Backgrounder
Glyphosate and Environmental Fate Studies
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Before a herbicide can be registered for use, it must undergo rigorous studies to determine what happens to the compound after it is released into the environment, either from an intended use or an accidental release, such as a spill. These studies, referred to as “environmental fate” studies, are reviewed by the U.S. Environmental Protection Agency (EPA) and regulators in other world areas and are designed to provide answers to the following questions:

Does the herbicide:

- degrade after application? If so, what degradation products are formed after application?
- persist in soil?
- have residual herbicidal activity in soil?
- persist in water or sediment?
- leach through soil to reach groundwater?
- move from treated areas as runoff?
- move from treated areas as a vapor?
- accumulate in tissues of animals?

Laboratory and field studies have been conducted with glyphosate and glyphosate herbicides (such as Roundup UltraMax, Roundup Pro, and AquaMaster™) to address these questions. The overall results of these environmental fate studies are summarized below

Degradation processes and products

The processes by which a herbicide is degraded must be understood before the U.S. EPA and other regulatory agencies will register the herbicide. Some products break down by chemical processes, others through photodegradation, and others by microbial activity or a combination of several processes. Glyphosate is primarily degraded by microbes and fungi in the soil or in surface water. Photodegradation in water and soil are not expected to contribute significantly to glyphosate degradation.

The identity and characteristics of the compounds that are formed as a herbicide degrades must also be determined. The primary environmental degradate of glyphosate in soil and water is aminomethylphosphonic acid (AMPA). AMPA is further degraded to naturally-occurring substances such as carbon dioxide and phosphate. Acute oral and dermal toxicity studies with rats and mice in the laboratory demonstrate that AMPA has very low acute toxicity to mammals (Williams *et al.*, 2000). A number of ecotoxicology studies have been conducted to assess AMPA's toxicity to aquatic and terrestrial species. Based on the results, AMPA can be characterized as having little toxicity to non-target organisms (Giesy *et al.*, 2000).

Degradation in soil

Studies must also be performed to determine how much of the herbicide would be expected to remain in soil following normal use, and the rate of degradation. Research shows that glyphosate is degraded over time by soil microorganisms. The degradation rate of chemical compounds is measured by their half-life (the time required for half of the applied compound to degrade). The average half-life for glyphosate, based on 47 agricultural and forestry studies conducted in diverse geographic locales, is 32 days (Giesy *et al.*, 2000). In most cases, over 90% of the applied glyphosate is expected to dissipate within six months after application.

Binding to soil

Glyphosate binds very tightly to most soils and sediments in the environment. Studies show that the soil-binding potential of glyphosate is stronger than that of nearly any other herbicide. A ratio known as the "soil adsorption coefficient" (K_{oc}) measures the soil-binding capacity of chemical compounds, with higher numbers meaning greater adsorption of the compound to soil.

The following table shows representative K_{oc} values for several herbicides, as reported by Wauchope *et al.* (1992):

Active ingredient	**K_{oc} (L/kg)**
2,4-D esters	100
Atrazine	100
Alachlor	170
Metolachlor	200
Pendimethalin	5,000
Trifluralin	8,000
Glyphosate	24,000
Oxyfluorfen	100,000

Herbicidal activity of residues in soil

Because of its strong soil-binding properties in most soils, glyphosate is not available for uptake by roots of nearby plants, and therefore poses negligible risk to non-target plants with roots in the application zone. Further evidence of this is provided by the fact that even susceptible, conventional crops may be planted directly into fields that were recently treated with a glyphosate herbicide. Studies also show that glyphosate herbicides, when used according to label directions, are not harmful to soil microbes, earthworms or other soil-dwelling organisms (Giesy *et al.*, 2000).

Degradation in water

Both field and laboratory studies have reported microbial degradation of glyphosate in aquatic environments (Giesy *et al.*, 2000). Analysis of available data representing many studies indicates that the typical aquatic half-life of glyphosate ranges from 7 to 14 days . Studies have established that microorganisms in surface waters break down glyphosate over time. Also, because of its strong affinity for soil, glyphosate binds to suspended sediment particles that are present in natural waters. As the particles settle to the bottom, microbial degradation continues. Toxicology studies show that glyphosate levels that might occasionally be detected in surface waters following terrestrial application are sufficiently low so that there is negligible risk to aquatic organisms. In situations where a glyphosate herbicide is applied to weeds growing in water, the exposure of non-target aquatic species is expected to be reduced due to interception by target vegetation and dissipation over time via binding to sediment and microbial degradation.

Leaching and runoff

Two primary factors determine whether a chemical is likely to leach through soil to groundwater or be subject to movement into surface water via runoff -- the rate of degradation in the soil, and the chemical's tendency to bind to soil. Slow degradation and a low tendency to bind to soil can result in leaching and runoff of a chemical, whereas higher degradation rates and tight binding to soil both limit the movement of a chemical by leaching and runoff.

With its combination of degradability and strong binding to soil, glyphosate has extremely low potential to move through the soil profile and has rarely been detected in groundwater. In addition, only limited amounts of glyphosate move to surface water as runoff. A three-year study of glyphosate transport from agricultural fields showed that less than 1 percent of glyphosate applied was typically lost as runoff. In one case, a loss of 1.85 percent of applied glyphosate was observed for a field treated at twice the recommended application rate, with more than 99 percent of the total runoff occurring during a severe rainstorm that occurred the day after application (Edwards *et al.*, 1980). If soil particles containing glyphosate are washed or blown into lakes or streams, the vast majority of the glyphosate will remain adsorbed to the soil and settle to the bottom as sediment. In sediment, glyphosate is degraded over time by microorganisms. Studies also show that sediment-dwelling organisms are not adversely affected by glyphosate (Simenstad *et al.*, 1996).

Bioaccumulation

Aquatic Species: In laboratory studies conducted with several aquatic species, glyphosate bioconcentration factors were less than or equal to 12, indicating that glyphosate has a low potential for bioaccumulation in aquatic animals (Giesy *et al.*, 2000). The low bioconcentration factors are a result of glyphosate being readily soluble in water, and therefore subject to rapid elimination from organisms in water.

Terrestrial Species: Studies conducted with laboratory mammals indicate that glyphosate is poorly absorbed when ingested; any absorbed glyphosate is rapidly eliminated, resulting in minimal tissue retention (Williams *et al.*, 2000). Feeding studies with chickens, cows and pigs have shown extremely low or non-detectable residues in meat and fat following repeated exposures. Negligible residues have also been reported in wild animals such as voles, chipmunks, hares and moose after feeding in treated areas.

Vapor and drift

The active ingredients in some herbicides are volatile, meaning that they can move as vapors to non-target areas after application. This can result in unintended consequences to sensitive plant species outside the treated area. Several laboratory studies show that glyphosate has extremely low vapor pressure and thus there is a negligible risk of glyphosate movement through volatility (Giesy *et al.*, 2000).

However, it is possible, as with any sprayed substance, that spray droplets could drift off-target during application. Research has demonstrated that application procedures and equipment can be optimized to significantly reduce spray drift in most circumstances. Spray drift can be minimized by taking into account spray droplet size, wind speed, other environmental factors and application equipment design. When drift does occur, there is a rapid decline in surface deposition with increasing distance from the target site for both ground and aerial applications.

Conclusions

The key properties of glyphosate that determine glyphosate's environmental fate are its:

- Microbial degradability in soil and water
- Strong binding to most soil types
- High water solubility
- Very low volatility

Glyphosate is microbially degraded over time to naturally occurring substances such as carbon dioxide and phosphate. There is minimal herbicidal activity from residues of glyphosate in soil, and glyphosate residues are not likely to move to groundwater. Glyphosate that reaches surface water either by intentional application, spray drift, runoff, or soil erosion is adsorbed to sediment and degraded over time. Glyphosate is unlikely to move offsite during or after application due to volatilization. Available data indicate that glyphosate is not likely to bioaccumulate in the tissues of non-target organisms.

References

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- Backgrounder: Glyphosate and Drift
- Backgrounder: Glyphosate and Water Quality
- Backgrounder: Formaldehyde is not a major degradate of glyphosate in the environment
- Backgrounder: Summary of Ecotoxicological Risk Assessment for Roundup® Herbicide