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The Trials of Glyphosate: Decades-Old Chemical in Weedkillers Faces Increasing Scrutiny

Glyphosate, the active ingredient in the world's most widely applied herbicides, is found in a wide range of weed-killing products, such as Roundup and Touchdown. The controversial herbicide, marketed to home gardeners, land managers and farmers, is beset by lawsuits and a growing list of questions about its effects on human health and the environment.

A closely-watched lawsuit against German pharmaceutical giant Bayer, which acquired Roundup maker Monsanto for \$63 billion last fall, will proceed to a second phase after the jury determined there's a credible link between the weedkiller and the plaintiff's non-Hodgkin lymphoma diagnosis — the company's liability and possible damages will be determined during the second phase.

The verdict from the U.S. District Court for the Northern District of California is a setback for Bayer. The trial — the first federal trial to consider the argument that Roundup causes cancer — is the second of more than 11,000 Roundup cases set to go to trial in the United States. Bayer, which cites decades of studies and data that has shown the product to be safe, denies allegations that Roundup causes cancer.

The Rise of Glyphosate: Usage, Health Studies and Evaluations

MILLIONS OF POUNDS OF ACTIVE INGREDIENT APPLIED IN THE U.S.

The benefits of glyphosate

Monsanto (now owned by Bayer) says glyphosate has low toxicity and is environmentally friendly, allowing crops to be grown using no-till methods that retain nutrients and sediments, improve soil health and reduce carbon emissions. The company says no other pesticide has been more extensively tested, and that glyphosate does not persist in the environment, does not bioaccumulate and is neither mutagenic nor carcinogenic.

1974:

Developed by Monsanto, glyphosate is introduced to the market as Roundup.

1985:

EPA determines glyphosate "possibly carcinogenic to humans," basing the decision on a study revealing tumors in mice.

1991:

EPA re-evaluates mouse study, changing its classification of glyphosate to "evidence of non-carcinogenicity in humans."

20 ppm limit

EPA limits on glyphosate residues in oats in parts per million

TOTAL USE

276.4

26.5 NON-AG

249.9 AGRICULTURAL

GAO
FDA

2016
Under pressure from GAO, FDA begins testing for glyphosate residue in corn, soybeans, milk and eggs.

A study of prevalence and concentration in people

Over a 20-year period, a University of California San Diego Health study tracked glyphosate and its metabolite AMPA in the urine of elderly people in the Southern California suburb of Rancho Bernardo, revealing a rise in prevalence and concentration in one population.

1993-96 PREVALENCE

12% prevalent

0.20 µg/L

5%

0.17 µg/L

AVERAGE CONCENTRATION IN THOSE WITH DETECTABLE AMOUNTS, IN µg/L

Area of circle in proportion with concentration

● Glyphosate ● AMPA

AVERAGE CONCENTRATION IN URINE

2013-16 PREVALENCE

70%

0.45 µg/L

71%

0.40 µg/L

An association with shorter pregnancies?

In 2018, scientists* found that higher glyphosate levels were significantly associated with shortened gestational periods in women from Central Indiana tested in 2015-2016.

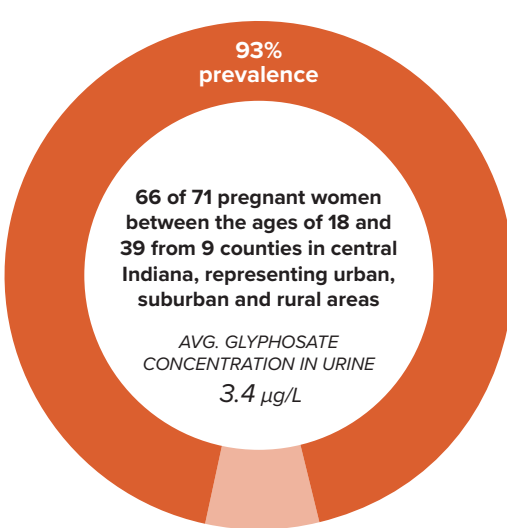
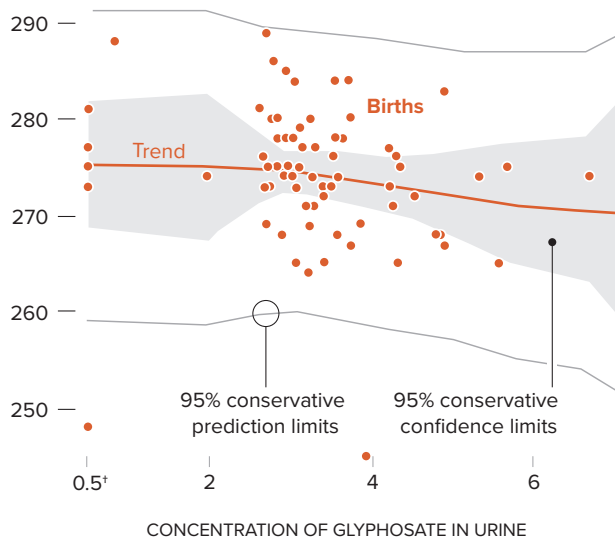
More than 90 percent of the women tested were Caucasian. None of their drinking water samples had detectable levels of glyphosate. Higher glyphosate levels were found in women living in rural areas, who consumed more than 24 ounces of caffeinated beverages per day.

The authors caution that "further investigations in a more geographically and racially diverse cohort would be necessary before these findings could be generalized."

*Indiana University Fairbanks School of Public Health, University of California San Francisco, Franciscan Health in Indianapolis and Indiana University School of Medicine; published in the journal Environmental Health

LENGTH OF PREGNANCY, IN DAYS

$r = -0.30, p = 0.01$



Residues in food

Farmers sometimes apply GBH to food crops, such as oats and wheat, at the end of the growing season to dry them out before harvest, which can increase dietary exposure to the chemicals, depending on the crop.

A 2017 **EPA** analysis calculated that children ages 1-2 had the highest daily exposure to glyphosate residues in food (0.23 mg/kg/day), much higher than California's "No Significant Risk Level," but well below EPA's maximum exposure level.

Tests commissioned by the **Environmental Working Group** revealed the presence of glyphosate in more than 95 percent of oat-based cereals and granola bars marketed to children, and in all of wheat-based foods tested. An earlier EWG test also found glyphosate in 31 percent of oat products that were grown organically, but those had residues at much lower levels than in conventionally grown products.

Levels of exposure

IN MILLIGRAMS PER KILOGRAM OF BODYWEIGHT PER DAY

EPA reference dose: 1.75

Amount EPA determines a person can be exposed to daily with no appreciable risk of adverse health effects.

0.016 California's NSRL (**1.1 milligrams per day**, assuming for a 70 kg person)

0.47 EPA estimate of child exposure (via diet, sprayed lawns, hand-to-mouth behavior)

0.50 EU acceptable daily intake

EPA estimate of maximum occupational exposure 7

Cancer

Nearly all regulatory agencies say glyphosate is safe when used as directed.

2015: The **World Health Organization's International Agency for Research on Cancer** classified glyphosate as "probably carcinogenic," noting a positive association with non-Hodgkin lymphoma, or NHL. Based on that finding, California's Office of Environmental Health Hazard Assessment in 2017 classified glyphosate as "known to cause cancer," setting minimum risk levels for exposure.

2017: Evaluation of the cancer-causing potential of glyphosate, **EPA** concluded that the animal studies they reviewed were "remarkably consistent" in demonstrating no clear association between glyphosate exposure and cancer. In their review of human epidemiological studies, EPA found no evidence of an association with cancer, but that the risk of NHL could not be determined based on available data.

2018: A jury awarded a school groundskeeper with NHL \$289 million in damages after finding that Monsanto failed to adequately warn of the weed killer's cancer risks. Since the verdict, more than 11,000 similar lawsuits have been brought against the company.

2019: In a meta-analysis of studies on exposure to glyphosate-base herbicide, or GBH, five scientists — three of whom served on EPA's science review board evaluating glyphosate in 2016 — reported, "GBH exposure is associated with increased risk of NHL in humans." The analysis (Mutation Research-Reviews in Mutation Research) found that heavy exposure increases incidences of NHL by 41 percent.

RISK OF DEVELOPING NHL

2.0%

General population

2.8%

Heavy GBH exposure

Undisclosed ingredients

Additives used in GBH can be much more toxic and disruptive to endocrine systems than "active ingredient" glyphosate, according to a 2017 study published in Toxicology Reports. But herbicide manufacturers in the U.S. are not required by **EPA** to disclose the identity of "other ingredients," which can also include surfactants, antifreeze, antifoaming agents and solvents, and amount to 59 to 96 percent of the formulation, depending on the product.

Soil health

Glyphosate clings to soil particles, reducing the possibility of it leaching into surface water. The chemical breaks down through bacterial action in 4 to 180 days.

A 2012 review of numerous studies (Journal of Agriculture and Food Chemistry) found that GBH do not affect mineral nutrition in crops and do not increase crop diseases.

A 2008 study published in Pest Management Science found minor effects on soil biological/chemical properties, concluding that enhanced organic carbon and plant residues in surface soils resulting from no-till practices might "buffer any potential effects of glyphosate." Other studies have found that GBH can negatively affect some earthworm species (Nature: Scientific Reports) and suppress mycorrhizae fungi, which help plants absorb nutrients (Science of the Total Environment).

Effects on wild fauna

The **National Pesticide Information Center** says the toxicity of GBH greatly depends on the formulation, but glyphosate itself is non-toxic or mildly toxic to freshwater invertebrates, fish and amphibians, and that the risks posed to birds and other wildlife are mostly from alterations to their habitats.

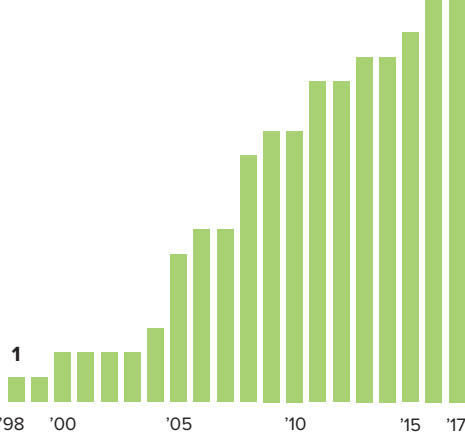
A 2018 study (PNAS) found that exposure of bees to glyphosate can negatively affect their beneficial gut microbiota, "potentially affecting bee health and their effectiveness as pollinators."

Superweeds

Farmers often use GBH in concert with genetically engineered crops, which resist the chemical while it kills competing weeds. But a rapidly growing number of weed species have grown resistant to glyphosate, prompting farmers to use multiple herbicides, which can increase human and environmental exposure to the chemicals.

Glyphosate-resistant weed species

U.S. TOTAL



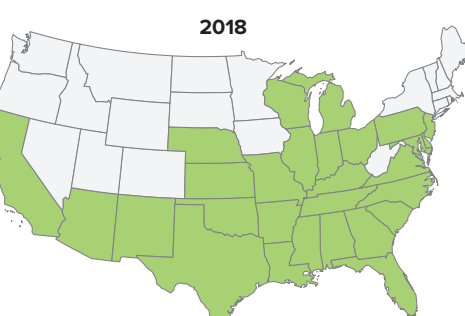
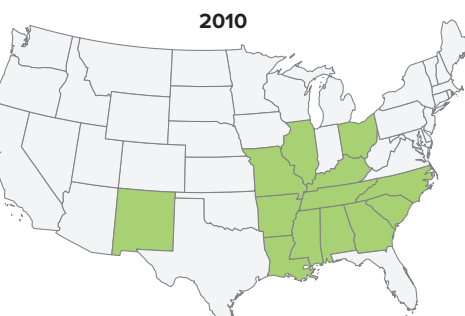
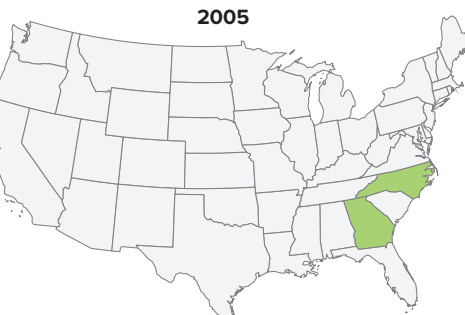
Pushback from a native American food source

Once cultivated by native Americans for its abundant, highly nutritious seeds, **Palmer amaranth** now plays the role of drought-resistant aggressive weed, competing with cotton and soybeans. By 2018, 28 states had reported the weed developing resistance to glyphosate.



Amaranthus palmeri

■ RESISTANCE TO GLYPHOSATE



Sources: Monsanto, EPA, World Health Organization, Science, Journal of the American Medical Association, Toxicology Reports, Pest Management Science, National Cancer Center, National Pesticide Information Center, European Journal of Food Safety, Environmental Working Group, Environmental Sciences Europe, Environmental Toxicology and Pharmacology, Reuters, Journal of Korean Medical Science, Neurotoxicity Research, National Agriculture Statistical Service, International Survey of Herbicide Resistant Weeds, Environmental Science and Pollution Research International, Science of the Total Environment, Journal of Agricultural and Food Chemistry, Biofilms and Microbiomes, Nature: Scientific Reports, Ecotoxicology and Environmental Safety, Journal of Agricultural and Food Chemistry, Proceedings of the National Academy of Sciences, Soil Biology and Biochemistry, EU, Mutation Research-Reviews in Mutation Research, Michael Antoniou (King's College London)

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