Herbicide Use by Ontario’s Forest Industries

Report Prepared for Northwatch
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1.0 Introduction

Sixty-six percent of Ontario’s land (approximately 70 million hectares) is covered by forest and wooded areas. Of the forested area, 90% is provincially owned. Thirty-three percent (approximately 24 million hectares) of the forested area is available for a variety of development activities, including timber production\(^1\).

In 2003, harvesting for timber production took place on 204,000 hectares of Ontario forests\(^2\). Regeneration of this area (with the exception of roads, landings and slashpiles) is required by law\(^3\). Regeneration can occur as a result of natural root or seed growth, direct (artificial) seeding, or by planting seedlings. Ground preparation must occur, to control vegetation growth in clear-cut areas and to protect the valuable seedlings. The methods used for ground preparation include both chemical (herbicide application) and mechanical techniques (trenching, mixing, brushing and chopping). In Ontario, aerial application of herbicides is by far the most common method of ground preparation. In 2003, approximately 70,000 hectares of deforested areas were treated aerially with glyphosate\(^4\). Figure 1 shows that aerial application of both glyphosate and 2,4-D (2,4-dichlorophenoxyacetic acid) remained relatively constant through the last decade.

![Figure 1. Ontario regenerating forest area treated with herbicides (glyphosate and 2,4-D), 1990-2003 (Source: National Forestry Database, October 2005).](image)

The purpose of this document is to review the recent literature and summarize information on the potential impacts of herbicides (glyphosate) on Ontario’s forest ecosystems.

2.0 Type and amount of herbicides used in Ontario forestry
Five herbicides are currently registered for forestry use in Ontario: 2,4-D and glyphosate, both registered for aerial application, and simazine, hexazinone and picloram, which are registered for ground application only. Of the five herbicides, only 2,4-D and glyphosate are used in Ontario’s forest industry in significant volumes. Figures 2 and 3 represent the amounts of 2,4-D and glyphosate used in Ontario’s forests since 1992.

Since the early 1990s, glyphosate, a non-selective herbicide, has accounted for more than 90% of the herbicide used by Ontario’s forest industry, while the use of 2,4-D has been fluctuating over the years.
2,4-D is a selective herbicide, and though highly toxic to broad-leafed plants, is less harmful to grasses and woody species. This quality, although desirable for control of weeds in home gardens and agricultural areas, is not so efficient in reforestation areas where the need is to eliminate all unwanted vegetation, including grasses. As a result, glyphosate has been the herbicide of choice in the forest industry. This document will focus primarily on recent studies on glyphosate and the potential environmental hazards associated with application of this pesticide in forest ecosystems.
3.0 Glyphosate

Glyphosate (N-(phosphonomethyl) glycine), is a broad-spectrum herbicide, in that it destroys or damages a variety of vegetative species including grasses, sedges, broad-leaved weeds, and woody plants. It is registered in Canada for use in agriculture, forestry and residential areas, as well as commercial and industrial uses.

Glyphosate was first introduced by Monsanto Company in 1971, and has been registered in the U.S. since 1974 and in Canada since 1976. Until the early 1990s, Monsanto was the sole producer of glyphosate products. Since then, Monsanto’s patent has expired, allowing other agrochemical companies to produce glyphosate products as well. This has resulted in a rapid increase in the number of glyphosate products. In Ontario, the number of registered formulations of glyphosate has increased four-fold since the early 1990s, and currently there are over 60 registered glyphosate products in Ontario. However, only 7 of these products are registered for aerial application (see Table 1). All glyphosate products registered for aerial spraying on woodlots and forests are classified as restricted (i.e., subject to interdisciplinary review and permit requirements under provincial legislation). In Ontario, only licenced applicators are permitted to handle the restricted products.

Table 1: Glyphosate products registered for forest and woodlots application in Ontario.

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Ontario Classification</th>
<th>Aerial Application Allowed</th>
<th>Use Location</th>
<th>Use Site</th>
<th>Registrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>VISION SILVICULTURE HERBICIDE</td>
<td>2 *</td>
<td>Yes</td>
<td>FOR</td>
<td>Various outdoor sites</td>
<td>MONSANTO CANADA INC.</td>
</tr>
<tr>
<td>NUFARM RAZOR TMP LIQUID HERBICIDE</td>
<td>2 *</td>
<td>Yes</td>
<td>NCR</td>
<td>Various outdoor sites</td>
<td>NUFARM AGRICULTURE</td>
</tr>
<tr>
<td>VANTAGE PLUS MAX HERBICIDE SOLUTION</td>
<td>2 *</td>
<td>Yes</td>
<td></td>
<td>Various outdoor sites</td>
<td>DOW AGROSCIENCES CANADA INC.</td>
</tr>
<tr>
<td>VISIONMAX SILVICULTURE HERBICIDE</td>
<td>2 *</td>
<td>Yes</td>
<td>WLD</td>
<td>Forests and woodlots</td>
<td>MONSANTO CANADA INC.</td>
</tr>
<tr>
<td>ROUNDUP ULTRA LIQUID HERBICIDE</td>
<td>2 *</td>
<td>Yes</td>
<td></td>
<td>Various outdoor sites</td>
<td>MONSANTO CANADA INC.</td>
</tr>
<tr>
<td>RENEGADE HC LIQUID HERBICIDE</td>
<td>2 *</td>
<td>Yes</td>
<td></td>
<td>Various outdoor sites</td>
<td>MONSANTO CANADA INC.</td>
</tr>
<tr>
<td>ROUNDUP TRANSORB HC LIQUID HERBICIDE</td>
<td>2 *</td>
<td>Yes</td>
<td>URB</td>
<td>Various outdoor sites</td>
<td>MONSANTO CANADA INC.</td>
</tr>
<tr>
<td>FORZA SILVICULTURE HERBICIDE</td>
<td>6**</td>
<td>No</td>
<td>FOR</td>
<td>Forests and woodlots</td>
<td>CHEMINOVA CANADA INC.</td>
</tr>
</tbody>
</table>

Source: Pesticide Products Information System (PEPSIS)
* Classification 2: The pesticides in this category are restricted to use by certified agriculturist, licenced exterminators and registered custom sprayers. A record must be kept for each sale.
** Classification 6: The pesticides in this category are unrestricted industrial packages (package size larger than 1 kilogram in weight or 1 litre in volume). Sale may be made by general licenced holders and limited vendors.
Roundup® is the most heavily used glyphosate product in agriculture, whereas Vision®, is used exclusively in forestry operations to minimize vegetative competition with high-value seedlings. Vision® is the only glyphosate product permitted for forest and woodlot aerial application in Ontario (see Table 1).

In addition to the active ingredient (the ingredient that kills or otherwise manages the target plant), glyphosate products contain non-active ingredients or “formulants”. These are ingredients designed to improve the efficacy of the active ingredient, and include surfactants, solvents, emulsifiers and adjuvants. The surfactant most commonly used in glyphosate products is polyoxyethylene amine. Although formulants do not directly kill pests, in combination with the active ingredients, they can be quite hazardous to ecosystem health. Laboratory and field experiments show that glyphosate products are much more toxic than glyphosate alone. In one recent study, researchers found that Roundup® was more toxic to human placental cells than glyphosate on its own. In this study the researchers also found that Roundup® significantly reduced the activity of aromatase (an enzyme that is crucial for production of the sex hormone) at concentrations 10 times lower than recommended use in agriculture. However, despite these recent findings, most toxicity testing is performed only on the active ingredient(s), which often comprise only a small fraction of the total weight or volume of a product. This is a critical point because the approval process for pesticide products is based in part on toxicity testing.

4.0 The environmental fate of glyphosate

4.1 Soil

Glyphosate attaches itself strongly to soil particles and is therefore not likely to leach or percolate through soil to ground or surface water. It is considered to be moderately to highly persistent in soil, depending on the type of soil and climatic conditions. The estimated mean half-life (the time required for 50% of a substance to be eliminated or disintegrated by natural processes) of glyphosate in soil is 47 days, with a range of 1 to 174 days. Glyphosate is metabolized (digested) by soil microbes. The major substance resulting from microbial metabolism in both soil and water is aminomethylphosphonic acid (AMPA), the concentration of which increases as glyphosate concentrations decrease over time. Glyphosate and AMPA have very similar chemical structures and toxicological characteristics.

4.2 Water and Sediments

In water, glyphosate rapidly combines with solid particles suspended in water, allowing it to settle out of water and into sediments. Glyphosate's persistence in water is shorter than its persistence in soils. Two Canadian studies found that the half-life of glyphosate in pond water was 12 to 60 days. Glyphosate persists longer in pond sediments. For example, the half-life in pond sediments in Missouri was calculated at 120 days, with a half-life of more than a year in pond sediments in both Michigan and Oregon.
5.0 Toxicity Profile

5.1 Mammalian Toxicity

Glyphosate is classified as being slightly toxic to practically non-toxic to laboratory animals such as rats and mice. The oral LD$_{50}$ for rats (the dose that causes 50% of the test animals to die when orally exposed to glyphosate) is 4,320 milligrams of glyphosate per kilogram of body weight (mg/kg), while the LD$_{50}$ for dermal application to rabbits is greater than 2000 mg/kg, placing it in EPA’s toxicity category III, meaning “Caution” (on a scale of I to IV, with class I being the most toxic).

5.2 Aquatic toxicity

5.2.1 Invertebrates

Technical glyphosate is considered slightly toxic to the water flea (Daphnia magna), with an LC$_{50}$ value (the concentration that causes 50% of test animals to die) of greater than 50 mg/L. Glyphosate products, however, are classified as moderately to slightly toxic to water fleas, with a 2-day EC$_{50}$ (concentration having 50% of effect compared to control) ranging from 5.2 to 5600 mg/L.

5.2.2 Fish

Technical glyphosate is considered practically non-toxic to fish on the basis of acute (short-term) toxicity. The 96 hour LC$_{50}$s for bluegill sunfish, harlequin and rainbow trout are 168 mg/L, 120 mg/L and 86 mg/L, respectively. However, in chronic (long-term) toxicity tests, glyphosate causes gill and liver damage to fish after two weeks exposure at concentrations of 5 mg/L and 10 mg/L respectively.

In addition, some glyphosate products, including Roundup®, are considered to be moderately toxic to fish and invertebrates. Many researchers suggest that the combination of the active ingredient and the surfactants present in the Roundup® formulation are responsible for this increased toxicity. For example, the 96 hour LC$_{50}$s of the surfactant (MON 0818), glyphosate and Roundup® in rainbow trout are 2.0 mg/L, 86 mg/L and 8.3 mg/L, respectively, suggesting an order of magnitude higher toxicity value for Roundup® than for technical glyphosate.

5.3 Toxicity to Amphibians

A number of recent studies have indicated that Roundup® is extremely toxic to amphibians, causing genetic damage and disrupting normal tadpole development. In a recent study, Roundup® killed 96% to 100% of leopard frog and tree frog tadpoles and the majority of wood frog tadpoles in a small experimental pond. The researchers suggested that the surfactant in the Roundup® formulation accounted for the high degree of toxicity rather than the active ingredient. In forest ecosystems, small ponds are more likely to be affected by the aerial spraying of reforested areas since the no-spray buffer zones which applicators are required to conserve are usually designed to protect only large water bodies. In Australia, because of their toxic affects on tadpoles and frogs, most glyphosate products have been banned from use in or near water bodies.
5.4 Toxicity to Birds

Glyphosate is practically non-toxic to bobwhite quail and mallard ducks, with a dietary LD$_{50}$ greater than 2000 mg/kg and an LC$_{50}$ of greater that 4000 mg/L$^{33}$. However, glyphosate indirectly impacts bird populations by changing the structure of plant communities in clear-cut areas, causing a reduction in bird populations due to lack of food, shelter and nest supports$^{34}$. For example, a study in Nova Scotia which compared bird populations in clear-cut areas treated with glyphosate and control areas (with no pesticide treatment) found that overall population densities of the birds were reduced and did not return to normal after two years post treatment$^{35}$. A similar study in the State of Maine showed that songbird populations decreased following glyphosate treatment of clear-cut areas$^{36}$.

5.5 Effects on other non-target species

Both glyphosate and glyphosate products are non-toxic to honey bees, with LD$_{50}$ values greater than 100 micrograms per bee$^{37}$. However, glyphosate use may negatively impact a variety of other beneficial species. A study conducted by the International Organization for Biological Control found that exposure to Roundup$^\circledR$ killed over 50% of three species of beneficial insects – wasps, lacewings and ladybugs$^{38}$. Impacts on other beneficial insects have also been shown in field studies. For example, in North Carolina, populations of large carabid beetles declined in wheat fields treated with glyphosate products and did not recover for 28 days$^{39}$. In addition, studies show that glyphosate may effect plant growth by inhibiting the growth of nitrogen-fixing bacteria in soil$^{40}$.

5.6 Effects on wildlife

Wildlife is adversely affected by forestry herbicide applications which reduce plant diversity, thus limiting the availability of food, shelter and breading/rearing areas for young. A study conducted in the State of Maine on clear-cut areas treated with Roundup$^\circledR$ found that populations of insect-eating shrews and plant-eating voles declined and did not return to normal until 2 to 3 years post-treatment$^{41}$. In another study in British Columbia, it was reported that deer mice populations declined by 83% following glyphosate treatment$^{42}$.

5.7 Mutagenicity

Although earlier genotoxicity tests suggested that glyphosate does not cause mutations in genetic material$^{43}$$^{44}$, recent studies suggest otherwise. In one study, researchers found a significant increase in DNA damage in bullfrog tadpoles treated with Roundup$^\circledR$ at concentrations of 6.75 and 27 mg/L for 24 hours$^{45}$. There was no DNA damage observed when Roundup concentrations were lower (1.6 mg/L). Another study found that both glyphosate and Roundup caused DNA damage in mouse liver and kidney cells, with more pronounced damage associated with exposure to Roundup$^{46}$.

5.8 Carcinogenicity

Based on standard cancer studies, the U.S. Environmental Protection Agency concluded that glyphosate should be classed as having “evidence of non-carcinogenicity for humans”$^{47}$. However, an epidemiological study in Sweden concluded that people who were occupationally exposed to
glyphosate had a threefold higher risk of developing hairy cell leukemia, a form of non-Hodgkin's lymphoma (NHL, a cancer of the lymphatic system)\textsuperscript{48}. In a recent epidemiological study, conducted in a large region of Canada, researchers found an increased risk of NHL associated with glyphosate use and the risk was associated with increases in the number of days used per year\textsuperscript{49}. In a study of a large group of pesticide applicators in Iowa and North Carolina, researchers found an association between glyphosate exposure and multiple myeloma (bone marrow tumours)\textsuperscript{50}.

5.9 Reproductive/endocrine effects

In male rabbits, glyphosate increases the frequency of abnormal and dead sperm at doses which are 1/10 and 1/100 of the LD\textsubscript{50} \textsuperscript{51}. Because it is difficult to associate a specific toxic effect (e.g., cancer, organ damage, birth defect) with direct human exposure to a specific pesticide, the effect of pesticides on human reproductive systems are relatively unknown. Most of our knowledge comes from accidental exposure, workplace exposure and epidemiological studies. A recent Ontario survey of farming families and pesticide applicators found an association between fathers' use of glyphosate and increases in spontaneous abortions, miscarriages and premature births\textsuperscript{52}. A laboratory test revealed that both glyphosate and Roundup\textsuperscript{®} disrupt activity of an enzyme crucial for synthesis of sex hormones at concentrations 100 times lower than the recommended use in agriculture\textsuperscript{53}.

6.0 Conclusion and recommendations

Glyphosate is considered a low risk pesticide by its manufacturer and by the regulatory agencies. This is due to its low acute toxicity and its relatively low toxicity to birds and mammalian species. However, recent studies show that glyphosate and its formulations are toxic to aquatic invertebrates as well as amphibians and mammals. Glyphosate is also a potential mutagen, endocrine disruptor and carcinogen.

In summary, scientific evidence suggests that using glyphosate for management of forest vegetation in forest regenerated areas is not as harmless as previously thought. There is potential that glyphosate and its formualnts can cause harm to wildlife, humans and the ecosystem in general.

It is recommended that an entirely new approach be taken to determine the safety of pesticides, and in particular, glyphosate.

1) The toxicity, environmental fate and effects of pesticides should be determined by testing the product rather than the active ingredient only. Surfactants used in glyphosate formulations need to be evaluated for their effects and toxicity. Susan, do you mean this at the federal (PMRA) level or at the Ontario (classification) level?

2) More research is needed to assess the long-term and chronic effects of glyphosate exposure, including endocrine disruption, mutagenic effects and carcinogenicity of both glyphosate and glyphosate products.

3) Comprehensive environmental monitoring is required in order to determine a realistic buffer zone in order to protect aquatic life. Special measures should be taken to protect small ponds and wetland areas during aerial application.
7.0 Endnotes

1 Up-Front, The State of Canada’s Forest 2004-2005
2 Up-Front, The State of Canada’s Forest, 2004-2005
3 Ontario Ministry of Natural Resources website at http://ontariosforests.mnr.gov.on.ca/silvicultureoverview.cfm#contents
4 National Forestry Database, 2005
5 Decision of the Environmental Assessment Board on the OMNR Timber Class Environmental Assessment for Timber Management on Crown Lands in Ontario (May, 1994)
6 National Forestry Database, 2005
7 Canadian Council of Forest Ministers, National Forestry Database Program, 2002
8 2,4-D Fact Sheet, http://www.pan-uk.org/pestnews/Actives/24d.htm.

42 from CWS