

PFAS Forever Chemicals: Disrupting Vitamin D

Per- and polyfluoroalkyl substances (PFAS) pose a mounting public health crisis through their interference with the vitamin D endocrine system, with **landmark 2025 research revealing PFAS reduce vitamin D levels by up to 50% and increase diabetes risk by 31%**. These "forever chemicals" don't just contaminate our environment—they directly block the vitamin D receptor (VDR), creating a cascade of health consequences including bone fractures, delayed puberty, and metabolic dysfunction. **Universal exposure affects nearly 100% of the population**, ([National Institute of Environm...](#)) with contamination found in 65% of medical bandages, ([Time +3](#)) widespread food packaging, and up to 70 million acres of U.S. farmland. While regulatory responses are accelerating globally, the persistence of these compounds means that exposure reduction strategies and emerging detoxification methods represent our most immediate defense against this pervasive threat.

PFAS directly sabotage vitamin D function at the molecular level

The most significant breakthrough in PFAS research came from mechanistic studies showing how these chemicals interfere with vitamin D at the cellular level. **PFOA competes directly with calcitriol (active vitamin D) for the same binding site on the vitamin D receptor**, ([ScienceDirect](#)) creating what researchers describe as "functional hypovitaminosis D"—where vitamin D levels appear normal but the hormone cannot function properly.

The March 2025 landmark study analyzing 2,114 postmenopausal women from NHANES data revealed devastating impacts: **PFOS exposure increased vitamin D deficiency risk by 150%, while PFOA nearly tripled the risk** (odds ratio 3.146). The study found dose-dependent vitamin D reductions, with PFOA causing the most severe decreases ($\beta = -17.288$ nmol/L) followed by PFOS ($\beta = -15.969$ nmol/L). Surface plasmon resonance analysis confirmed a 10% reduction in vitamin D binding capacity when PFOA is present, while molecular docking studies showed PFOA binds to the same receptor site through halogen bonds with key amino acids.

This molecular interference disrupts the entire vitamin D signaling cascade. When PFOA co-incubates with vitamin D, it significantly blunts the upregulation of critical VDR target genes including TRPV6 (calcium transport), calbindin-D9k (calcium binding), CYP24A1 (vitamin D metabolism), and osteocalcin (bone formation). ([ScienceDirect](#)) The result is reduced mineralization in human osteoblasts and elevated parathyroid hormone levels despite seemingly adequate vitamin D status—a compensatory mechanism indicating cellular vitamin D starvation.

Metabolic and developmental consequences span multiple organ systems

The health implications of PFAS-vitamin D disruption extend far beyond bone health. The July 2025 Mount Sinai study analyzing 360 participants found **each increase in PFAS mixture exposure**

associated with 31% higher likelihood of developing type 2 diabetes, with PFOS contributing most strongly to this association. The study revealed PFAS disrupt multiple metabolic pathways including glutamate metabolism, arginine and proline metabolism, and drug metabolism via cytochrome P450 enzymes.

Bone health suffers dramatically from PFAS exposure, with systematic reviews confirming moderate evidence that PFOS, PFOA, and PFNA reduce bone mineral density across multiple populations. The effects are particularly pronounced in females and individuals under 60, with PFAS potentially affecting bone through PPAR γ receptor activation, leading to increased fat cell formation and decreased bone-forming osteoblast function. (ACS Publications) (PubMed Central) Multiple studies in Chinese adults found higher PFAS concentrations significantly correlated with reduced BMD and increased osteoporosis prevalence. (Frontiers +2)

Reproductive and developmental impacts are equally concerning. The University of Cincinnati's longitudinal study of 823 girls found **85% had measurable PFAS levels, with exposure causing an average 5-6 month delay in puberty onset**. This delay correlates with higher risks of breast cancer, renal disease, and thyroid disease later in life. (Cincinnati Children's) (University of Cincinnati) Norwegian studies of 300 boys showed similar effects, with higher PFNA and PFHxS levels associated with later pubertal onset and reduced testosterone levels. (ACS Publications)

The European Food Safety Authority identified immune system suppression as the most critical PFAS health concern, with exposure reducing antibody response to vaccines and decreasing infection resistance. (EFSA +2) Additionally, PFAS cause liver toxicity, with strong evidence linking exposure to nonalcoholic fatty liver disease and elevated liver enzymes. (US EPA) (FDA)

Contamination pervades daily life through unexpected pathways

PFAS contamination has reached alarming levels across consumer products and environmental pathways. The verification of widespread medical bandage contamination proves particularly concerning:

Mamavation's testing of 40 bandages from 18 brands found 26 contained organic fluorine above 10 ppm, (MAMAVATION +2) with concentrations reaching 374 ppm. (Healthcare Packaging) (Time) Band-Aid OURTONE Flexible Fabric BR65 showed the highest contamination, (Healthcare Packaging) (Time) while 63% of bandages marketed to Black and Brown communities contained PFAS, (MAMAVATION) (EHN) raising environmental justice concerns.

Food packaging represents another major exposure source, though regulatory action has accelerated. The FDA completed its phase-out of PFAS grease-proofing agents in February 2024, formally determining 35 Food Contact Notifications for PFAS no longer effective by January 2025. (FDA +2) However, legacy contamination persists, with tea consumption associated with 24.8% higher PFHxS levels and restaurant food showing elevated PFAS exposure compared to home-cooked meals. (Keck School of Medicine of USC)

Agricultural contamination affects an estimated 70 million acres of U.S. farmland through PFAS-contaminated biosolids used as fertilizer—approximately 18% of all agricultural land. (EWG) The EPA's January 2025 draft risk assessment reveals health risks at concentrations as low as 1 ppb, with contaminated soils in Pennsylvania showing significantly higher PFAS levels than control soils. (US EPA) (Nature) Quebec studies found biosolids concentrations ranging from 12-1,310 µg/kg, (ScienceDirect) while Alabama and Maine cases demonstrate major soil and groundwater contamination from industrial biosolids application.

Current drinking water contamination affects massive populations, with **9,552 contaminated sites across all 50 U.S. states affecting 172 million people**. (Environmental Working Group) (ewg) The USGS estimates 45% of U.S. tap water contains PFAS, (Earthjustice +3) while European monitoring shows 23,000 contaminated sites with approximately 2,300 high-risk "hotspots." Consumer product testing reveals widespread contamination in textiles (35 of 60 products exceeded 100 ppm fluorine), (EWG) contact lenses (100% of 18 brands contained organic fluorine), (EHN) (MAMAVATION) and dental floss (33% of 39 brands contained PFAS). (EHN) (MAMAVATION)

Regulatory landscape shows mixed progress amid political pressures

Global PFAS regulation underwent significant shifts in 2025, with varying approaches across jurisdictions. The United States saw partial federal rollbacks when **EPA announced in May 2025 it would maintain drinking water limits only for PFOA and PFOS at 4 parts per trillion but extend compliance deadlines from 2029 to 2031**. (White & Case LLP +3) The agency plans to rescind regulations for four other PFAS (PFHxS, PFNA, HFPO-DA/GenX, and PFBS) with final rule expected Spring 2026. (White & Case LLP +2)

State-level action has accelerated dramatically, with over 350 PFAS bills introduced across 39 states in 2025. (MultiState) New Mexico enacted the most comprehensive state regulation (HB 212), banning PFAS in cookware, food packaging, and dental floss by 2027, extending to carpets, cleaning products, cosmetics, and textiles by 2028, with all intentionally added PFAS banned by 2032 unless deemed "currently unavoidable use." (MultiState)

The European Union accelerated its comprehensive approach, with ECHA publishing an updated restriction proposal in August 2025 covering approximately 10,000+ PFAS substances across all sectors. (NatLawReview +2) The proposal, refined after evaluating 5,600+ public comments, aims for implementation by 2026-2027 with various transition periods. (NatLawReview) The EU maintains the world's most stringent drinking water standard at 0.5 µg/L (500 ppt) for all PFAS, (ECHA) (Roland Berger) while its Packaging and Packaging Waste Regulation implements a comprehensive food packaging PFAS ban effective August 12, 2026.

Canada pioneered a class-based regulatory approach, with its March 2025 State of PFAS Report concluding the entire PFAS class (excluding fluoropolymers) is "toxic" under the Canadian Environmental

Protection Act. (KPMG Canada) This makes Canada the first jurisdiction to classify the entire PFAS class as toxic, leading to a three-phase risk management approach targeting firefighting foams, consumer products, and industrial uses. The Stockholm Convention continues expanding PFAS listings, with current meetings addressing long-chain PFCAs (C9-21) for potential global elimination. (ECHA)

Practical exposure reduction strategies offer measurable benefits

Despite widespread contamination, evidence-based strategies can significantly reduce PFAS exposure.

Water filtration represents the most effective intervention, with reverse osmosis systems achieving up to 99% PFAS removal and granular activated carbon filters removing 88-99% when properly certified.

(US EPA +2) The EPA emphasizes looking for NSF/ANSI Standard 58 certification for reverse osmosis and NSF/ANSI Standard 53 certification for activated carbon filters specifically for PFOA/PFOS reduction.

(CDC +3)

Dietary interventions show promising results, with **breakthrough research revealing soluble fiber supplements can reduce PFAS levels by 8% after just 4 weeks**. Psyllium husk (found in Metamucil) and oat beta-glucan supplements work by trapping PFAS in a gel matrix for fecal elimination when taken with meals during bile production. Studies consistently show people with high-fiber diets have lower PFAS levels, while cruciferous vegetables support liver detoxification pathways.

Consumer product avoidance requires vigilance but offers significant impact. Avoid products labeled "non-stick," "waterproof," "stain-resistant," or "wrinkle-free," opting instead for cast iron, carbon steel, or ceramic cookware, untreated natural fabrics, and PFAS-free personal care products (Consumer Reports)

(consumerreports) identified through Environmental Working Group's Skin Deep database. The immediate transfer of food from packaging, particularly avoiding reheating in original containers, reduces exposure as heat increases PFAS migration. (Consumer Reports) (consumerreports)

Medical interventions show promise for high-exposure individuals. Cholestyramine, a prescription bile acid sequestrant, demonstrates significant PFAS reduction in clinical studies, while regular blood donation (particularly plasma donation) proves effective for persistent PFAS like PFOS and PFHxS. Recent firefighter studies showed substantial reductions with regular blood and plasma donation protocols.

Testing options are increasingly accessible, with at-home blood testing available through companies like EmpowerDX (\$299 for 16 PFAS compounds) and Quest Health (\$79-500 depending on panel size). Some states offer free testing in contaminated areas, and the CDC Blood Level Estimation Tool provides estimates based on water exposure data. (CDC)

Conclusion

The convergence of scientific evidence reveals PFAS as a uniquely troubling class of environmental contaminants that fundamentally disrupt human physiology through direct interference with the vitamin

D endocrine system. The molecular mechanism—competitive binding at the vitamin D receptor—provides a clear biological pathway explaining the cascade of observed health effects from bone disease to diabetes to delayed development. [ScienceDirect](#) With nearly universal population exposure and environmental persistence measured in decades to centuries, PFAS represent a transgenerational health threat requiring immediate action. [Earthjustice +4](#)

The regulatory response, while accelerating in some jurisdictions, remains fragmented and politically vulnerable, as demonstrated by the U.S. federal rollbacks of 2025. This regulatory uncertainty places greater emphasis on individual and community-level exposure reduction strategies, fortunately supported by emerging scientific evidence for practical interventions including water filtration, dietary fiber supplementation, and targeted medical treatments for high-exposure individuals.

The PFAS-vitamin D connection illuminates a broader truth about environmental health: seemingly distant industrial chemicals can hijack fundamental biological systems with effects that manifest across generations. As the scientific understanding deepens and contamination continues, the imperative for both regulatory action and personal protection strategies becomes ever more urgent in safeguarding human health against these persistent molecular invaders.