Friends of the Earth

New Roundup, New Risks

Bayer's controversial weedkiller is more toxic than ever

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Acknowledgments

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I. INTRODUCTION

In 2021, with over 100,000 lawsuits pending from cancer victims who were exposed to glyphosate in Roundup weedkiller, Bayer announced it would remove glyphosate from Roundup sold to consumers starting in 2023.[1] We investigated to see if Bayer followed through with this promise. We found that, as of October 2024, not only is glyphosate-based Roundup still being sold to U.S. consumers, but the replacements for glyphosate in new residential Roundup formulations are dramatically more worrisome for our health and the environment. With no requirement from the Environmental Protection Agency (EPA) to warn consumers of the new dangers, people are unknowingly being exposed to higher risks.

The weedkiller Roundup was first commercialized fifty years ago by The Monsanto Company.[2] Over the next few decades, Roundup became a household brand used by millions of Americans for lawn and garden maintenance, and its main ingredient, glyphosate, became the most widely used – and lucrative – agricultural chemical in the history of the world.[3]

Roundup is now the product of German pharmaceutical and chemical company Bayer, which purchased Monsanto in 2018. Just weeks after the $63 billion deal closed, the first of several thousand lawsuits filed against Bayer over Roundup's link to a blood cancer called non-Hodgin's lymphoma (NHL) went to trial.[4] The jury not only found Bayer (Monsanto) responsible for the plaintiff's cancer, but it also found that the company "acted with malice" by failing to warn him of the dangers of Roundup.[5]

For decades, Monsanto aggressively marketed Roundup as "safe" and "non-toxic" despite evidence that exposure to glyphosate is associated with damage to DNA, elevated risk of cancer, and reproductive problems including low-birth weight, preterm delivery, and early-life neurodevelopmental disruption, among other serious health concerns.[6,7,8,9,10,11,12,13,14] Bayer has now been sued by over 165,000 people and has been forced to pay $16 billion to resolve Roundup-related cases.[15,16] While farmers and groundskeepers are among those who have sued, most plaintiffs are people who used Roundup around their homes and rural properties.[17] While farmers apply far more Roundup in any given year (approximately 90% of the total pounds applied),[i] most non-agricultural applications are made with small-scale, handheld equipment that leads to much higher exposures for applicators per hour of spraying or per area treated.

The Roundup trials unearthed a trove of internal corporate documents showing the profound extent of deceit and disinformation the company used to cover up the dangers of Roundup, deploying similar tactics to those used by Big Oil and Big Tobacco to keep harmful products on the market (see the report Merchants of Poison).[18]

At a time when the human toll of Roundup is more apparent than ever, and when transparency and honesty about the safety of the pesticide industry's products is called for, this report reveals a disturbing truth: **Bayer's reformulation of residential Roundup made it more toxic, and Bayer continues to mislead the public about Roundup's potential to harm people and the planet.**

i Note that Bayer only reformulated residential Roundup sold to consumers, not Roundup for agriculture or professional groundskeeping.

Key Findings

We analyzed labels to look for active ingredients in Roundup products sold at the two largest lawn and garden stores in the U.S., Lowe's and Home Depot, from June to October 2024. We wanted to determine two things.

First, whether Bayer has followed through on its public commitment to remove glyphosate from all Roundup products sold to U.S. home and garden consumers starting in 2023 – a commitment made in an attempt to restore investor confidence in the company and stop the deep and prolonged slide in its stock price associated with the lawsuits.[19]

Second, what ingredients Bayer has replaced glyphosate with, and whether they are safer for consumers and the environment.

Our analysis found that:

1. **Several Roundup products sold to consumers still contain glyphosate.** We identified seven Roundup products containing glyphosate for sale in 2024.

2. **New Roundup formulations are 45 times more toxic to human health**, on average, following chronic, long-term exposures. We identified eight Roundup products in which Bayer has replaced glyphosate with combinations of four different chemicals: diquat dibromide, fluazifop-P-butyl, triclopyr, and imazapic. All four chemicals pose greater risk of long-term and/or reproductive health problems than glyphosate, based on the EPA's evaluation of safety studies. Diquat dibromide - present in all the new formulations - is 200 times more chronically toxic than glyphosate, classified as a highly hazardous pesticide, and is banned in the EU. Imazapic is also banned in the EU.[20]

3. **New Roundup formulations pose significantly more harm to the environment.** On average, the chemicals replacing glyphosate in Roundup formulations are significantly more likely to harm bees, birds, fish, earthworms, and aquatic organisms. They are also significantly more persistent in the environment and more likely to leach down into groundwater, increasing the risk of contaminating waterways and drinking water.

In short, the new Roundup is not the old Roundup – it's worse. Consumers are unknowingly exposing themselves and the environment to higher risks. Bayer's failure to warn consumers about the new risks is negligent, unethical, and should be unlawful.

Smoke and mirrors: Bayer deceives the public and the EPA allows them to get away with it

Roundup is among the most prevalent options on store shelves for consumers seeking a weedkiller. While consumers are familiar with glyphosate-based Roundup, "Roundup" is now a diverse line of different pesticide products sold under the same brand name. The new formulations for lawn and garden applications are being sold with very similar packaging and instructions for use, making them easily confused with the original formulation (see Image 1).

Image 1. A new Roundup formulation with ingredients triclopyr, fluazifop-P-butyl, and diquat dibromide being sold next to a glyphosate-based formulation at Home Depot (10/1/24)

While pesticide active ingredients and their concentrations must, by law, be stated on product labels, the labels on new Roundup formulations are not required to (and don't) include language alerting consumers that the products now contain mixtures of different chemicals that pose markedly higher risks to people who handle and apply them. The average consumer – even if they read the small print on the label and notice the new ingredients – knows little about the physical and chemical properties, ecotoxicology, and mammalian toxicology of glyphosate compared to the alternate active ingredients that are taking its place. Consumers do not have the knowledge required to make an informed choice nor to alter how they use the product to minimize their exposures.

The U.S. Food and Drug Administration does not allow Bayer or other drug companies to replace the aspirin in a brand-name pain reliever with oxycontin or fentanyl, and for good reason. The EPA's Office of Pesticide Programs should adopt a similar policy, prohibiting companies from radically changing the active ingredients in brand name products like Roundup.

Furthermore, chemicals classified as highly hazardous present too many risks to be allowed in consumer products at all. A 2021 analysis of herbicide products sold by Home Depot and Lowe's found that half contained highly hazardous chemicals.[21] This is indicative of the ongoing failure of the EPA to adequately protect consumers and the environment from these chemicals.

Finally, the EPA only requires manufacturers to list active ingredients on pesticide labels, but formulations are a mix of active ingredients and so-called "inert" ingredients. Federal law allows pesticide manufacturers to hide the identity and concentration of inert ingredients as "Confidential Business Information." However, inert ingredients can have serious health implications.

Inert ingredients – also known as coformulants, surfactants, and adjuvants – are added to make the product more shelf-stable, increase its efficacy, hasten the movement of active ingredients into target organisms, and/or enhance a user's ability to mix the product with other pesticides or fertilizers. Inert ingredients can, and often do, make the overall products more toxic.[22,23] This is the case with Roundup. The surfactants in essentially all U.S.-sold Roundup brands dramatically increase the rate at which glyphosate moves through skin compared to glyphosate alone. As a result, glyphosate penetrates people's skin much more readily, increasing their exposure.[24]

II. RECOMMENDATIONS

Bayer's decision to impose a new set of risks on millions of Roundup users to bolster its stock price is unconscionable. And the Environmental Protection Agency's failure to ban harmful pesticides from consumer products, or at the very least require warning labels on products and clear directions to reduce exposures, is a public health catastrophe. It is yet another reminder of the deep flaws in federal pesticide law that allow pesticide registrants to keep dangerous products on the market.

Bayer

Bayer should invest in developing safer chemistries and sunset products like Roundup that contain chemicals linked to serious health harms. At the very minimum, given the major changes in the active ingredients in Roundup products, Bayer should:

- Switch to a new brand name so that consumers do not assume that their use of, and exposure to, the new "Roundup" will pose no more risks than exposure to the old Roundup.
- Add cautionary statements and warnings to new product labels alerting consumers to the specific higher risks associated with the new active ingredients and formulations.
- Educate consumers on the persistence of some of the new active ingredients and their toxicity to wildlife so that consumers can take necessary precautions to avoid harm to the environment.

Home & Garden Retailers

- Immediately remove all Roundup products from shelves and online sales.
    - At the minimum, ensure labels and point-of-purchase information on Roundup products accurately conveys the nature and levels of new risks.
- Aggressively work to phase out other hazardous pesticide products.
- Increase offerings of organic and other safer options.

Environmental Protection Agency

- Require warnings and cautionary language on all pesticide labels for ingredients associated with harm to human health, including DNA damage and cancer warnings on glyphosate-based Roundup and clear language on the risks posed by the new active ingredients in Roundup formulations.
- Prohibit companies from changing the active ingredients in brand name products without rebranding and informing consumers.
- In accordance with the best and latest science, prohibit the presence of chemicals in consumer products that can pose significant risks to human health and the environment.

Consumers

- Roundup – both glyphosate-based and non-glyphosate – should never be used by or near pregnant women.
- Choose non-chemical weed management options like mowing, using a weed whacker, mulching, or hand pulling weeds.
- Especially in households with children, choose least-toxic options for lawn and garden care if chemicals are used. Consumers seeking safer alternative herbicides and insecticides at home and garden stores can look for the Organic Materials Review Institute (OMRI) label. OMRI is an independent organization that reviews products against the strict requirements in federal organic standards. Consumers can trust that "OMRI-approved" means that a product is compatible with the National Organic Standards and is a far safer alternative than synthetic chemical herbicides. This is because the term "organic" is backed by a robust set of criteria governed by federal law under the National Organic Program at the United States Department of Agriculture (USDA). The list of herbicides and other pesticide products allowed in organic production is highly restricted to include only least-toxic ingredients derived primarily from natural (non-synthetic) sources.
- If chemicals are used, wear gloves, long-sleeve shirts, long pants, and shoes, and change and wash clothes once finished spraying to reduce dermal exposures.

III. BACKGROUND

In March 2015, the International Agency for Research on Cancer (IARC) announced its decision to classify glyphosate as a "probable" human carcinogen.[25] This triggered the beginning of an intensive, ongoing reassessment of Roundup and glyphosate-based herbicide (GBH) use, exposures, risks, and safety. It also led thousands of individuals to file lawsuits alleging that years of exposure to Roundup had caused their non-Hodgkin's lymphoma (NHL).

In the spring of 2018, the German chemical-pharmaceutical company Bayer was in the final stages of purchasing Monsanto. Bayer saw great value in Monsanto's seed and biotechnology assets, intellectual property, and other income streams, but especially Roundup – which is, and remains, by far the highest-selling and most profitable pesticide ever discovered. The acquisition closed on June 7th, 2018, with Bayer purchasing Monsanto for $63 billion in an all-cash deal.[26]

Just weeks later, the first Roundup-NHL trial began in San Francisco. The plaintiff was Dewayne "Lee" Johnson, a groundskeeper for a Northern California school district. His work included weed control across multiple school campuses, a task usually accomplished by spraying Roundup "(Ranger Pro)". The jury found Monsanto responsible for Lee Johnson's cancer and awarded him $39.25 million in compensatory damages and $250 million in punitive damages. After appeal, the punitive damage award was reduced to $39.25 million, for a total award of $78.5 million.[27]

Two other trials followed in California. The Hardeman case in federal court resulted in a jury award of $80.1 million on March 27, 2019, later reduced to $25.3 million.[28] On May 13, 2019, the Alva and Alberta Pilliod trial in state court resulted in a shocking jury punitive damage award of a combined $2 billion. The total damages awarded to the Pilliods by the jury were reduced to $86.7 million during the appeal process.[29]

When Bayer completed its acquisition of Monsanto in mid-2018, about 4,500 Roundup-NHL lawsuits were pending around the country. The success of plaintiffs in the first three trials received widespread news coverage. Heavy advertising by law firms soon followed in an effort to recruit new plaintiffs. The total number of cases shot upward rapidly, exceeding 100,000 by the end of 2019. In the spring of 2020, Bayer agreed to a settlement of more than $10 billion, impacting cases filed in the federal Multi-District Litigation (MDL) and resolving about 95,000 cases, leaving at least 30,000 still awaiting trial and/or future settlement agreements.[30]

In 2021, in response to investor concern, Bayer announced a five-point plan entitled "Managing the Roundup Litigation."[31] The plan included these actions:

1. Seek reversal – by the Supreme Court – of a long-standing legal precedent governing a pesticide manufacturer's responsibility when a legal use of a pesticide triggers economic damage or harms a person's health.
2. Aggressively defend existing Roundup-NHL cases.
3. Remove glyphosate from U.S. lawn and garden Roundup formulations beginning in 2023.
4. Put in place a claims process and formula to more quickly resolve future cases, and at lower total costs.
5. Promote a new product safety webpage designed to convince people that Roundup is safe.

This report focuses on the third point of Bayer's five-point plan. In a more detailed explanation of this point, Bayer stated:

"To further reduce future litigation risk, we have transitioned the manufacturing of our glyphosate products for the U.S. residential L&G [lawn and garden] market to new

formulations that have different active ingredients starting in 2023. We have taken this action exclusively to manage litigation risk and not because of any safety concerns. The vast majority of claims have come from residential L&G users, so this step largely eliminates the primary source of future claims. This action does not impact any of our glyphosate-based agriculture or professional products."[32]

Bayer hoped that pledging to reformulate lawn and garden Roundup products would reassure investors that far fewer new cases would be filed in the near future. But approximately 80,000 people are newly diagnosed with NHL each year in the U.S.,[33] and given the typical decade or more lag time between exposure to Roundup and development of NHL, many people who have been heavy and repeat users of lawn and garden Roundup products are likely to join the litigation over the next 10 to 20 years, at least. Future cases might also include other blood cancers and/or adverse reproductive outcomes associated with glyphosate-based Roundup.

Accordingly, any reduction in liability risk stemming from reformulation is unlikely to manifest for several years. And given that the new formulations for lawn and garden Roundup are far more toxic than the old formulations, liability risk may actually increase.

IV. FINDINGS

For this report, we analyzed Roundup products sold by Home Depot and Lowe's, both in stores and online, from June to October 2024. We assessed the human health and environmental risks of these products based on data and the risk assessment methods relied on by the EPA. See Appendix II – Methodology for more details.

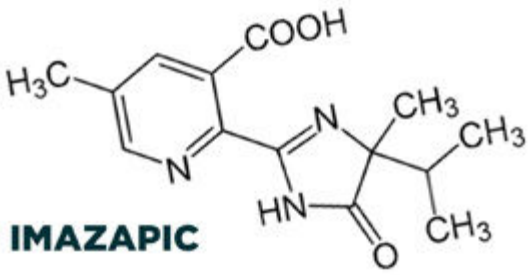
It is important to note that, while we depend on EPA data to compare toxicity, the EPA process for review and approval of pesticides is fundamentally flawed and not sufficiently protective of human health.[34,35,36] An emblematic example is the EPA's refusal to acknowledge the cancer risk posed by glyphosate despite available science and the findings of the World Health Organization International Agency for Research on Cancer, the world's premiere independent cancer research agency.[37,38,39] For more insight on the limitations of EPA assessment of pesticide toxicity, see Appendix II - Methodology.

Roundup Active Ingredients

We found seven glyphosate-based Roundup weedkillers and eight non-glyphosate Roundup weedkillers. These individual products are variations within product lines; they have slight differences in terms of chemical concentrations, size of bottle, and application options. The similarity across the sets of glyphosate-based and non-glyphosate products provided clear insight into the chemicals that Bayer is replacing glyphosate with. There were both glyphosate-based and non-glyphosate Roundup Weed & Grass Killers, and the same was true for Roundup Poison Ivy and Tough Brush Killers, as well as product lines offering "extended control" or "prevention of future weeds" (see Appendix Table 1).

In the non-glyphosate products, Bayer has replaced glyphosate with variations of four new active ingredients: diquat dibromide, fluazifop-P-butyl, triclopyr, and imazapic (see Table 1).

Note that the so-called "inert" ingredients in the products may differ – we cannot tell because federal law allows pesticide manufacturers to claim the identity and concentration of inert ingredients in a formulated pesticide as "Confidential Business Information" and hence, they are not subject to disclosure.



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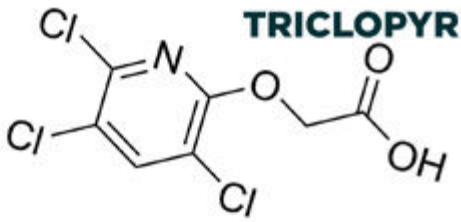

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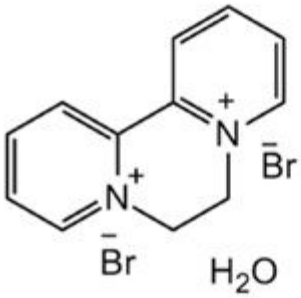
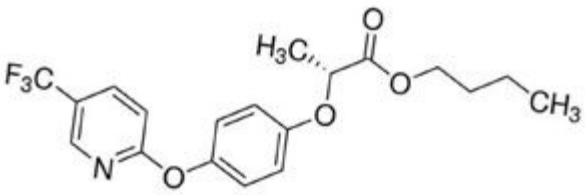


DIQUAT DIBROMIDE



FLUAZIFOP-P-BUTYL

Table 1. Active Ingredients Replacing Glyphosate in Roundup Lawn and Garden Products in 2024				
Product Lines and Products	**Diquat dibromide**	**Fluazifop-P-butyl**	**Triclopyr**	**Imazapic**
Roundup Weed & Grass Killer 4				
Roundup Weed & Grass Killer 4	X	X	X	
Roundup Weed & Grass Killer 4 Concentrate	X	X	X	
Roundup Dual Action				
Roundup Dual Action Weed & Grass Killer Concentrate	X	X	X	X
Roundup Dual Action Weed & Grass Killer Plus 4 Month Preventer	X	X	X	X
Roundup Dual Action Weed & Grass Killer Plus 4 Month Preventer Concentrate	X	X	X	X
Roundup Dual Action 365 Weed & Grass Killer Plus 12 Month Preventer Concentrate	X	X	X	X
Roundup Poison Ivy & Tough Brush				
Roundup Poison Ivy Plus Tough Brush Weedkiller 2	X	X	X	
Roundup Poison Ivy Plus Tough Brush Killer Concentrate	X	X	X	

Health and Environmental Risks of New Roundup Formulations

While it is concerning that glyphosate remains in Roundup lawn and garden products despite decades of harm, it is even more disturbing that the new formulations available to consumers pose increased risk to human health and to wildlife including birds, bees, and fish, as well as increased risk of leaching into groundwater.

1. Health Risks

Harms associated with Roundup active ingredients

Like most pesticides, the active ingredients in Roundup (inclusive of glyphosate) have been linked to a variety of harms to human health, including birth and developmental abnormalities; cancer; endocrine disruption; kidney or liver damage; stomach and GI tract toxicity; neurotoxicity; reproductive dysfunction; and irritation, inflammation, or allergic reactions affecting the skin, eyes, or respiratory system.[40] Each of the four new Roundup active ingredients are associated with more than one of these risks (see Appendix IV - Summary of Health Effects).

Comparison of toxicity

We found that all the new active ingredients in lawn and garden Roundup formulations pose a greater risk to human health than glyphosate. Table 2 compares the acute (short-term) and chronic (long-term) toxicity of glyphosate with the acute and chronic toxicity of the new active ingredients being used in Roundup products available to consumers. Note that for both measurements, the higher the number, the ***less*** toxic the pesticide is.

Diquat dibromide – present in all the new formulations – is twenty-seven times more acutely toxic and two hundred times more chronically toxic to humans than glyphosate. This stark increase in risk underscores why diquat dibromide is classified as a highly hazardous pesticide and why it should not be allowed in consumer products *at all*, let alone substituted for glyphosate without warning.

Understanding where the numbers come from

Acute toxicity expresses the risk of injury or death from a single short-term exposure. It is expressed as LD-50, or the lethal dose at which 50% of test animals succumb. For our analysis, we used the Hazard Dose 5% (HD5) from the **Pesticide Risk Tool** database. The HD5 is set at the lower 5% tail of the distribution of available LD-50 values. Chronic toxicity encompasses harm accumulated from long-term exposures to a chemical. The standard metric used in pesticide risk assessments is a chemical's chronic Reference Dose (cRfD)[ii] or in other countries, the chemical's Acceptable Daily Intake (ADI), a metric calculated in largely the same way as EPA-set cRfDs. For our analysis, we used cRfDs set by the US EPA, with the exception of imazapic's ADI, which was set by the European Food Safety Agency.

Table 2. Mammalian Toxicity of Glyphosate Compared to Alternative Active Ingredients in Roundup Lawn and Garden Formulations

Active Ingredient	Mammalian Toxicity Thresholds (mg/kg/day)			
	Acute Toxicity	Comparison to glyphosate	Chronic Toxicity	Comparison to glyphosate
Glyphosate, isopropylamine salt	1,365		1.0	
Imazapic, ammonium salt	1,279	1 time >	0.46	2.2 times >
Fluazifop-P-butyl	809	1.6 times >	0.0051	196 times >
Triclopyr, triethylamine salt	123	11 times >	0.05	20 times >
Diquat dibromide	50.3	27 times >	0.005	200 times >

Notes:
1. Acute mammalian toxicity is the Hazard Dose 5% (HD5) from the Pesticide Risk Tool database. The HD5 is set at the lower 5% tail of the distribution of available LD50 values.
2. Chronic RfDs are from the EPA with the exception of imazapic, which is an ADI from the European Food Safety Agency (EFSA).

To compare the health risks of the different Roundup formulations available to consumers accurately and fairly, we compared the acute and chronic toxicity of products according to (i.e. weighted by) the concentration of each active ingredient in a formulated product. The higher the concentration of an active ingredient in a formulation, the more weight placed on that active ingredient's acute and chronic toxicity in calculating the formulation's overall HD5 and cRfD (see Appendix II – Methodology).

We found that, on average, **the new formulations are 3.9-fold more acutely toxic and 45.6-fold more chronically toxic than the glyphosate-based Roundup formulations.** The significant increase in chronic toxicity is especially alarming, as consumers who habitually use Roundup are exposed over long periods of time, even decades – the definition of chronic exposure.

ii See https://www.epa.gov/iris/reference-dose-rfd-description-and-use-health-risk-assessments for a detailed explanation of how EPA sets cRfDs. In general, active ingredients with a cRfD at or above 0.1 mg/kg/day are regarded as relatively low risk, while active ingredients with a cRfD below 0.001 mg/kg/day pose concerns related to chronic, day-to-day exposure. A few pesticides have cRfDs below 0.0001 mg/kg/day and are regarded as extremely hazardous.

2. Environmental Risks

To compare potential risks to the environment, we looked at the toxicity of the active ingredients in Roundup formulations to standard target organisms used by the EPA: bees, birds, fish, crustaceans, algae, and earthworms. We also looked at the likelihood of the chemicals leaching into groundwater and how long they persist in the environment.

Even small amounts of these chemicals can harm non-target organisms like beneficial insects, aquatic life, and other wildlife in the surrounding environment when they leach into soil or water. They can disrupt ecosystem balance and potentially cause long-term environmental damage.

Harm to wildlife

We found that, on average, the new formulations pose significantly greater risks to biodiversity and ecosystem health than glyphosate-based Roundup. Both glyphosate-based Roundup and the new formulations are associated with negative impacts on birds, bees, aquatic organisms and fish, and soil organisms including earthworms. This represents widespread harm to biodiversity and threatens the health and integrity of the ecosystems that humans inherently depend on for our existence. Roundup sprayed in urban and suburban areas is just as prone as Roundup sprayed on farms to be washed away by rain into drains and small streams and to eventually find its way into larger rivers headed to coastal areas and the ocean.

Table 3 compares the ecotoxicity profile of the new active ingredients in Roundup formulations to glyphosate (see Appendix Table 3 for original data). What emerges is that diquat dibromide, fluazifop-P-butyl, and triclopyr – present in all the new formulations we identified – pose significantly more harm to aquatic organisms and earthworms than glyphosate. Diquat dibromide also poses greater harm to birds and bees.[iii]

Table 3. Toxicity to Target Organisms of Active Ingredients Replacing Glyphosate in Roundup Lawn and Garden Formulations

	Bees		Birds		Fish		Crustacean	Algae growth	Earthwarms
	Oral	Contact	Acute	Chronic	Acute	Chronic	Acute		
Glyphosate	100 ug/bee	100 ug/bee	232 HD5 mg/kg	1.28 mg/kg/day	1587 HC5 ug/L	42.7 MATC ug/L	4643 HC5 ug/L	507 HC5 ug/L	5000 geomean of LC50 ug/g
Diquat dibromide	4.5 times >	1.5 times >	13 times >	18 times >	2 times <	2 times <	57 times >	63 times >	33 times >
Fluazifop-P-butyl	2 times <	2 times <	1.5 times <	Insufficient data	7 times >	8.6 times >	11 times >	6 times >	5 times >
Triclopyr	Insufficient data	Similar	1.4 times >	Similar	5.8 times >	6.8 times >	22 times >	7 times >	Insufficient data
Imazapic	Insufficient data	Similar	Similar	8.7 times <	10.5 times <	10.3 times <	1.3 times <	144 times >	Insufficient data

iii Results from the Pesticide Risk Tool from the website https://pesticiderisk.org/.

Groundwater leaching & soil persistence

We found that, on average, the new active ingredients in Roundup formulations are more likely to leach into groundwater and to persist in the soil for longer periods of time than glyphosate.

Scientists measure a pesticide's likelihood to move through the soil and leach into groundwater via the GUS index (Groundwater Ubiquity Score). Another important environmental property of pesticides is their persistence, or how long they remain in the soil or environment after they are applied. Scientists measure this in terms of a chemical's half-life. A half-life is the time it takes for a chemical to break down to the point where the remaining concentration is one-half the initial level.

Of the new active ingredients in Roundup, imazapic and triclopyr raise the most concern in terms of groundwater leaching. Both are more likely to contaminate drinking water, which is problematic because they are both more toxic to human health. Glyphosate is rated as having "low" potential to leach into groundwater, while imazapic and triclopyr are rated as having "high" potential. Imazapic's GUS index value is twenty times higher than that of glyphosate and triclopyr's is eighteen times higher. Imazapic is thirty-six times more persistent in soil while triclopyr is close to five times more persistent. Their increased likelihood to leach into groundwater is concerning given that imazapic is 2.2 times more chronically toxic to human health than glyphosate, while triclopyr is 20 times more chronically toxic.

Diquat dibromide has a very low GUS index value. However, unlike glyphosate, it is very persistent in soil, with an estimated half-life of 5,500 days – ***over 15 years*** – compared to 6.5 days in the case of glyphosate. As a result, when used repeatedly (e.g., a few times a year), levels of diquat dibromide in soil can incrementally rise over time. In such a scenario, soil organisms would be subjected to repeated long-term exposure to the chemical, undermining soil health, and by extension, undermining overall ecosystem function.

Fluazifop-P-butyl has a low GUS index value, and so poses little threat to groundwater. It dissipates rapidly in soil with a half-life of around 8 days, comparable to glyphosate.

Table 4. Persistence and Leaching Potential of Active Ingredients Replacing Glyphosate in Roundup Lawn and Garden Formulations

	GUS Index	Potential to move in groundwater	Soil persistence
Glyphosate, isopropylamine salt	0.193	Low	6.5
Diquat dibromide	-7.88	Very low	5,500
Fluazifop-P-butyl	0	Low	8.2
Imazapic, ammonium salt	3.87	High	232
Triclopyr, triethylamine salt	3.67	High	30*

Notes:
The GUS index (Groundwater Ubiquity Score) measures the likelihood of a chemical to move through the soil and leach into groundwater. Soil persistence is measured as DT50 field values - how long it takes for half of a chemical to degrade in the soil in field conditions.
* Result for triclopyr, another chemical form of the active ingredient

V. CONCLUSION

It took decades of advocacy and tens of thousands of lawsuits to convince Bayer that Roundup needed to be reformulated. Bayer's 2021 pledge to remove glyphosate from lawn and garden formulations initially seemed like a hard-won victory for health, safety, and the environment. But instead, the new Roundup is far more toxic than the products it is replacing.

Rather than playing out as a victory, this report reveals that it is an emblematic case of regrettable substitution – a chemical being banned or discarded in favor of ones that are even worse. Regrettable substitution underscores the need for lawmakers, regulatory agencies, and advocates to move beyond targeting single chemicals in isolation and instead pursue holistic social and political reform around the production, distribution, and use of chemicals.

The findings of this report also underscore that Bayer, like other chemical companies, cannot be trusted to protect consumer health. While this report focuses on consumer Roundup, the same is true in the agricultural sector where pesticide companies continue to aggressively market and thwart regulation of scores of hazardous pesticides. The fundamental goal of chemical companies is to sell chemicals. There is nothing in the fifty-year history of Roundup that indicates that Bayer-Monsanto is willing to forego higher sales and profits to make its products more assuredly safe. Nor has Bayer-Monsanto been willing to give consumers the information they need to use Roundup as safely as possible. It is essential that lawmakers and regulatory agencies – including a strengthened EPA – take responsibility for ensuring that people and ecosystems are safeguarded against toxic chemicals and the unethical activities of the companies that manufacture them.

APPENDIX

Appendix I. Roundup Brand Products for Sale at Lowe's and Home Depot in 2024 – In Store and Online

We found seven glyphosate-based Roundup products and eight non-glyphosate Roundup products for sale at Lowe's and Home Depot in 2024. These individual products are grouped by product line with slight variations in terms of chemical concentrations, size of bottle, and application options. Note that there are similar sets of product lines across glyphosate and non-glyphosate options: Roundup Weed & Grass Killers, Roundup Poison Ivy and Tough Brush Killers, and product lines offering "extended control" or "prevention of future weeds."

Since Monsanto, and now Bayer, have long capitalized on the popularity of the Roundup brand name, "Roundup" encompasses an array of different products. Some of this "brand extension" has included non-glyphosate products, such as Roundup for Lawns (glyphosate would kill lawn grass, hence a different combination of active ingredients is used in these products) and even Roundup brand insecticides (glyphosate is an herbicide, not an insecticide). We excluded these products from the analysis, as our goal was to compare the toxicity of glyphosate-based Roundup weedkillers with the new non-glyphosate weedkillers being marketed as Roundup. We also excluded regional products that were permutations on other formulations – Roundup formulations can vary slightly by region to match different weed pressures.

Appendix Table 1. Roundup Brand Products for Sale at Lowe's and Home Depot in 2024 - In Store and Online

Glyphosate-Based Products		Non-Glyphosate Products	
Roundup Weed & Grass Killer III		**Roundup Weed & Grass Killer 4**	
Roundup Ready-to-Use Weed & Grass Killer III	Glyphosate, isopropylamine salt, 2.0% Pelargonic acids and related fatty acids, 2.0%	Roundup Ready-to-Use Weed & Grass Killer 4	Triclopyr, triethylamine salt, 0.122% Fluazifop-P-butyl (ISO), 0.097% Diquat dibromide, 0.073%
Roundup Weed & Grass Killer Concentrate Plus	Glypohsate, isopropylamine salt, 18% Diquat dibromide, 0.73%	Roundup Weed & Grass Killer 4 Concentrate	Triclopyr, triethylamine salt, 2.50% Fluazifop-P-butyl (ISO), 2.00% Diquat dibromide, 1.50%
Roundup Super Concentrate Weed & Grass Killer	Glyphosate, isopropylamine salt, 50.2%		
Roundup Poison Ivy & Tough Brush		**Roundup Poison Ivy & Tough Brush**	
Roundup Poison Ivy Plus Tough Brush Killer Concentrate	Glyphosate, isopropylamine salt, 18% Triclopyr, triethylamine salt, 2%	Roundup Poison Ivy Plus Tough Brush Weedkiller 2	Triclopyr, triethylamine salt, 0.122% Fluazifop-P-butyl (ISO), 0.097% Diquat dibromide, 0.073%
Roundup Ready-to-Use Poison Ivy Plus Tough Brush Killer	Glyphosate, isopropylamine salt, 1.0% Triclopyr, triethylamine salt, 0.1%	Roundup Poison Ivy Plus Tough Brush Killer Concentrate	Triclopyr, triethylamine salt, 2.50% Fluazifop-P-butyl (ISO), 2.00% Diquat dibromide, 1.50%
Roundup Max Control / Extended Control		**Roundup Dual Action / Weed Preventer**	
Roundup Max Control 365 Concentrate	Glyphosate, isopropylamine salt, 18% Immazapic, ammonium salt, 1.6% Diquat dibromide, 0.73%	Roundup Dual Action Weed & Grass Killer Concentrate	Triclopyr, triethylamine salt, 2.50% Fluazifop-P-butyl (ISO), 2.00% Imazapic, ammonium salt, 1.60% Diquat dibromide, 1.50%

Roundup Extended Control Weed & Grass Killer Plus Weed Preventer Concentrate	Glyphosate, Isopropylamine salt, 18% Diquat dibromide, 0.73% Imazapic, ammonium salt, 0.3%	Roundup Dual Action Weed & Grass Killer Plus 4 Month Preventer	Triclopyr, triethylamine salt, 0.122% Fluazifop-P-butyl (ISO), 0.097% Imazapic, ammonium salt, 0.078% Diquat dibromide, 0.073%
		Roundup Dual Action Weed & Grass Killer Plus 4 Month Preventer Concentrate	Triclopyr, triethylamine salt, 2.5% Fluazifop-P-butyl (ISO), 2.0% Diquat dibromide, 1.5% Imazapic, ammonium salt, 0.3%
		Roundup Dual Action 365 Weed & Grass Killer Plus 12 Month Preventer Concentrate	Triclopyr, triethylamine salt, 2.50% Fluazifop-P-butyl (ISO), 2.00% Imazapic, ammonium salt, 1.60% Diquat dibromide, 1.50%

Appendix II. Methodology

We identified Roundup products for sale at Lowe's and Home Depot stores in California and Maryland as well as online from June to October 2024 (see Appendix Table 1).

We then grouped these by primary formulation – combinations and concentrations of different active ingredients. We found six primary glyphosate-based formulations and three primary non-glyphosate formulations sold as Roundup (see Appendix Table 2). Note that formulations with the same active ingredients are sold under different product names. Also note that the inert ingredients in the products may differ – we cannot tell because federal law allows pesticide manufacturers to claim the identity and concentration of inert ingredients in a formulated pesticide as "Confidential Business Information," and hence they are not subject to disclosure.

Appendix Table 2. Active Ingredients Grouped by Primary Roundup Formulations for Sale at Lowe's and Home Depot in 2024

Active Ingredients	Glyphosate-Based Formulations						Non-Glyphosate Formula-		
	#1	#2	#3	#4	#5	#6	#1	#2	#3
Glyphosate, isopropylamine salt	18%	18%	2%	50%	18%	18%			
Diquat dibromide	0.73%				0.73%	0.73%	1.5%	1.5%	1.5%
Fluazifop-P-butyl							2.0%	2.0%	2.0%
Imazapic, ammonium salt					1.6%	0.3%	1.6%	0.3%	
Pelargonic acid			2%						
Triclopyr, triethylamine salt		2.0%					2.5%	2.5%	2.5%
Representative Products									
	Roundup Weed & Grass Killer Concentrate Plus	Roundup Concentrate Poison Ivy Plus Tough Brush Killer	Roundup Ready-to-Use Weed & Grass Killer III	Roundup Super Concentrate Weed & Grass Killer	Roundup Max Control 365 Concentrate	Roundup Concentrate Extended Control Weed & Grass Killer Plus Weed Preventer	Roundup Dual Action Weed & Grass Killer Concentrate	Roundup Dual Action Weed & Grass Killer Plus 4 Month Preventer Concentrate	Roundup Poison Ivy Plus Tough Brush Killer Concentrate*

*Same formulation as Roundup Weed & Grass Killer Concentrate 4

We calculated the weighted average acute and chronic toxicity of each of the formulations taking account of the concentrations of each active ingredient in an overall formulation. The weights assigned to each active ingredient used to calculate a formulated product's acute and chronic toxicity add up to one. For example, the weights corresponding to the 2% concentration of glyphosate and 2% of pelargonic acid in "Roundup Ready-to-Use Weed & Grass Killer III" were 0.5 and 0.5 (the concentration of each active ingredient in the product divided by the total concentration of both active ingredients, or 2%/4%, which equals 0.5).

Next, we calculated the weighted average acute and chronic toxicity by multiplying the weights for each active ingredient in a formulation by the LD-50 and cRfD of the active ingredient. (Note that the higher the value of an LD-50 or cRfD, the *less* toxic the chemical is.) We then added the results together, creating the formulation's acute/chronic toxicity weighted by the relative shares of each active ingredient in a formulation relative to the total amount of active ingredient in the formulation.

Last, we calculated average LD-50 and cRfD across the six glyphosate-based and three non-glyphosate formulation groups. We divided the average acute toxicity for the glyphosate-based group by the average acute toxicity in the non-glyphosate group to find the difference in average acute toxicity, and we repeated this step for chronic toxicity.

Concentrate vs Ready-to-Use Formulations

Roundup products are typically sold as dilute Ready-to-Use (RTU) or as concentrate formulations. The labels on all concentrated Roundup products call for the applicator to mix the concentrate with water to produce a more dilute spray solution that is comparable in the concentration of its active ingredients to the corresponding RTU product.

The amount of each active ingredient in RTU Roundup formulations is generally lower than the concentrate products by a constant amount, usually 20-fold. We used concentrate formulas in the calculations described above.

However, if we calculated the weighted average LD-50 and cRfD for the corresponding RTU formulation, the results would be the same. In addition, the active ingredients in a RTU formulation are supposed to be applied at the same rate of active ingredient per area treated as the concentrated product after it is mixed with, for example, 20-parts of water for each part of concentrate.

Real-world exposures and risks may vary

While we used standard LD-50 and cRfD values, assessing an applicator's real-world exposures and risk across products would depend on many variables including the clothing worn by the applicator, the application equipment used and whether it leaks, wind conditions, and whether the applicator wore gloves or other Personal Protective Equipment. When spray solution permeates clothing, dermal exposure rises sharply and can continue for several hours after completion of spraying, unless the applicator changes clothes.

The basic application-rate direction on lawn and garden Roundup product labels is to "thoroughly wet" the leaves on weeds. Assuming applicators follow the directions for mixing a concentrated product with water and interpret "thoroughly wet" in the same way, applicators would spray roughly the same amount of active ingredient in a given area. In reality, applicators may apply widely different amounts for a variety of reasons.

Limitations of EPA's approach to setting chronic Reference Doses

Our analysis of the toxicity of active ingredients in new and old Roundup is based on EPA's assessment of the chronic toxicity of pesticide active ingredients. This assessment leads to the setting of a pesticide's chronic Reference Dose (cRfD). Although there are limitations inherent in this approach discussed below, cRfDs are the only widely accepted measure of chronic toxicity that is available to compare pesticide active ingredients.

One limitation is that cRfDs reflect the chronic toxicity of single active ingredients, yet people who apply Roundup or other pesticide

products are exposed to whole formulations which include surfactants and adjuvants. Such added ingredients are considered by EPA as "inert ingredients" even though they often make pesticide products more toxic and/or change the physical and chemical properties of the formulated product in ways that increase human or environmental risk. For example, in the case of glyphosate-based Roundup, the inert ingredients make the formulation more toxic than glyphosate alone and increase the rate at which glyphosate moves through human skin, increasing exposure.

Another limitation is that a pesticide's cRfD is based on one specific adverse effect observed in an animal toxicology study. But some pesticides are known to increase the risk of several different adverse health outcomes impacting different key systems in the body (e.g., immune, reproductive, metabolic, the microbiome, kidney function). The levels at which cRfDs are set do not account for the number of adverse effects known to arise from exposure to an active ingredient, the severity of the adverse effect (e.g., life-threatening damage to the liver versus a period of slower growth among young animals), nor the reversibility of an adverse effect (weight gain or loss versus permanent loss of kidney function).

Another limitation is that the EPA typically does not consider data on whether a pesticide damages DNA or increases cancer risk when setting chronic RfDs. The evaluation of chronic toxicity and cancer risk are separate analyses. Plus, the methods used by EPA and other regulators to quantify cancer risk from data generated in rodent cancer bioassays are imperfect. Subjective judgements often must be made in interpreting cancer bioassay study results that can lead to disagreements among scientists about whether a pesticide poses oncogenic risk, and if so, at what level of exposure.

This is the case with glyphosate and glyphosate-based herbicides (GBHs). The EPA's Office of Pesticide Programs (OPP), which sets cRfDs, currently classifies glyphosate as "not likely" to pose cancer risk, whereas the WHO's International Agency for Research on Cancer (IARC) classifies glyphosate and GBHs as "probable" human carcinogens. Scientists in the EPA's Office of Research and Development (ORD) also concluded that glyphosate should be classified as a "possible" or "probable" carcinogen considering available data and the EPA's cancer risk assessment guidelines. To understand how and why IARC and the EPA's ORD reached different conclusions on the oncogenicity of glyphosate and GBHs than the EPA's Office of Pesticide Programs, see Benbrook, 2019. In brief, IARC and EPA's ORD placed substantial weight on toxicology research in both humans and animal studies focused on the health impacts of formulated GBH products, whereas the EPA's OPP focused on pesticide-registrant-commissioned toxicology studies testing the impacts of pure glyphosate in just animal studies.

A thorough assessment of the different health risks stemming from exposures to glyphosate versus the replacement active ingredients in new Roundup lawn and garden formulations is constrained by the lack of comprehensive research on all potential health impacts of the chemicals, alone and especially in combination, as well as a lack of publicly accessible data and standardized comparisons.

Note that, while the public conversation – and lawsuits - on the toxicity of Roundup is focused on increased risk cancer among applicators, evidence is mounting that exposure to glyphosate is associated with heightened risk of a range of adverse health outcomes among applicators ***and the general public***. These include: increased risk of metabolic syndrome, damage to DNA, kidney and liver disease, preterm birth, low birth weight, neurodevelopmental problems, GI tract issues, and disruption of the gut microbiome.

Emerging science on glyphosate and GBHs drives home a key point – different people face varying levels of different adverse health risks depending on when they are exposed, how they are exposed, levels of exposure, and how often and for how long they are exposed. Unfortunately, the way the EPA sets chronic RfDs does not take these factors into account.

Appendix III. Ecological Toxicity Data

Appendix Table 3. Ecological Toxicity of Glyphosate and Alternative Active Ingredients in Lawn and Garden Roundup Formulations

Active Ingredient	Pollinators		Birds		Fish and Aquatic Organisms			Algae	Earth-worms
	Oral (ug/bee)	Contact (ug/bee)	Acute HD5 (mg/kg)	Chronic tox (mg/kg/day)	Fish acute HC5 (ug/L)	Fish chronic MATC (ug/L)	Crustacean acute HC5 (ug/L)		
Glyphosate, isopropylamine salt	100	100	232	1.28	1587	42.7	4643	507	5000
Diquat dibromide	21.6	64	17.8	0.07	3021	86.7	81.3	8.07	152
Fluazifop-P-butyl	200	200	340		225	4.98	409	81.3	1000
Imazapic		100	224	11.2	16799	439	6204	3.52	
Triclopyr, triethylamine salt		100	164	1.41	276	6.23	208	71.1	

Source: Pesticide Risk Tool, https://pesticiderisk.org/

Appendix IV: Summary of Health Effects

Assessment of the health impacts associated with pesticide exposure are drawn primarily from animal studies and studies of highly exposed populations, such as farmworkers or rural communities. For health impacts not listed below, such as endocrine disruption, metabolic effects, and disruption of the gut microbiome, impacts are often insufficiently studied. Thus, lack of a particular health effect in the chart below does not indicate conclusive evidence that it is not a potential concern.

Appendix Table 4: Summary of Health Effects Associated with Alternative Active Ingredients in Lawn and Garden Roundup

	Diquat dibromide	Triclopyr	Fluazifop-P-butyl	Imazapic
Reproductive Effects	X	X	X	
Developmental / Birth Defects	X	X	X	
Kidney / Liver Damage	X	X	X	X
Neurotoxicity	X*	X*		
Sensitizer / Irritant	X	X		X
Other	X[1]			X[2]

* Research indicates potential neurotoxicity, more research required
1 Cataracts
2 Musculoskeletal/Hematological

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