Glyphosate:

Ecological Fate and Effects and Human Health Summary

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Washington State Department of Agriculture
Natural Resources Assessment Section

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Glyphosate, CAS # 1071-83-6, is a synthetic glycine herbicide with a chemical mode of action that causes plant cell death by inhibiting an enzyme essential for protein synthesis. Products containing glyphosate have been registered by the Washington State Department of Agriculture (WSDA) for use in Washington since the late 1970s and is a non-selective herbicide that kills both broadleaf and grassy weeds. It is found in hundreds of different pesticide products with a wide variety of uses including both commercial and residential uses. Glyphosate is also the most widely used herbicide both globally and in the United States (Benbrook 2016). All pesticide products containing glyphosate in the United States are registered by the U.S. Environmental Protection Agency (EPA) under the Federal Insecticide Fungicide Rodenticide Act (U.S. Code 1947). In addition to the registration of individual products, glyphosate is also currently undergoing registration review by EPA. During registration review, EPA assesses risks to human health and the environment from continued use of the pesticide. EPA released its Interim Registration Review Decision for Glyphosate in January 2020 as part of the registration review process. With regard to human health, the document stated that glyphosate does not pose a risk to human health based on current use patterns (EPA 2020). With regard to the environmental safety of glyphosate, EPA is currently engaged in a process of consultation required by the Endangered Species Act (ESA) to ensure that the use of glyphosate does not jeopardize any ESA-listed species. EPA plans to release a draft biological evaluation in fall 2020 followed by final endangered species determinations sometime in 2021. This overview document focuses on important characteristics of glyphosate, as well as Washington State monitoring and usage data; it is not a comprehensive analysis.

Ecological Fate and Effects

Physical and Chemical Properties

Glyphosate is highly soluble in water and is an active ingredient in many liquid pesticide products. Glyphosate is also formulated as a solid consisting of glyphosate and a counter ion that together form a salt. These glyphosate salts dissolve readily in water and dissociate into glyphosate and the associated counter ion. Table 1 lists some of the physical and chemical properties of glyphosate.

Table 1: Physical and chemical properties of glyphosate (Hetrick and Blankinship 2015)

Physical/Chemical Property	Parameter	Narrative description
Solubility	12,000 mg/L at 25° C	Highly soluble in water
Volatility (vapor pressure)	9.75×10^{-10} mmHg at 25° C	Unlikely to volatilize from soil
n-octanol-water partitioning coefficient (log K_{ow})	< -3	Unlikely to bioaccumulate in fish

Environmental Fate and Transport

Environmental fate and transport studies are conducted on glyphosate and submitted to EPA as a requirement of pesticide registration under FIFRA. Several study results for glyphosate are shown in Table 2. The primary metabolite of glyphosate detected in all environmental fate studies was aminomethylphosphonic acid (AMPA), CAS # 74341-63-2.

Table 2: Environmental fate and transport properties from Hetrick and Blankinship 2015

Studies submitted to EPA	Parameter	Narrative description
Mobility in soil	Minimum K_{Foc} =1,600 (sandy loam) Maximum K_{Foc} = 33,000 (silty clay loam) K_{Foc} is the Freundlich organic carbon partitioning coefficient	Depending on organic carbon content of the soil, mobility in soil ranges from “slightly mobile” to “hardly mobile” (White 2010)
Abiotic hydrolysis	Stable for at least 30 days	Not a major route of transformation
Aqueous photolysis	Half-life = 216 days	Stable, not a major route of transformation
Aerobic soil metabolism	Minimum half-life = 1.8 days (sandy loam) Maximum half-life = 109 days (silt loam)	Major route of transformation
Aerobic aquatic metabolism	Minimum half-life = 14.1 days Maximum half-life = 518 days	Major route of transformation
Anaerobic aquatic metabolism	Minimum half-life = 199 days Maximum half-life = 208 days	Stable, not a major route of transformation

For more information on the relationship between pesticides, soil, and water, please see WSDA’s “Pesticide Application and Water Quality” brochure by going to agr.wa.gov and searching for “Natural Resources Assessment Section publications” through the “Let’s Find It” box.

Toxicity to Non-Target Organisms

Glyphosate alone has low acute toxicity to mammals, birds, fish and insects. The toxicity of individual glyphosate-containing products may vary depending on the presence and concentration of additional active and inactive ingredients. Other active ingredients formulated with glyphosate include: 2,4-D, dicamba, imazapic, imazethapyr, mesotrione, metolachlor, prodiamine, and triclopyr (WSDA 2020). Inactive ingredients are considered confidential business information and inclusion on labels or safety data sheets is not required under federal or state regulations. Table 3 lists several toxicological endpoints from acute exposure studies where test organisms were exposed to glyphosate, AMPA, or products containing glyphosate. LC_{50} is the concentration that is lethal to 50% of test organisms and EC_{50} is the concentration that results in a specific effect in 50% of test organisms. LD_{50} is the dose that is lethal to 50% of test organisms, administered either by oral gavage or administered by incorporation into the diet.

Table 3: Acute toxicity of glyphosate, glyphosate-containing products, and AMPA to non-target organisms (Hetrick and Blankenship 2015)

Test material	Test organism	Endpoint	Concentration	Toxicity category (EPA 2015)
Technical grade glyphosate	Bluegill sunfish	96-hour LC_{50}	43,000 µg/L	Slightly toxic
Formulated product (30% glyphosate) (Hurley et al. 2009)	Rainbow trout	96-hour LC_{50}	3,100 µg/L	Moderately toxic
Technical grade glyphosate (Hurley et al. 2009)	*Daphnia magna* (aquatic invertebrate)	48-hour EC_{50}	49,900 µg/L	Slightly toxic
Formulated product (41% glyphosate isopropyl amine) (Hurley et al. 2009)	*Daphnia magna* (aquatic invertebrate)	48-hour EC_{50}	3,000 µg/L	Moderately toxic
AMPA	Rainbow trout	96-hour LC_{50}	499,000 µg/L	Practically nontoxic
AMPA	*Daphnia magna* (aquatic invertebrate)	48-hour EC_{50}	683,000 µg/L	Practically nontoxic
Technical grade glyphosate	Bobwhite quail	Oral LD_{50}	> 3,196 mg/kg body weight	Slightly toxic
Technical grade glyphosate	Bobwhite quail	Dietary LC_{50}	> 4,971 ppm	Slightly toxic
Technical grade glyphosate	*Rattus norvegicus* (Norway rat)	Oral LD_{50}	4,800 mg/kg body weight	Practically nontoxic
Technical grade glyphosate	*Apis mellifera* (Honey bee)	48-hour oral LD_{50}	> 100 µg/bee	Practically nontoxic

In addition to acute exposure studies like those listed in Table 3, studies measuring the chronic toxicity of glyphosate consistently show that glyphosate alone has very low toxicity to non-target organisms (Hetrick and Blankinship 2015).

The EPA publishes aquatic life benchmarks for pesticides, as shown in Table 4. These benchmark values are chosen by selecting the most protective values for each category and applying an additional safety factor. The aquatic life benchmarks are used by EPA and the states as a set of reference values that support the interpretation of pesticide monitoring data.

Table 4: EPA aquatic life benchmarks (Hurley et al. 2009)

EPA criteria	Glyphosate EPA aquatic life benchmarks (µg/L)	AMPA EPA aquatic life benchmarks (µg/L)
Acute fish	21,500	249,500
Chronic fish	25,700	n/a
Acute invertebrate	26,600	341,500
Chronic invertebrate	49,900	n/a
Nonvascular plants (acute)	12,100	n/a
Vascular plants (acute)	11,900	n/a

For additional information about glyphosate and the potential effects of exposure to products containing glyphosate, review the National Pesticide Information Center's General Fact Sheet and Technical Fact Sheet by visiting http://npic.orst.edu and searching for "glyphosate" in the search box.

Human Health Effects

There is currently substantial disagreement among experts on the potential for glyphosate exposure to cause cancer in humans. In March 2015, the World Health Organization's International Agency for Research on Cancer classified glyphosate as Group 2A: probably carcinogenic to humans (International Agency for Research on Cancer 2015). However, many other groups, including EPA, have not come to the same conclusion. EPA's Cancer Assessment Review Committee (CARC) has reviewed the carcinogenicity of glyphosate three times since the early 1980s. In the most recent report published in 2015 CARC again classified glyphosate as not likely to be carcinogenic to humans based on a review of currently available studies (EPA 2016).

Both of these classifications are based on the assessment of a large number of studies with a variety of methodologies and contradicting conclusions. While some studies claim evidence of carcinogenic effects, many have found no evidence of carcinogenic effects. For a detailed list of documents relevant to EPA's evaluation of the carcinogenic potential of glyphosate, visit https://www.epa.gov/ and search for "EPA's evaluation of the carcinogenic potential of glyphosate".

EPA has conducted extensive analysis of the potential risks to human health associated with the current uses of glyphosate and reached the following four conclusions (EPA 2014):

- Glyphosate does not pose a risk to human health,
- There is no indication that children are more sensitive to glyphosate,
- There is no indication that glyphosate is an endocrine disruptor,
- Glyphosate is not likely to be carcinogenic to humans.

These conclusions are not only based on EPA's own extensive risk assessment processes, but on the analysis of FIFRA scientific advisory panels commissioned by EPA to provide additional independent study and opinions from leaders in the scientific community outside of EPA. For more information from EPA on glyphosate and its registration review process, visit https://www.epa.gov/ and search for "glyphosate" to view EPA's glyphosate web-based fact sheet.

Glyphosate in Washington State

WSDA registers all pesticide products sold in Washington State, including all those containing glyphosate. As of September 2020, there were 219 formulated products containing glyphosate registered in Washington State (WSDA 2020). Some products contain two different glyphosate salts.

- 15 products that contain glyphosate in its acid form (no counter cation); CAS# 1071-83-6
- 2 products that contain glyphosate as a diammonium salt; CAS# 69254-40-6
- 4 products that contain glyphosate as a dimethylammonium salt; CAS# 34494-04-7
- 1 product that contains glyphosate as an ethanolamine salt; CAS# 40465-76-7

- 183 products that contain glyphosate as an isopropylamine salt; CAS# 38641-94-0
- 7 products that contain glyphosate as a ammonium salt; CAS# 114370-14-8
- 15 products that contain glyphosate as a potassium salt; CAS# 70901-12-1

Product Label Information

Recommendations for Applicators

Although EPA concluded that glyphosate does not pose a risk to human health, this conclusion is based on the expectation that pesticide applicators understand and follow the product labels. Pesticide product labels provide the information needed to use the product safely and effectively. The label is required by law to be sold on or with the pesticide container, and it is a violation of federal law to use the pesticide in a manner inconsistent with its label. In addition, state and federal law requires that both residential pesticide users and professional applicators read and fully understand the product label before using any pesticide. Pesticide users must follow all label directions, including the use of personal protective equipment (PPE). Reducing exposure by following the label instructions and any associated PPE requirements is the best way to minimize the risks associated with applying pesticides. In the event of an accidental exposure, the product label provides information on first aid response and when to seek medical attention.

Product labels also list allowable use sites, which will vary from one product to another. Examples of labeled use sites include agriculture, farmsteads (non-crop), forestry, horticulture, commercial, residential, non-residential, utility rights-of-way, habitat management, restoration, pasture, aquatic, and wetland sites.

Examples of label information on human health risks, PPE requirements, and avoiding exposure include:

- Causes moderate eye irritation. Avoid contact with eyes or clothing. Wash thoroughly with soap and water after handling.
- Applicators and other handlers must wear a long-sleeved shirt, long pants, and shoes plus socks.

Examples of label information on reducing the potential for ecological exposure include:

- *For terrestrial uses:* Do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark. Do not contaminate water when cleaning equipment or disposing of equipment wash waters or rinsate.
- *For aquatic uses*: Do not contaminate water when disposing of equipment waste waters. Treatment of aquatic weeds can result in oxygen depletion or loss due to decomposition of dead plants. This oxygen loss can cause fish suffocation.

For more guidance on how to read pesticide product labels, see the "Understanding Pesticide Product Labels" brochure by going to agr.wa.gov and searching for "Natural Resources Assessment Section publications" through the "Let's Find It" box.

WSDA Usage Data

WSDA collects pesticide usage data through meetings with growers, commodity leaders, crop consultants and university researchers. In the past 10 years, WSDA has gathered glyphosate usage data for apple, barley, cherry, field corn, cranberry, Concord grape, wine grape, hops, pear and potato (Table 5).

Table 5: Glyphosate usage data

Crop name	Survey year	Surveyed acres	Total pounds applied
Apple	2020, 2015	189,525	387,803
Barley	2011	73,850	26,129
Cherry	2020	46,039	30,252
Corn, Field	2012	199,395	339,283
Cranberry	2019	1,879	125
Grape, Concord	2011	16,267	8,188
Grape, Wine	2015	60,078	117,539
Hops	2014	41,988	149
Pear	2020, 2015	21,246	22,445
Potato	2019	180,178	67,534

Pesticide usage data can be useful in many ways. For example, coupling usage data with other data sets such as the land use geodatabase or monitoring data allows the agency to better understand use patterns and to assess risk to the environment and human health. Most recently, inclusion of pesticide usage data became a requirement of EPA’s data review and this data is now being used by EPA to refine risk estimates for threatened and endangered species. WSDA is also one of only a few states that collects usage data and is working with EPA on how best to collect and use pesticide usage data.

WSDA Monitoring Results for Glyphosate

Although glyphosate is not included in WSDA’s routine surface water monitoring program sampling, there have been three special studies since 2015 where surface water samples were tested for glyphosate and AMPA. In each study, surface water grab samples were analyzed by liquid chromatography with tandem mass spectrometry at the Washington State Department of Ecology’s Manchester Environmental Laboratory in Port Orchard, Washington.

The two studies WSDA conducted in 2015 and 2019 are referred to in this section as agricultural/urban studies; they were conducted in watersheds where land use was predominantly agricultural, urban, or a mixture of the two. Monitoring sites for the special studies were chosen from the preexisting WSDA surface water monitoring sites and included locations in both Eastern and Western Washington. Twelve monitoring sites sampled in the 2015 study were also sampled in the 2019 study. Sampling weeks for the 2015 study were selected based on pesticide usage data collected by WSDA and data from the U.S. Department of Agriculture’s National Agricultural Statistics Service that indicated which weeks applicators were most likely to be using glyphosate-based herbicides. Sampling for the 2019 study was conducted every two weeks for the duration of the surface water monitoring program’s seasonal sampling schedule for each site monitored (Figure 1).

The third study, the 2017 forest study, was conducted by WSDA with assistance from the Hoh Tribe. The study was designed to assess herbicide concentrations downstream of timber harvest areas in the Hoh River watershed located in the Olympic Peninsula. Staff sampled during the time when herbicide applications were expected within the actively harvested watershed (Figure 1).

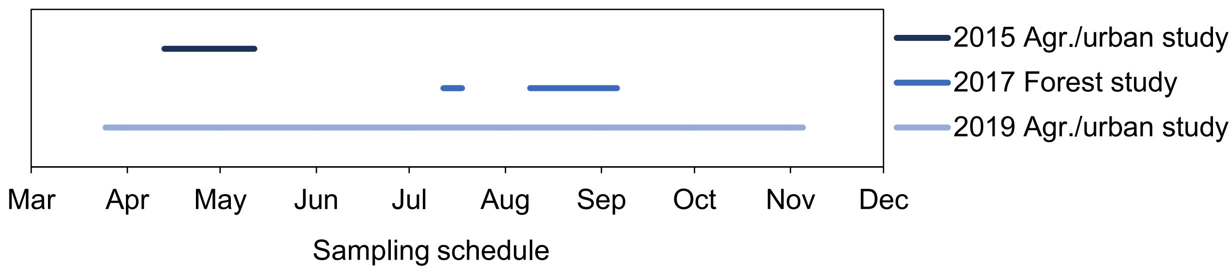

Figure 1: Sampling schedule for three special studies. Note: During the 2017 forestry study, background samples were collected in mid-July prior to the time period when forest land managers typically apply glyphosate-based products.

Glyphosate and AMPA were found in many different watersheds and within each land use category. Table 6 shows a data summary of all three special studies. This data is included only to provide information about glyphosate presence in these specific watersheds at the time samples were collected. It is not representative of conditions in other streams or other watersheds with similar land uses and should not be used to make conclusions about other regions, watersheds, or other points in time within the watersheds that were sampled during these studies. The reporting limit for the analytical method used by the laboratory to measure the concentration of glyphosate and AMPA in the samples from all three studies was 0.008 µg/L.

Table 6: Summary data from three special studies

Special study	# of sampling events	# of sites monitored	# of sites with detections	Detection frequency (%)	Average concentration (µg/L)	Maximum concentration (µg/L)
2015 Agr./urban						
Glyphosate	70	14	13	77	0.196	1.5
AMPA	70	14	12	66	0.121	0.38
2017 Forest						
Glyphosate	24	4	2	17	0.084	0.266
AMPA	24	4	1	8	0.012	0.015
2019 Agr./urban						
Glyphosate	173	14	14	90	0.700	18.4
AMPA	173	14	14	90	0.821	16.7

The concentrations of glyphosate in all three studies were compared to EPA's aquatic life benchmarks and EPA's National Primary Drinking Water Regulation Benchmarks. It should be noted that no surface water sites tested in the special studies are sources for public drinking water.

The maximum concentration of glyphosate in any sample was 18.4 µg/L (detected in 2019). That is at least 38 times below the EPA's maximum contaminant level for glyphosate in drinking water (700 µg/L) and at least 647 times below EPA's most sensitive aquatic benchmarks for fish, aquatic invertebrates, and aquatic plants. The highest average glyphosate concentration from these three WSDA monitoring studies (0.7 µg/L) is 0.1% of the drinking water benchmark and 0.0059% of the most sensitive aquatic benchmark.

The maximum concentration of AMPA in any sample (also detected in 2019) was 16.7 µg/L. That detection is at least 14,940 times below EPA's most sensitive aquatic benchmarks for fish and aquatic invertebrates. There is no established drinking water benchmark for AMPA.

One of the main uses of WSDA's surface water monitoring data is to identify any pesticides nearing concentrations high enough to threaten aquatic communities. WSDA assesses the monitoring data using a decision matrix that was developed by EPA Region 10 states (Washington, Oregon, Idaho, and Alaska) to select watershed and statewide Pesticides of Concern (POC). WSDA maintains and updates this list yearly in order to identify the highest priority pesticides for education and outreach programs. POCs may receive additional monitoring, review, and even potential regulatory action under the Washington State Pesticide Management Strategy (Cook and Cowles 2009). Currently glyphosate is not a WSDA POC due to its lack of EPA aquatic life benchmark exceedances.

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