ChemicalWatch Factsheet

Glyphosate

Glyphosate (N-phosphono-methyl glycine) is a registered herbicide with the U.S. Environmental Protection Agency (EPA) first registered in 1974. Since its registration, its popularity has increased dramatically due to erroneous industry claims that it is of low toxicity, and the promotion of genetically modified (GM) crops engineered to be tolerant to glyphosate. Studies have reported that glyphosate is associated with an increased risk of non-Hodgkin Lymphoma (NHL), genetic damage, and endocrine disruption, as well as environmental damage including water contamination and harm to amphibians. Researchers have also determined that the "inert" ingredients in glyphosate products, especially polyethoxylated tallowamine or POEA- a surfactant commonly used in glyphosate and other herbicidal products- are even more toxic than glyphosate itself. Monsanto, makers of glyphosate, formulates scores of products such as Roundup™ and Rodeo™making glyphosate one of the most widely used and well-known herbicides in the world.

ChemicalWATCH Stats:

CAS Registry Number: 1071-83-6
Trade Name: Roundup
Use: Non- selective herbicide for broadleaf weed and grass control on food and non-food field crop sites.
Toxicity rating: Toxic.
Signal Words: Caution
Health Effects: Eye and skin irritation, associated with non-Hodgkin Lymphoma, and spontaneous abortions. Other ingredients in formulated products are linked to developmental abnormalities, decreased sperm count, abnormal sperms and cell death of embryonic, placental and umbilical cord cells.
Environmental Effects: Weed resistance due to use of GM fields, water contamination, soil quality degradation, toxic to aquatic organisms.

General Use and Registration Status

Most commonly formulated as Monsanto's Roundup herbicide, glyphosate end-use products account for approximately 180-185 million pounds applied per year,[1] making it the number one commonly used chemical in the U.S. Glyphosate use is currently growing due in large part to the increased cultivation of GM crops that are tolerant to the herbicide. There are hundreds of products currently registered with EPA under numerous formulations[2] with active ingredient glyphosate (most commonly used as its three salts—isopropylamine, sodium and monoammonium salts—as well as the technical acid, in registered pesticide products).

First registered for use in 1974, glyphosate is used to kill a variety of broadleaf weeds and grasses. Labeled uses of glyphosate include over 100 terrestrial food crops as well as other non-food sites including forestry, greenhouse, rights-of-way, and residential.[3] The greatest glyphosate use, according to the U.S. Geological Survey (USGS), is in the Mississippi River basin where most applications are for weed control on GM corn, soybeans, and cotton.[4]

GM or herbicide-tolerant crops (Roundup Ready crops) have dominated U.S. agriculture in recent years. According to the 2010 Agricultural Chemical Use Report from the U.S. Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS), use of glyphosate has dramatically increased over the last several years, contrary to common claims from industry that GM crops would result in lower pesticide use rates. Data show that glyphosate use has skyrocketed to more than double the amount used five years ago, with 57 million pounds of glyphosate applied to corn fields in 2010 compared to 23 million pounds in 2005 and 4.4 million in 2000.[5]

The most recent comprehensive human health risk assessment for glyphosate was conducted in 2006 entitled "Glyphosate Human Health Risk Assessment for Proposed Use on Indian Mulberry and Amended Use on Pea, Dry." The last registration review for glyphosate was published in 1993. That assessment did not include an endangered species determination for glyphosate.[6] In 2009 EPA finalized the work plan for the registration review for glyphosate. It is estimated to be completed in 2015. During the review period the agency must collect up-to-date data and conduct comprehensive risk assessments in keeping with the standard set forth in the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). A number of ecological fate and effects studies, acute and sub-chronic neurotoxicity studies, and an immunotoxicity study have been requested. As part of the registration review, EPA was urged to reinstate the 10X safety factory for glyphosate to protect children and vulnerable populations, expand risk assessments to include effects to amphibians, aquatic plants, and soil biota, as well as the evaluation of POEA and non-POEA surfactants.

Mode of Herbicidal Action

Plants treated with glyphosate translocate the systemic herbicide to their roots, shoot regions and fruit, where it interferes with the plant's ability to form aromatic amino acids necessary for protein synthesis. Treated plants generally die in two to three days. Because plants absorb glyphosate, it cannot be completely removed by washing or peeling produce or by milling, baking or brewing grains. It has been shown to persist in food products for up to two years.[7]

Glyphosate Formulated Products and Other Ingredients

An increasing number of studies have found that formulated glyphosate products (Roundup) are more toxic than the active ingredient, glyphosate, alone. Roundup formulations can induce a dose-dependent formation of DNA adducts in the kidneys and liver of mice.[8] In Wister rats, formulated Roundup induced developmental retardation of the fetal skeleton, decreased sperm numbers, increased the percentage of abnormal sperms and produced a dose-related decrease in the serum testosterone level at puberty.[9] A molecular link between glyphosate-based products and cell cycle deregulation—a hallmark of tumor cells and human cancers was observed,[10] as well as exposure affects to human reproduction and fetal development.[11] Roundup reduces human placental JEG3 cell viability at least two times more efficiently than glyphosate, disrupts aromatase activity, and mRNA levels.[12] Human cell endocrine disruption on the androgen receptor, inhibition of transcriptional activities on estrogen receptors on HepG2, DNA damage and cytotoxic effects occurring at concentrations well below "acceptable" residues has also been observed.[13]

A 2008 study confirmed that the adjuvants in Roundup formulations kill human cells, particularly embryonic, placental and umbilical cord cells, even at very low concentrations, and causes total cell death within 24 hrs.[14] Polyethoxylated tallowamine or POEA—a surfactant used in Roundup and other herbicidal products—was found to be the most potent "inert" and was responsible for the elevated toxic effects. POEA is extremely toxic to aquatic organisms such as fairy shrimp[15] and *Daphnia magna*,[16] and accounts for more than 86% of Roundup toxicity observed in microalgae and crustaceans.[17] It has been determined that the order of toxicity is as follows; POEA > Roundup > glyphosate acid > IPA salt of glyphosate.

Acute Toxicity

EPA considers glyphosate to be "of relatively low oral and dermal acute toxicity."[18] Some glyphosate products are of higher acute toxicity, primarily due to eye and/or skin irritation. Symptoms following exposure to glyphosate formulations include: swollen eyes, face and joints; facial numbness; burning and/or itching skin; blisters; rapid heart rate; elevated blood pressure; chest pains, congestion; coughing; headache; and nausea.[19] In developmental toxicity studies using pregnant rats and rabbits, glyphosate caused treatment-related effects in high dose groups, including diarrhea, decreased body weight gain, nasal discharge and death.[20]

Chronic Toxicity

EPA has classified glyphosate as a Group E carcinogen—evidence of non-carcinogenicity for humans—based on the lack of convincing evidence of carcinogenicity in adequate studies. Since that decision, studies have found that people exposed to glyphosate are 2.7 times more likely to contract non-Hodgkin Lymphoma (NHL).[21] In 2002, a study of Swedish men showed that glyphosate exposure was significantly associated with an increased risk of NHL, and hairy cell leukemia—a rare subtype of NHL.[22] Further, a review of studies conducted on farmers by researchers at the National Cancer Institute showed that exposure to glyphosate was associated with an increased incidence of NHL.[23] Similarly, an Agricultural Health Study (AHS) found that glyphosate had a suggested association with multiple myeloma.[24] This association with multiple myeloma was observed with use of glyphosate and cumulative exposure days of use (a combination of duration and frequency).

Glyphosate and its formulated products adversely affect embryonic, placental and umbilical cord cells, and impacts fetal development. Preconception exposures to glyphosate were found to moderately increase the risk for spontaneous abortions in mothers exposed to glyphosate products.[25] In a Farm Family exposure study, all but one of the 79 children evaluated had detectable concentrations of glyphosate in their urine.[26] While most of the active ingredient glyphosate is excreted quickly from the body, it was concluded, "a part may be retained or conjugated with other compounds that can stimulate biochemical and physiological responses."[27]

Environmental Fate

EPA acknowledges that glyphosate has the potential to contaminate surface waters. If glyphosate reaches surface water, it is not broken down readily by water or sunlight.[39] For instance, half-life of glyphosate in pond water ranges from 70 to 84 days.[40] A survey by the USGS of 154 water samples from 51 streams in nine Midwestern States reports glyphosate detected in 55 (36%) of the samples, and aminomethylphosphonic acid or AMPA (a degradation product of glyphosate) detected in 107 (69%) of the samples.[41] APMA is typically detected much more frequently, especially in urban environments.[42] This survey found that glyphosate contamination endured from spring through to fall when many presumed it would have already degraded.

Glyphosate Tolerant-Crops Promotes Resistant Weeds

Of all corn planted in the U.S., GM herbicide-tolerant corn accounts for 72% of corn acreage in 2011 in the U.S., with over 90 million acres being planted.[28,29] One published report, which utilized data from USDA, shows that GM crops have been responsible for an increase of 383 million pounds of herbicide use in the U.S. over the first 13 years of commercial use of GM crops (1996-2008).[30] A survey of farmers' herbicide use patterns found that glyphosate use continues to increase, with many farmers making one to three post-applications per year.[31] Increased selection pressure from widespread use and reliance on glyphosate, and the simultaneous reductions in the use of sustainable weed management practices have resulted in glyphosate-resistant weeds.[32] It is well-established that herbicide resistance will evolve fastest where herbicide selection intensity is most persistent and many of these weed species have already demonstrated the ability to evolve resistance to a number of other herbicide modes of action (multiple-resistant weeds).

Glyphosate-resistant horseweed (*Conyza canadensis*) was first reported in 2000 in Delaware[33]and has since been found in several other states, including Mississippi, Arkansas, Tennessee, and California.[34,35] Data show that clusters of horseweed can grow robustly even when sprayed with four times the recommended amount of the herbicide glyphosate. A glyphosate-resistant biotype of horseweed also exists in non-crop areas.[36] In regions of the U.S. where Roundup-Ready crops dominate, there are now evolved glyphosate-resistant populations of economically-damaging weed species including *Lolium rigidum, Ambrosia artemissifolia* L., *Ambrosia trifida* L., *Amaranthus palmeri* S, *Amaranthus rudis, Amaranthus tuberculatus* (Moq) *Conyza* and *Lolium* spp.[37,38] In other parts of the world where Roundup-ready crops are used, weed resistance has also appeared. In Argentina and Brazil, for example, there are now evolved glyphosate-resistant populations of *Sorghum halepense L*. and *Euphorbia heterophylla* L.

Glyphosate and AMPA are more frequently detected in surface water rather than ground water.[43] In addition to surface waters, glyphosate has also been detected in significant levels in rain in agricultural areas across the Mississippi River watershed, according to USGS. Due to glyphosate's potential for water contamination, EPA has established a maximum contaminant level (MCL) for glyphosate (0.7ppm).[44] EPA lists the short- and long-term health effects for drinking water exposures: for relatively short periods of time, congestion of the lungs and increased breathing rate; for lifetime exposure at levels above the MCL: kidney damage and reproductive effects.

Glyphosate is moderately persistent in soil, with an average half-life of 47 days, although there are studies reporting field half-lives of up to 174 days.[45] Residues of glyphosate have been known to persist for months in anaerobic soils deficient in microorganisms. Recently, USDA officials have observed that the heavy use of Roundup on GM crops appears to be causing harmful changes in soil and potentially hindering yields of crops.[46]

Effects on Non-Target Animals

Glyphosate use directly impacts a variety of nontarget animals including insects, earthworms, and fish, and indirectly impacts birds and small mammals.[47] A study conducted by the International Organization for Biological Control found that exposure to Roundup killed over 50 percent of three species of beneficial insects – a parasitoid wasp, a lacewing and a ladybug.[48] Repeated applications of glyphosate significantly affected the growth and survival of earthworms.[49] Environmental factors such as high sedimentation, increases in temperature and pH levels have been shown to increase the toxicity of Roundup, especially to young fish.[50] Native freshwater mussels were found to be the most sensitive aquatic organisms tested with glyphosate-based chemicals and its surfactants.[51]

A 2012 study found that Roundup, in sublethal and environmentally relevant concentrations, causes two species of amphibians to change their shape by interfering with the hormones of tadpoles and potentially many other animals.[52] A 2005 study found that Roundup alone is "extremely lethal" to amphibians in concentrations found in the environment.[53] Another study found that *Rana pipiens* tadpoles chronically exposed to environmentally-relevant concentrations of glyphosate formulations, containing POEA, exhibited decreased snout-vent length at metamorphosis, increased time to metamorphosis, tail damage, and gonadal abnormalities.[54] Glyphosate and its salts, as well as its metabolite AMPA, are also likely to adversely impact the endangered California red-legged frog due to prey and habitat reduction.[55]

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