, 2025. Accessed July 28, 2026.
<https://www.epa.gov/ghgemissions/nitrous-oxide-emissions>
36. Royer SJ, Wiggin K, Kogler M, Dimitri D, Deheyn. Degradation of synthetic and wood-based cellulose fabrics in the marine environment: Comparative assessment of field, aquarium, and bioreactor experiments. Science of The Total Environment. 2021;791:148060.
doi:10.1016/j.scitotenv.2021.148060
37. Royer SJ, Greco F, Michaela Kogler, Deheyn DD. Not so biodegradable: Polylactic acid and cellulose/plastic blend textiles lack fast biodegradation in marine waters. PLOS ONE. 2023;18(5):e0284681. doi:10.1371/journal.pone.0284681
38. Vassilenko E, Watkins M, Chastain S, et al. Domestic laundry and microfiber pollution: Exploring fiber shedding from consumer apparel textiles. PLoS One. 2021;16(7):e0250346.
doi:10.1371/journal.pone.0250346
39. De Falco F, Gullo MP, Gentile G, et al. Evaluation of microplastic release caused by textile washing processes of synthetic fabrics. Environ Pollut. 2018;236:916-925.
doi:10.1016/j.envpol.2017.10.057
40. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Carbon Disulfide. US Department of Health and Human Services; 2025.
<https://www.atsdr.cdc.gov/toxprofiles/tp82.pdf>

41. Sieja K, Mach-Szczypiński J, Mach-Szczypiński J. Health effect of chronic exposure to carbon disulfide (CS₂) on women employed in viscose industry. *Medycyna Pracy*. 2018;69:329-335. doi:10.13075/mp.5893.00600
42. Sharma A, Kumar S, Bharat P. Carbon Disulfide (CS₂) Exposure and Human Reproductive Health- A Narrative Overview. *Journal of Reproduction and Infertility*. 2022;10. doi:10.47277/JIRB/10(2)/22
43. Hytönen E, Sorsamäki L, Kolehmainen E, Sturm M, Weymarn N. Lyocell Fibre Production Using NMMO – A Simulation-based Techno-Economic Analysis. *BioResources*. 2023;18:6384-6411. doi:10.15376/biores.18.3.6384-6411
44. Forfora N, Ortega R, Urdaneta I, et al. A Comparative Life Cycle Assessment of T-Shirt Production Using from Viscose, Lyocell, Cotton, and Polyester. *Sustainability*. 2026;18(8):4070. doi:10.3390/su18084070
45. Biodegradability of cellulose fibers, films, and particles: A Review: *BioResources*. Accessed July 28, 2026. <https://bioresources.cnr.ncsu.edu/>
46. Lott C, Berning A, Eckerle V, et al. Native and regenerated cellulose show similar environmental biodegradation behavior across global terrestrial and aquatic ecosystems. *bioRxiv*. Preprint posted online December 25, 2025:2025.12.24.696393. doi:10.64898/2025.12.24.696393
47. Du X, Wu Y, Tao G, et al. Association between PFAS exposure and thyroid health: A systematic review and meta-analysis for adolescents, pregnant women, adults and toxicological evidence. *Science of The Total Environment*. 2024;953:175958. doi:10.1016/j.scitotenv.2024.175958
48. White SS, Fenton SE, Hines EP. Endocrine disrupting properties of perfluorooctanoic acid,. *J Steroid Biochem Mol Biol*. 2011;127(1-2):16-26. doi:10.1016/j.jsbmb.2011.03.011

49. Berg V, Nøst TH, Hansen S, et al. Assessing the relationship between perfluoroalkyl substances, thyroid hormones and binding proteins in pregnant women; a longitudinal mixed effects approach. *Environ Int.* 2015;77:63-69. doi:10.1016/j.envint.2015.01.007
50. Fenton SE, Ducatman A, Boobis A, et al. Per- and Polyfluoroalkyl Substance Toxicity and Human Health Review: Current State of Knowledge and Strategies for Informing Future Research. *Environ Toxicol Chem.* 2021;40(3):606-630. doi:10.1002/etc.4890
51. Maxwell DL, Petriello MC, Pilsner JR. PFAS Exposure and Male Reproductive Health: Implications for Sperm Epigenetics. *Semin Reprod Med.* 2024;42(4):288-301. doi:10.1055/s-0044-1801363
52. Domingo JL. A review of the occurrence and distribution of Per- and polyfluoroalkyl substances (PFAS) in human organs and fetal tissues. *Environmental Research.* 2025;272:121181. doi:10.1016/j.envres.2025.121181
53. US EPA. Our Current Understanding of the Human Health and Environmental Risks of PFAS. October 14, 2021. Accessed July 28, 2026. <https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas>
54. Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS). National Institute of Environmental Health Sciences. Accessed July 28, 2026. <https://www.niehs.nih.gov/health/topics/agents/pfc>
55. Li S, Oliva P, Zhang L, et al. Associations between per-and polyfluoroalkyl substances (PFAS) and county-level cancer incidence between 2016 and 2021 and incident cancer burden attributable to PFAS in drinking water in the United States. *J Expo Sci Environ Epidemiol.* 2025;35(3):425-436. doi:10.1038/s41370-024-00742-2
56. Steenland K, Winquist A. PFAS and cancer, a scoping review of the epidemiologic evidence. *Environmental Research.* 2021;194:110690. doi:10.1016/j.envres.2020.110690

57. Goodrich JA, Walker D, Lin X, et al. Exposure to perfluoroalkyl substances and risk of hepatocellular carcinoma in a multiethnic cohort. JHEP Rep. 2022;4(10):100550. doi:10.1016/j.jhepr.2022.100550
58. IARC Monographs evaluate the carcinogenicity of perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS). Accessed July 28, 2026. <https://www.iarc.who.int/news-events/iarc-monographs-evaluate-the-carcinogenicity-of-perfluorooctanoic-acid-pfoa-and-perfluorooctanesulfonic-acid-pfos>
59. Zahm S, Bonde JP, Chiu WA, et al. Carcinogenicity of perfluorooctanoic acid and perfluorooctanesulfonic acid. The Lancet Oncology. 2024;25(1):16-17. doi:10.1016/S1470-2045(23)00622-8
60. A Never-Ending Story of Per- and Polyfluoroalkyl Substances (PFASs)? | Environmental Science & Technology. Accessed July 28, 2026. <https://pubs.acs.org/doi/10.1021/acs.est.6b04806>
61. Khan B, Burgess RM, Cantwell MG. Occurrence and Bioaccumulation Patterns of Per- and Polyfluoroalkyl Substances (PFAS) in the Marine Environment. ACS ES T Water. 2023;3(5):1243-1259. doi:10.1021/acsestwater.2c00296
62. Strong bioaccumulation of a wide variety of PFAS in a contaminated terrestrial and aquatic ecosystem. Environment International. 2025;202:109629. doi:10.1016/j.envint.2025.109629
63. Kotalik CJ, Hubbard LE, Perrotta BG, et al. Bioaccumulation and Transfer of Per- and Polyfluoroalkyl Substances (PFAS) in a Stream and Riparian Food Web Contaminated by Food Processing Wastewater. Environ Sci Technol. 2025;59(36):19444-19456. doi:10.1021/acs.est.5c04867
64. Taher H, Lohmann R. Chapter 11 Bioaccumulation of legacy and novel PFAS in the environment. In: Naidu R, Mallavarapu M, Liu Y, Umeh A, eds. Per- and Polyfluorinated Alkyl Substances. De Gruyter; 2025:495-518. doi:10.1515/9783110796797-011

65. Ragnarsdóttir O, Abou-Elwafa Abdallah M, Harrad S. Dermal bioavailability of perfluoroalkyl substances using in vitro 3D human skin equivalent models. *Environment International*. 2024;188:108772. doi:10.1016/j.envint.2024.108772
66. Green Science Policy Institute. (2013). Flame retardants. Retrieved from <http://greensciencepolicy.org/topics/flame-retardants/>
67. Siddiqi, M. A., Laessig, R. H., & Reed, K. D. (2003). Polybrominated diphenyl ethers (PBDEs): New Pollutants—Old diseases. *Clinical Medicine & Research*, 1(4), 281-290. Retrieved from <http://www.clinmedres.org/content/1/4/281.abstract>
68. Springer, C., Dere, E., Hall, S. J., McDonnell, E. V., Roberts, S. C., Butt, C. M., Boekelheide, K. (2012). Rodent thyroid, liver, and fetal testis toxicity of the monoester metabolite of bis-, a novel brominated flame retardant present in indoor dust. *Environmental Health Perspectives*, 120(12), 1711. Retrieved from <https://doi.org/10.1289/ehp.1204932>
69. Preston, E. V., McClean, M. D., Claus Henn, B., Stapleton, H. M., Braverman, L. E., Pearce, E. N., Webster, T. F. (2017). Associations between urinary diphenyl phosphate and thyroid function. *Environment International*, 101, 158-164. <https://doi.org/10.1016/j.envint.2017.01.020>
70. Eskenazi, B., Chevrier, J., Rauch, S. A., Kogut, K., Harley, K. G., Johnson, C., Trujillo, C., Sjödin, A., & Bradman, A. (2013). In utero and childhood polybrominated diphenyl ether (PBDE) exposures and neurodevelopment in the CHAMACOS study. *Environmental Health Perspectives*, 121(2), 257–262. <https://doi.org/10.1289/ehp.1205597>
71. Herbstman JB, Sjödin A, Kurzon M, Lederman SA, Jones RS, Rauh V, Needham LL, Tang D, Niedzwiecki M, Wang RY, Perera F. Prenatal exposure to PBDEs and neurodevelopment. *Environ Health Perspect*. 2010 May;118(5):712-9. doi: 10.1289/ehp.0901340. Epub 2010 Jan 4. PMID: 20056561; PMCID: PMC2866690.
72. Roze, E., Meijer, L., Bakker, A., Van Braeckel, Koenraad N J A, Sauer, P. J., & Bos, A. F. (2009). Prenatal exposure to organohalogens, including brominated flame retardants, influences

motor, cognitive, and behavioral performance at school age. *Environmental Health Perspectives*, 117(12), 1953-1958. <https://doi.org/10.1289/ehp.0901015>

73. Carignan, C. C., Mínguez-Alarcón, L., Williams, P. L., Meeker, J. D., Stapleton, H. M., Butt, C. 35 M., Hauser, R. (2018). Paternal urinary concentrations of organophosphate flame retardant metabolites, fertility measures, and pregnancy outcomes among couples undergoing in vitro fertilization. *Environment International*, 111, 232-238. <https://doi.org/10.1016/j.envint.2017.12.005>
74. Meeker, J. D., Johnson, P. I., Camann, D., & Hauser, R. (2009). Polybrominated diphenyl ether (PBDE) concentrations in house dust are related to hormone levels in men. *Science of the Total Environment*, 407(10), 3425-3429. <https://doi.org/10.1016/j.scitotenv.2009.01.030>
75. Hoffman, K., Lorenzo, A., Butt, C. M., Hammel, S. C., Henderson, B. B., Roman, S. A., Sosa, J. A. (2017). Exposure to flame retardant chemicals and occurrence and severity of papillary thyroid cancer: A case-control study. *Environment International*, 107, 235-242. <https://doi.org/10.1016/j.envint.2017.06.021>
76. Baron, E., Gimenez, J., Verborgh, P., Gauffier, P., De Stephanis, R., Eljarrat, E., & Barcelo, D. 57 (2015). Bioaccumulation and biomagnification of classical flame retardants, related halogenated natural compounds and alternative flame retardants in three delphinids from southern European waters. *Environmental Pollution*, 203, 107-115. 10.1016/j.envpol.2015.03.041 Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/25875161>
77. Ross, P. S. (2005). Fireproof killer whales (*Orcinus orca*): Flame-retardant chemicals and the conservation imperative in the charismatic icon of British Columbia, Canada. *Canadian Journal of Fisheries and Aquatic Sciences*, 63(1), 224-234. Retrieved from <https://doi.org/10.1139/f05-244>

78. US Environmental Protection Agency, (EPA). (2015). Flame retardants used in flexible polyurethane foam: An alternatives assessment update. Retrieved from https://www.epa.gov/sites/production/files/2015-08/documents/ffr_final.pdf
79. Gerlach, C. V., Das, S. R., Volz, D. C., Bisson, W. H., Kolluri, S. K., & Tanguay, R. L. (2014). Mono-substituted isopropylated triaryl phosphate, a major component of firemaster 550, is an AHR agonist that exhibits AHR-independent cardiotoxicity in zebrafish. *Aquatic Toxicology*, 154, 71-79. <https://doi.org/10.1016/j.aquatox.2014.05.007>
80. IARC. (2006). Formaldehyde, 2-Butoxyethanol and 1-tert-Butoxypropan-2-ol. International Agency for Research on Cancer. <https://publications.iarc.who.int/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Formaldehyde-2-Butoxyethanol-And-1--Em-Tert-Em--Butoxypropan-2-ol-2006>
81. US EPA. (2013, September 20). Facts About Formaldehyde [Other Policies and Guidance]. <https://www.epa.gov/formaldehyde/facts-about-formaldehyde>
82. ECHA. (n.d.). Substance Information—Formaldehyde. European Chemicals Agency. Retrieved September 10, 2025, from <https://echa.europa.eu/substance-information/-/substanceinfo/100.000.002>
83. PubChem. (n.d.). Formaldehyde. Retrieved September 10, 2025, from <https://pubchem.ncbi.nlm.nih.gov/compound/712>
84. CPSC. Total Lead Content. U.S. Consumer Product Safety Commission. Accessed July 28, 2026. <https://www.cpsc.gov/Business--Manufacturing/Business-Education/Lead/Total-Lead-Content>
85. Duroske E. Death by Fashion: Consumers Face Health Risks By Purchasing From Unregulated Fast Fashion Brands. *Loyola Consumer Law Review*. 2023;35(2):261.

86. Initial tests find lead in children's fast-fashion clothing. American Chemical Society. Accessed July 28, 2026.
<https://www.acs.org/pressroom/presspacs/2026/march/initial-tests-find-lead-in-childrens-fast-fashion-clothing.html>
87. Xiong M, Cui D, Cheng Y, et al. Heavy Metals in Infant Clothing: Assessing Dermal Exposure Risks and Pathways for Sustainable Textile Policies. *Toxics*. 2025;13(8):622.
doi:10.3390/toxics13080622
88. Benkhaya S, M'rabet S, El Harfi A. Classifications, properties, recent synthesis and applications of azo dyes. *Heliyon*. 2020;6(1):e03271. doi:10.1016/j.heliyon.2020.e03271
89. Liu Y, Cui Y, Xu Y, Wang W, Li Y. Carcinogenic risks of aromatic amines and their radical oxidation products: Construction of adverse outcome pathways, development of priority control lists, and mechanistic analysis of carcinogenesis. *Ecotoxicology and Environmental Safety*. 2025;303:119037. doi:10.1016/j.ecoenv.2025.119037
90. IARC. Chemical Agents and Related Occupations. Vol 100F. Accessed July 28, 2026.
<https://publications.iarc.who.int/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Chemical-Agents-And-Related-Occupations-2012>
91. IARC. Some Aromatic Amines and Related Compounds. Accessed July 28, 2026.
<https://publications.iarc.who.int/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Some-Aromatic-Amines-And-Related-Compounds-%C2%A0-2021>
92. Participation E. Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives

91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC (Text with EEA relevance).

<https://webarchive.nationalarchives.gov.uk/eu-exit/https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02006R1907-20200824>. Accessed July 28, 2026.

<https://www.legislation.gov.uk/eur/2006/1907/annex/XVII/table/9>

93. Selvaraj V, Swarna Karthika T, Mansiya C, Alagar M. An over review on recently developed techniques, mechanisms and intermediate involved in the advanced azo dye degradation for industrial applications. *Journal of Molecular Structure*. 2021;1224:129195.
doi:10.1016/j.molstruc.2020.129195
94. Berradi M, Hsissou R, Khudhair M, et al. Textile finishing dyes and their impact on aquatic environs. *Heliyon*. 2019;5(11):e02711. doi:10.1016/j.heliyon.2019.e02711
95. Mosa F, Mohammed W. Ecological and Biological Impacts of Azo Compounds: A Concise Review of Toxicity, Degradation, and Sustainable Solutions. In: 2025.
96. Ibrahim S. An overview of azo dyes environmental impacts. *GSC Advanced Research and Reviews*. 2025;24:102-111. doi:10.30574/gscarr.2025.24.1.0196
97. Latef S, Jwaid A. A comprehensive review of environmental and health risks of textile dyes and strategies for eco-safe remediation. *IOP Conference Series: Earth and Environmental Science*. 2025;1545:012109. doi:10.1088/1755-1315/1545/1/012109
98. Chung KT. Azo dyes and human health: A review. *J Environ Sci Health C Environ Carcinog Ecotoicol Rev*. 2016;34(4):233-261. doi:10.1080/10590501.2016.1236602