

Understanding Glyphosate's Growing Presence in Agriculture and Its Effects on Human Health

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STORY AT-A-GLANCE

- › Glyphosate has become the most widely used herbicide in history, with usage increasing 100 to 300-fold since the late 1970s, resulting in its presence in 60% to 80% of the general population through food, water, and air exposure
- › Research has shown glyphosate can accumulate in the kidney, liver, colon, and brain, cross the blood-brain barrier, and has been found in human breast milk, indicating it doesn't simply get excreted as claimed
- › A two-year study found that exposure to Roundup (a glyphosate-based herbicide) at doses far below permissible levels caused organ damage and increased tumor incidence, particularly mammary tumors in female test subjects
- › Glyphosate has been identified as an endocrine disruptor, showing eight out of 10 key characteristics associated with endocrine-disrupting chemicals, and can affect future generations through epigenetic changes
- › Studies show switching to an organic diet can reduce urinary glyphosate levels by about 71% within six days, with the highest sources of exposure being conventional grains, processed foods, and the "Dirty Dozen" produce items

A pesticide is any substance or mixture of substances designed to kill, repel, or control pests. Let's break it down into the two components: The term "pest" refers to any organism (insects, weeds, rodents, fungi, bacteria, etc.) that is considered harmful or

undesirable, particularly in agricultural settings. And then "-cide" is a suffix derived from the Latin word "caedere," meaning "to kill."

It is commonly used in words to indicate something that kills or destroys, such as herbicide (kills plants), insecticide (kills insects), and fungicide (kills fungi).

Pesticides serve as an umbrella term for substances targeting pests, with subcategories defined by the type of pest being addressed, such as herbicides for weeds, insecticides for insects, fungicides for fungi, and rodenticides for rodents.

There are natural options that can be highly effective in controlling pests, including neem oil, pyrethrins extracted from specific flowers, rotenone derived from plant roots, diatomaceous earth, *Bacillus thuringiensis* (a bacteria-based solution), sulfur, garlic and pepper extracts, and copper-based compounds. Many of these options are used in organic agriculture.

And then there are chemical agents. The types of synthetic pesticides commonly used in conventional agriculture include:

Pesticide category	Main target	Examples
Insecticides	Insects	Cypermethrin, chlorpyrifos, malathion, imidacloprid, and the now banned DDT
Herbicides	Weeds	Glyphosate, 2,4-D, atrazine, dicamba, paraquat, glufosinate
Fungicides	Fungi, molds and mildew	Mancozeb, chlorothalonil, azoxystrobin, propiconazole

Pesticide category	Main target	Examples
Rodenticides	Rodents like rats and mice	Warfarin
Nematicides	Parasitic nematodes (roundworms)	Fenamiphos, oxamyl, 1,3-dichloropropene
Bactericides	Bacteria	Kasugamycin, streptomycin, oxytetracycline
Miticides/acaricides	Mites and ticks	Abamectin, bifenazate, fenpyroximate

Waging chemical warfare against natural biological systems inevitably has consequences – Mother Nature will always prevail! While the widespread use of synthetic pesticides in global agriculture is driven by their ability to boost crop yields and produce cheap, abundant food.

This chemical-dependent farming system is deeply rooted in government policies and the profit-driven business models of Big Ag corporations.

Government subsidies, shaped by powerful agricultural lobbying, prioritize high-yield, chemical-intensive methods, which inadvertently fosters conditions that favor pesticide use, and favor chemical solutions over natural alternatives.

This system is further entrenched by the business model of major chemical corporations. These companies develop and patent pesticides, securing exclusive rights to their products for years. This monopolistic control allows them to command premium prices and substantial profits.

Their market power is further amplified by offering comprehensive agricultural packages that bundle pesticides with seeds and fertilizers, creating a cycle of dependency that reinforces their industry dominance.

It is important to keep this in mind when assessing mainstream messaging about the "safety" of glyphosate and other pesticide usage – of course they don't want you to think these are bad since that is a threat to their business model!

Occasional pesticide use may not be that big of a deal, but our current agricultural system's heavy dependence on these chemicals has severe implications for both environmental and human health.

In this article, let's focus on glyphosate and why we should be concerned that it dominates our agriculture system. (There are of course problems with other pesticides, too!). The evidence as a whole suggests we need to be cautious of our long-term exposure!

So What Is Glyphosate?

Glyphosate is a synthetic, non-specific, systemic herbicide that kills many types of weeds and other vegetation by disrupting with the "shikimate pathway," a biochemical pathway that essential for plant survival. Since this pathway is absent in human cells, international "authorities" consider glyphosate to have no toxicity in humans. However, increasing evidence suggests otherwise.¹

Glyphosate is the active ingredient in many herbicide products, including the popular "Roundup" product. These are referred to as glyphosate-based formulations (GBFs). GBFs unfortunately contain a range of other problematic chemicals in addition to glyphosate.² GBFs are used in agriculture, commercial, industrial, and residential settings due to its broad-spectrum herbicidal properties.

The second most common use of glyphosate, after agriculture, is in landscape and turf management which include gardens, lawns, public spaces, parks, alongside roads and on golf courses.

In the grand scheme of things, glyphosate is still relatively "new." And it is a common trend in industry that many things aren't officially labeled as a "health hazard" *until* they start causing major health problems, since there's way too much money to be made

by big businesses in the meantime! (Two examples include DDT and agent orange – which weren't banned until they were proven to cause serious health problems). Science often lags industry!

So let's recap briefly – In 1964, the patent was issued for use of glyphosate as a metal chelating and descaling agent to clean out mineral deposits in pipes and boilers. Then in 1971, glyphosate was patented as an herbicide after the discovery of its herbicidal properties.

In 1974, glyphosate was first sold to farmers by Monsanto, the company that was recently acquired by Bayer. Since the late 1970s, the use of glyphosate-based herbicides has increased between 100 to 300-fold!³

Glyphosate has become the most widely used chemical herbicide in history (for agriculture, commercial, industrial and residential settings) due to its broad-spectrum herbicidal properties. Tragically, this compound, which has been classified as a "probable carcinogen" by the International Agency for Research on Cancer,⁴ is now pervasive in our food, water, and air.

The surge in global pesticide use can be traced to a fundamental shift in agricultural practices – the transition to industrial farming, particularly through the advent of genetically engineered crops in the mid-1990s. These GMO crops were engineered with a specific purpose: to either produce their own insecticides or withstand powerful herbicides, or both.

Today, this technology dominates major crops, with approximately 94% of soybean production now using genetically engineered seeds designed to resist Monsanto-Bayer's glyphosate-based Roundup herbicide.

Before "Roundup Ready" crops, farmers had to carefully limit herbicide application to avoid damaging their crops. But with plants engineered to withstand glyphosate, farmers could spray more frequently and intensively. Between 1990 and 2014, glyphosate use exploded from 7.7 million pounds to 250 million pounds – a staggering 1,347% increase.

However, glyphosate's reach extends beyond just GMO agriculture through an unexpected practice: pre-harvest desiccation. So, Glyphosate isn't just used to kill weeds – farmers have discovered they can use glyphosate as a drying agent on non-GMO crops, particularly in regions with short growing seasons and wet harvests. This "desiccation" practice involves spraying crops with glyphosate shortly before harvest to force uniform drying and enable earlier harvesting.

Originally developed in 1980s Scotland to address unreliable grain drying conditions, the technique has spread globally, leading to a 400% increase in glyphosate use on non-GMO wheat alone over the past two decades.⁵

*"The herbicide, glyphosate, is applied to wheat crops before harvest to encourage ripening resulting in higher glyphosate residues in commercial wheat products within North America."*⁶

Desiccation has now expanded to numerous crops including barley, oats, corn, lentils, beans, chickpeas, potatoes, millet, sugar beets and others. This widespread adoption of glyphosate, both in GMO cultivation and as a pre-harvest desiccant in non-GMO crops, helps explain why the global glyphosate market is projected to grow from \$10.92 billion in 2024 to \$11.89 billion in 2025, representing an 8.9% annual growth rate.

A common misconception is that "non-GMO" labeling equates to chemical-free farming. However, the "non-GMO" label only signifies that the crops have not been genetically modified; it does not address whether pesticides or herbicides were used during cultivation. In fact, pesticides are commonly applied to non-GMO crops.

It also unfortunately means we are being exposed to much higher levels than ever before, in the food we eat and in the feed consumed by livestock.

When animals consume grains and other feed crops treated with glyphosate, traces of the chemical can accumulate in their systems, ultimately resulting in higher levels of glyphosate residues in meat and dairy products, raising concerns about the potential health implications of chronic low-level glyphosate exposure throughout the food chain.

Health Consequences of Glyphosate

Now that we understand a little more of the backstory of glyphosate infiltration into the food system – what's the big deal? Why should we care?

Monsanto originally claimed Roundup was safe based on a 90-day trial in rats. Well, one research group wanted to put this to the test and extend this 90-day trial to two years.⁷ The results are very concerning!

"Our study design was based on that of the Monsanto investigation in order to make the two experiments comparable, but we extended the period of observation from Monsanto's 90 days to 2 years. We also used three doses of GMOs (instead of Monsanto's two) and Roundup to determine treatment dose response, including any possible non-linear as well as linear effects.

This allowed us to follow in detail the potential health effects and their possible origins due to the direct or indirect consequences of the genetic modification itself in the NK603 GM maize, or due to the R herbicide formulation used on the GM maize (and not G alone), or both ...

We then also tested for the first time three doses (rather than the two usually employed in 90-day protocols) of the R-tolerant NK603 GM maize alone, the GM maize treated with R, and R alone at very low environmentally relevant doses, starting below the range of levels permitted by regulatory authorities in drinking water and in GM feed ...

Our findings show that the differences in multiple organ functional parameters seen from the consumption of NK603 GM maize for 90 days escalated over 2 years into severe organ damage in all types of test diets. This included the lowest dose of R administered (0.1 ppb, 50 ng/L G equivalent) of R formulation administered, which is well below permitted MRLs in both the USA (0.7 mg/L) and European Union (100 ng/L).

Surprisingly, there was also a clear trend in increased tumor incidence, especially mammary tumors in female animals, in a number of the treatment groups. Our data highlight the inadequacy of 90-day feeding studies and the need to conduct long-term (2 years) investigations to evaluate the life-long impact of GM food consumption and exposure to complete pesticide formulations."

There was organ damage when the study was extended to two years at a Roundup dose far below permissible levels in the U.S. and the E.U. Additionally, tumor incidence, particularly mammary tumors in females, increased in several treatment groups.

The results emphasize the inadequacy of short-term (90-day) studies and the importance of long-term research to fully assess the health risks of GM food and pesticide formulations. Unfortunately, there is currently no long-term data on the effects of glyphosate exposure in humans (this is pretty hard to accomplish in a well-controlled environment).

But does this mean we shouldn't be concerned of the alarming data in animals? NO! Just because something doesn't immediately kill you does not make it safe. Long term chronic exposure is a huge health threat.

And since glyphosate is present in 60% to 80% of the general population,⁸ we actually may be part of an ongoing, real-time experiment on its long-term health effects as we speak. Let's dive in a little more to see what recent research says about the potential health concerns of glyphosate exposure. (There is plenty of evidence showing us it is not safe!)

Stored in the Body/Bioaccumulates

While many point to the fact that glyphosate is water soluble, so it is "easily excreted" by the body – they forget about these glyphosate-based-formulations where other ingredients are mixed in, such as surfactants.

Studies show accumulation in the kidney, liver and colon^{9,10,11} and in human biological fluids, representing a severe human health risk.

Studies also demonstrate that glyphosate can cross the blood-brain barrier and accumulate in the brain in a dose-dependent manner, increasing the risk of neurodegenerative diseases like Alzheimer's.¹²

The presence of glyphosate in human breast milk¹³ is concerning for many health experts since it suggests that this chemical, despite being 'water soluble, is accumulating in tissues and passing through biological barriers in ways that are not well understood!

Inflammation and DNA Damage

There are several studies documenting that it can induce inflammation and oxidative stress in various types of cells.^{14,15,16,17,18,19,20,21,22,23,24} As a result, glyphosate can increase DNA damage, significantly increasing cancer risks^{25,26,27,28,29} and kidney and liver dysfunction.^{30,31,32,33}

Endocrine Disruption

Glyphosate has been shown to disrupt endocrine function^{34,35,36} and can lead to hormonal imbalances by influencing key hormonal pathways in the body.^{37,38}

A 2020 review paper concluded that glyphosate exhibits eight out of 10 key characteristics associated with "endocrine disrupting chemicals," suggesting that glyphosate-based herbicides alter the biosynthesis of sex hormones.³⁹

Roundup concentrations in the range of 10^3 times below the "MRL" can induce endocrine disturbances in human cells.⁴⁰

Other alarming findings include that glyphosate can reduce sperm motility^{41,42} can interfere with protein synthesis, which can suppress spermatogenesis and cell growth,⁴³ and decrease serum testosterone in young male rats.⁴⁴

Impacts Next Generation Through Epigenetics

There is also data demonstrating that glyphosate not only impacts an individual's health but also impacts the health of their descendants through epigenetic changes by interfering with normal methylation processes and gene expression.^{45,46}

Perinatal exposure to low doses of glyphosate formulations impaired female reproductive performance and induced fetal growth retardation and structural congenital anomalies in mammal F2 offspring.⁴⁷

Exposure to glyphosate at doses deemed "safe" for human health during gestation significantly increased anogenital distance (AGD) in both male and female rat pups. AGD is the measurement between the anus and the genitalia and is often used as a biological marker in toxicology and reproductive studies to assess the effects of endocrine-disrupting chemicals.

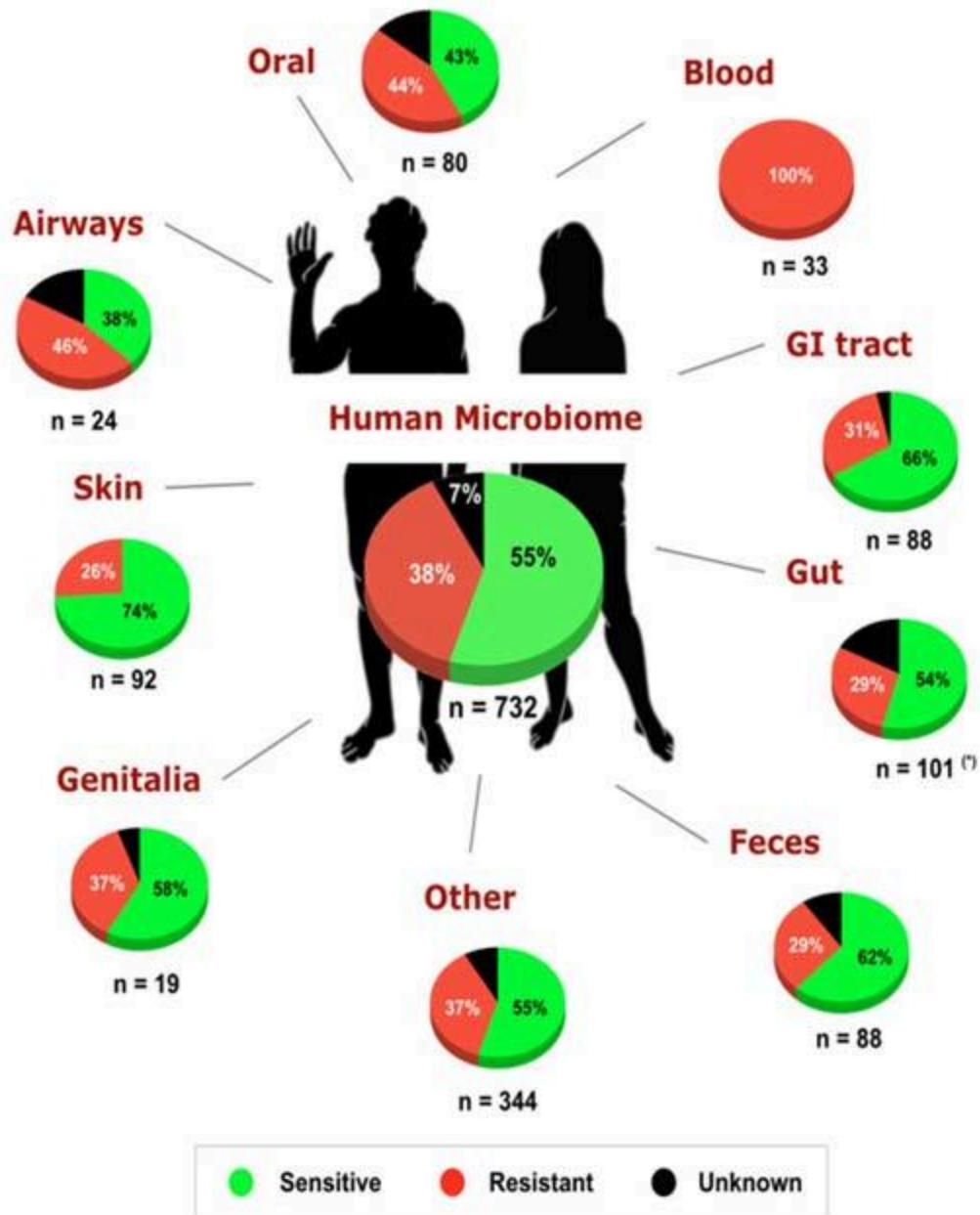
Changes in AGD, particularly during development, can indicate hormonal imbalances or disruptions caused by environmental exposures, such as pesticides or other chemicals. Additionally, treatment with Roundup delayed the onset of first estrus and was associated with elevated serum testosterone levels in adult rats.⁴⁸

Disrupts Gut Health

Regulatory agencies claim glyphosate is harmless to humans because we don't have the shikimate pathway that glyphosate targets. Well, the microbes in our gut contain this pathway! Oops! Humans are made up of approximately 30 trillion human cells and about 39 trillion microbial cells, meaning the microbes in our gut slightly outnumber our human cells.

Glyphosate targets the shikimate pathway by inhibiting the activity of a key enzyme in this pathway, 3-phosphoshikimate 1-carboxyvinyltransferase (EPSPS), which is present in many of the microbes in our gut, disrupting gut health and throwing off our natural gut balance.

Glyphosate-sensitive Class I EPSPS enzymes are found in all bacteria, but its impact varies significantly among species. The Human Microbiome Project found that 732 out of 941 bacteria species in our gut have at least one copy of the gene that glyphosate targets. This means that 55% of our gut bacteria are sensitive to glyphosate, 38% are resistant, and 7% are unclassified.⁴⁹



"Commensal bacteria (the 'good guys') appear to be more susceptible to glyphosate, as they are more likely to possess glyphosate-sensitive Class I EPSPS enzymes than potentially pathogenic bacteria, thereby promoting dysbiosis."

Beneficial bacteria are more likely to possess Class I EPSPS enzymes which makes them susceptible to dying off, and opportunistic pathogens in the gut are more likely to possess glyphosate-resistant Class II EPSPS enzymes, allowing them to thrive under glyphosate exposure.

In other words – glyphosate hinders the growth of beneficial gut bacteria while promoting the growth of pathogenic bacteria, leading to dysbiosis.

"Glyphosate residues on food could cause dysbiosis, given that opportunistic pathogens are more resistant to glyphosate compared to commensal bacteria."⁵⁰

Here, we evaluate the literature surrounding glyphosate's effects on the gut microbiome and conclude that glyphosate residues on food could cause dysbiosis, given that opportunistic pathogens are more resistant to glyphosate compared to commensal bacteria."⁵¹

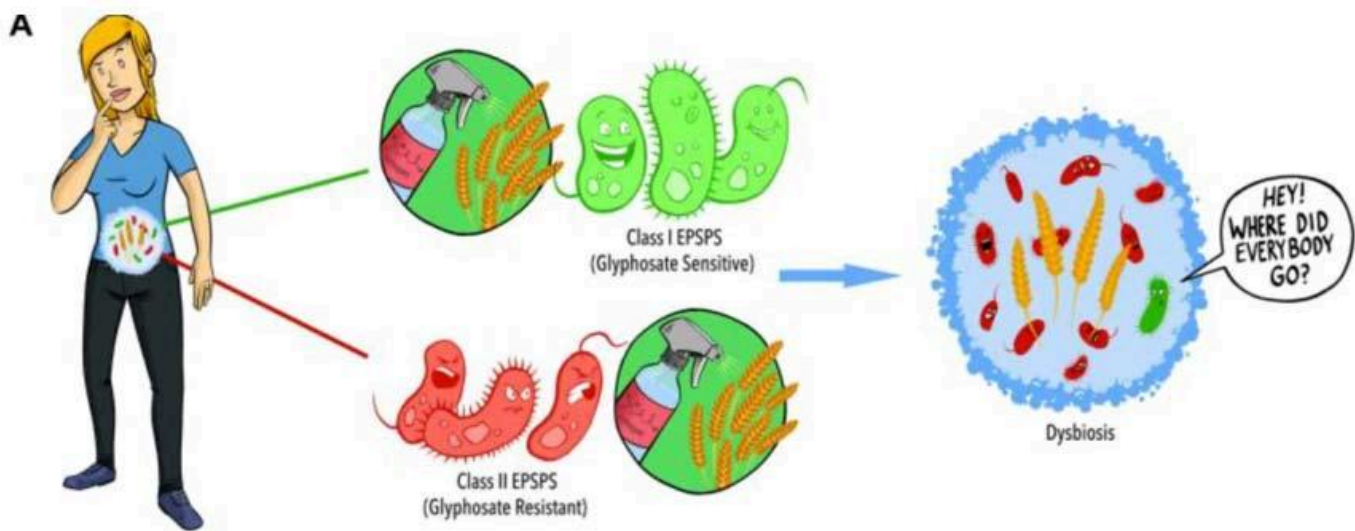


Image from: [Front Microbiol. 2020 Sep 25;11:556729](#)

Glyphosate is designed to kill weeds and microorganisms in the soil, but our digestive systems contain trillions of microorganisms. So yes, glyphosate and glyphosate-based herbicides negatively impact gut health^{52,53,54} by inducing inflammation⁵⁵ and causing dysbiosis.

This has negative systemic implications since gut health impacts the whole body including mood, brain function, and immunity. And unfortunately, this gut impact wasn't

really considered when the "safe" human intake standards were created.

Scientists frequently discuss how the negative gut impacts are not considered when "regulatory agencies" set the "acceptable daily intake" (ADI), which is determined by dividing the no-observed-effect-level (NOEL) by a safety factor.

"However, only direct glyphosate toxicity was considered when determining the NOEL. Alarmingly, glyphosate's influence over health through secondary means, such as the gut microbiome, was never considered. Given that the gut microbiome is critical for our overall health and disease susceptibility, glyphosate residues on wheat may contribute to dysbiosis, thereby affecting our overall health."⁵⁶

Compounding Impacts

Research suggests that the health risks associated with glyphosate exposure are even more pronounced when it comes to glyphosate-based herbicides (GBHs), or "Glyphosate-Based-Formulations (GBFs)," rather than pure glyphosate,^{57,58,59} likely due to the cumulative toxic effects of the additional chemicals involved.

While pure glyphosate is used in some cases, it is typically found as part of a GBH/GBF, where it is combined with other ingredients to enhance its ability to penetrate plant tissues more effectively.

For example — it has been shown that Roundup is more toxic than glyphosate alone.⁶⁰ Roundup includes the co-formulant polyethoxylated tallow amine (POEA) which has been demonstrated to have toxic effects.^{61,62}

The issue is further complicated by the proprietary nature of most of these GBHs/GBFs, where the ingredients and their relative proportions remain undisclosed. This lack of transparency poses a significant challenge for researchers, who are left in the dark about the specific components, their quantities, and the potential synergistic effects when these chemicals interact.

Adding to the concern, crops are often treated with a "cocktail" of agrochemicals in industrial ag, including other herbicides alongside GBHs. For example, research has shown that glyphosate's cytotoxic effects can intensify when combined with other herbicides, such as Paraquat.⁶³ This synergistic interaction suggests that even low levels of glyphosate residues in our food supply could have serious health consequences when combined with other widely used agrochemicals.

Alarming, this synergistic phenomenon has never been thoroughly studied, leaving a critical gap in our understanding of the full risks posed by these chemical concoctions.

Highest Sources

Glyphosate enters the human body through inhalation, ingestion, or contaminated food.⁶⁴ And as a systemic herbicide, it is deeply absorbed by plants and moves throughout, including the roots, stems, and fruits. This means glyphosate cannot be washed off produce and isn't broken down by cooking or heating.^{65,66}

So, the best strategy is to reduce exposure through mindful food sourcing when you can. Processed foods are the most likely source of glyphosate contamination, making it another compelling reason to reduce or eliminate their consumption!

Studies consistently show that switching to an organic diet (since glyphosate is not allowed in organic agriculture) or choosing foods that are tested to be low in glyphosate, dramatically reduce glyphosate levels in the body.^{67,68} In one study, an organic diet intervention reduced urinary glyphosate levels by 70.93% and its main metabolite AMPA by 76.71% within six days.⁶⁹ A diet higher in organic food is also associated with a reduced risk of cancer.⁷⁰

When it comes to grains, choosing organic (or knowing a chemical free, regeneratively grown source) is essential. Grains, including wheat, corn, soy, rice, oats, and beans, often contain the highest concentrations of pesticides since many are genetically modified (and thus sprayed throughout the season), and non-GMO grains are frequently

desiccated with glyphosate-based-herbicides before harvest, which increases pesticide residue.

The Environmental Working Group (EWG) routinely tests food for pesticides, and one of the highest sources tested are a common breakfast staple in many homes: Quaker Oatmeal Squares (since the oats are likely desiccated right before harvest).⁷¹ A light glyphosate bath on your breakfast cereal – yum!

For produce, aim to buy organic whenever possible, but try to prioritize sourcing organic for the "Dirty Dozen" to reduce your pesticide exposure – the 12 fruits and vegetables with the highest pesticide residues, according to the EWG's 2024 report,⁷² include strawberries, spinach, kale, collard greens, mustard greens, grapes, peaches, pears, nectarines, apples, peppers, cherries, blueberries, and lettuce.

When it comes to meat, eggs, and dairy, if you are buying these at the grocery store – organic is the best choice. Glyphosate accumulates in eggs^{73,74,75,76} and glyphosate is present in the meat of cattle and in the urine of cows that consume contaminated food.⁷⁷

But better yet is getting to know your local farmer. Not all farmers can afford the organic certification process, but many are committed to sustainable, chemical-free practices. And "organic" is not required for something to be chemical free. Instead, know your farmer and ask about their farming practices!

Supporting these farmers and farm cooperatives is a great way to make a positive impact on your health, the agricultural system as a whole, and the environment.

Conclusion

Regulatory agencies establish "tolerable limits" for glyphosate, but these limits overlook potential long-term and cumulative effects, fueling concerns about its safety in animal feed and the broader food chain. While some food samples may fall below the U.S. Environmental Protection Agency's (EPA) "allowable daily intake" (ADI) of 1.75 mg per kg of body weight, critics argue that this threshold is fundamentally flawed.

Plus, why is the U.S. limit nearly six times higher than the European Union's ADI of 0.3 mg per kg? Why does such a significant disparity exist?

The ADI fails to account for recent evidence linking glyphosate to probable carcinogenicity, its pervasive presence in food and water, the evidence of severe gut disruption, and its potential role as an endocrine disruptor, which could affect hormone levels differently across various stages of human development.

Additionally, safety tests were based only on isolated glyphosate, ignoring the compounded toxicity of commercial formulations containing other harmful chemicals. Compounding the risk, glyphosate residues from multiple food sources accumulate, amplifying exposure day to day.

In conclusion, the widespread presence of glyphosate in our bodies, combined with regulatory gaps and the herbicide's persistent nature in food, calls for urgent action. By being more mindful of our food choices, we can take meaningful steps to reduce exposure and protect our health from the potential long-term effects of this pervasive chemical.

Supporting food systems that do not rely on toxic pesticides is a crucial step toward shifting agriculture from the bottom up. You can make a difference by supporting organic and regenerative farmers.

Think of it as voting with your fork (or spoon) – you're essentially voting against the chemical-based conventional farming system!

Real, lasting change will likely not come from the top down, as Big Ag continues to profit from harmful practices. By empowering and supporting sustainable, pesticide-free farming, we can create a healthier future for future generations to come.

About the Author

Ashley Armstrong is passionate about helping others restore metabolic health and in creating an alternative food system low in PUFAs and low in toxic agrochemicals like

glyphosate.

Armstrong is the co-founder of [Angel Acres Egg Club](#), which specializes in low-PUFA (polyunsaturated fat) eggs that are shipped to all 50 states. Recent laboratory testing has confirmed that Angel Acres eggs are completely free of glyphosate!

This achievement reflects a commitment to quality and a unique partnership with row crop farmers who practice regenerative agriculture practices to produce the low-PUFA chicken feed ingredients and do not use agrochemicals.

Armstrong also co-founded [Nourish Food Club](#), which ships low-PUFA chicken, low-PUFA pork, beef, cheese, A2 dairy and traditional sourdough to all 50 states. While the egg club has memberships open, Nourish Food Club has a temporary waiting list.

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