Canadian Association of Physicians for the Environment

équiterre

Backgrounder: Glyphosate: Ubiquitous and Worrisome

Glyphosate, better known under its first trademark, RoundUp™ (Monsanto), is a wide-spectrum herbicide often associated with genetically modified crops (RoundUp Ready™), but also used to clear all vegetation for other crops or road maintenance.

Today, it is the most widely sold herbicide in the world,[1-4] including in the province of Québec (Figure 1).[5, 6] Increased cultivation of genetically modified crops is associated with both increased sales of glyphosates[7] and increased detection of glyphosates in the water of rivers flowing through Québec's corn and soy regions.[8] Glyphosates were found in nearly all—up to 97.5%—of the streams sampled in 2014.[8]

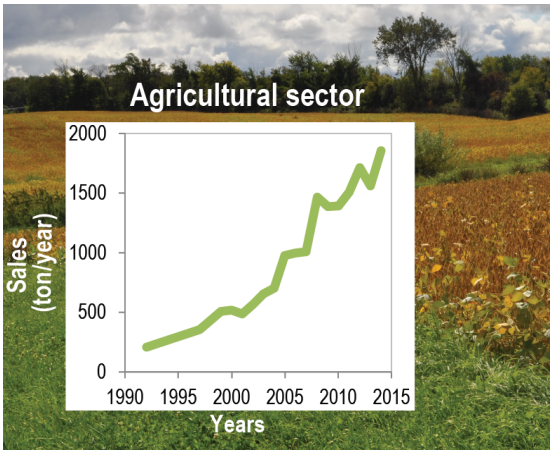

Figure 1: Glyphosate sales in Québec.

Glyphosate, Bacteria and Human Health

Glyphosate kills plants by preventing the synthesis of aromatic amino acids which are essential for plants (Figure 2).[9] Initially, this mode of action was thought to be restricted to plants, meaning that glyphosate was deemed to be a safe herbicide for all other life forms.[9] However, we now know that fungi, bacteria and animals can also be affected by glyphosate.[10] Because it can affect soil bacteria, glyphosate could play a role in the nutrition and diseases of plants that are not targeted.[10-14] Because it affects bacteria living in the digestive tract, glyphosate could also have an adverse impact on human health.[15] Monsanto holds a patent for the use of glyphosate as a wide-spectrum antibiotic.[16]

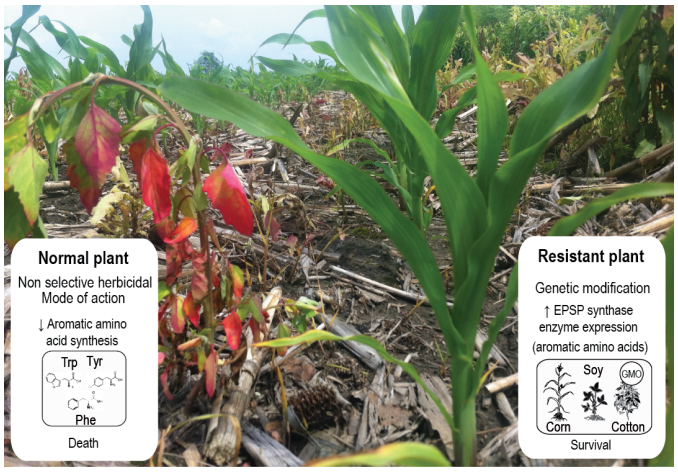

Figure 2: Glyphosate mode of action in normal plants, and resistance mechanism in genetically modified plants.

Widespread Use of Glyphosate

Early on in its use, glyphosate was considered a safer alternative for human health and the environment compared to the herbicides it replaced.[17, 18] Nearly 200 commercial formulations containing different salts of glyphosate are registered for use in Canada,[19] while more than 400 formulations exist in the USA for use on more than 100 food crops.[20] The majority of grain corn (88%) and soy (59%) sown in Québec is genetically modified, often to resist glyphosate; this trend is continuously increasing.[21] Glyphosate is used as a pre-harvest drying-agent for cereals.[22, 23] It is also used in apple orchards, and in fields where grapes, blueberries,

cranberries, strawberries, sugar beets and asparagus grow.[24] In the USA, 90% of orange groves and 80% of pistachios, almonds and grapefruit orchards, are treated with glyphosate each year.[20] Finally, glyphosate is also used in a wide variety of commercial, industrial and residential applications, for instance, to eliminate weeds along roadsides, railroads, in flower beds, on golf courses, at airports, and even for landscaping purposes in schoolyards and parks.[24-26]

Nuisance for Crops and Wild Flora

Glyphosate affects all plants, not just the targeted weeds.[27-29] Below lethal doses, glyphosate may affect plant nutrition by immobilizing certain soil nutrients, limiting nitrogen fixation in soy root nodules,[14, 30] or limiting associations between plants and beneficial fungi.[31] In addition, it suspected that there is an indirect link between glyphosate and certain plant diseases such as fusarium wilt in wheat.[32, 33]

Glyphosate also impacts agricultural ecosystems. For example, milkweed populations, which were historically abundant, are declining due to glyphosate; this coincides with the decline of the monarch butterfly which depends on milkweed for its survival.[34]

Weed Resistance to Glyphosates

In the long term, repeated use of glyphosate encourages natural selection of plants resistant to glyphosate in both agriculture[35-39] and forestry.[40] This can force farmers to increase the dosage or repeat the treatments with glyphosate. It can also force them to combine glyphosates with more toxic herbicides that had been abandoned previously.[8, 35-39] Resistant weeds have been found in Ontario and are expected shortly in Québec.[8]

Environmental Persistence and Contamination of Water

When glyphosate is applied, a fraction may drift with the wind, and another fraction may directly reach soils where it strongly attaches to particles (Figure 3).[10, 41, 42] Mainly under the influence of soil bacteria, glyphosate is primarily degraded into aminomethyl phosphonic acid (AMPA), a toxic metabolite.[41] While glyphosate normally decomposes rapidly (1 day to 6 months in soils),[10, 43] a cold climate—such as the winters of Québec—can extend the time required for the breakdown of half of the concentration present up to 9 or even 24 months.[44-48] This environmental persistence is not being taken into account in Health Canada's re-evaluation for glyphosate.[49]

Over time, glyphosate adsorption sites in soil may become saturated.[50] Consequently, subsequent applications of glyphosate, or even phosphorus amendments which compete for the same soil adsorption sites, may cause glyphosate to leach through soil into water.[46, 51] Because it is highly soluble in water,[52] a fraction of glyphosate can eventually leach from soils exposed to rain and end up in surface waters.[53] Glyphosate is detected in 88% to 97.5% of agricultural rivers monitoring in Québec.[8] In parallel, traces of this herbicide have been found in subsurface waters around the world, including in the USA and Europe,[50, 54-59] raising concerns among researchers about the potential for adverse impacts on human health.[60, 61] Contrary to current knowledge, Health Canada holds that glyphosate infiltration in groundwater is improbable.[49]

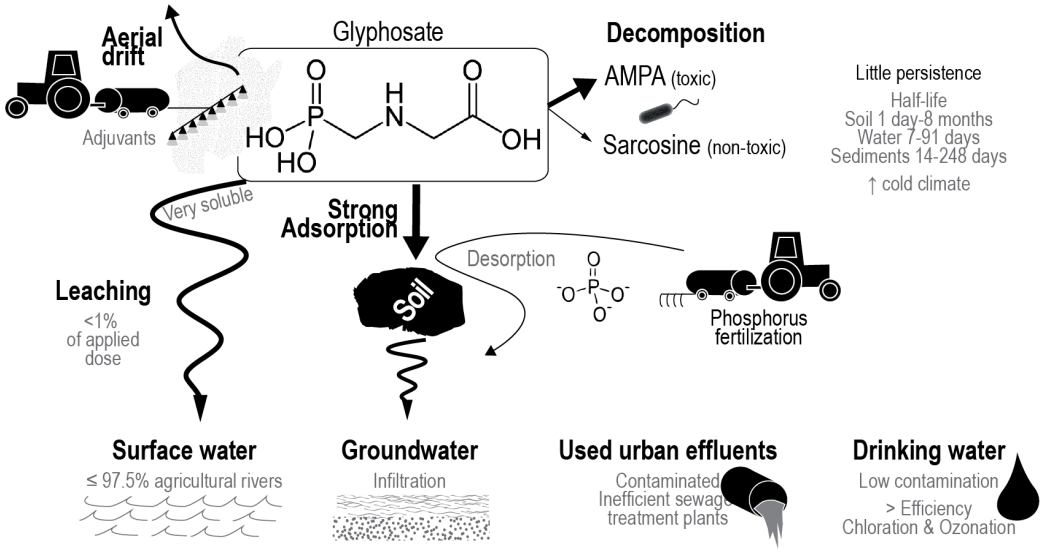

Figure 3: Glyphosate movement and environmental persistence.

People Exposed via Drinking Water and Food

Contaminated water or food ingestion is the primary pathway for exposure of the general population. Dermal or respiratory exposure is more of a concern for ocupational exposure of workers.[62]

In Québec, agricultural activities are concentrated in the St-Lawrence River valley, a source of drinking water for 45% of the province's population.[63] In tributaries of this river, around which corn and soy are intensively farmed, glyphosate concentrations up to 4.8 and 18 µg/l have been measured.[8] At the same time, water treatment plants appear to be ineffective in removing glyphosate from urban effluents.[64] Fortunately, drinking water treatment plants, which rely on chlorination or ozonation, can effectively decrease levels of glyphosate.[65-67] Glyphosate was below the detection limit in Montréal's drinking water distribution network between 2010 and 2014[68-70] and detected only once (maximum concentration of 2.1 $\mu g \cdot L^{-1}$) in a 2005-2009 study that tracked 204 water distribution networks in the province.[71] Although conforming to Canada's and Québec's drinking water criteria (< 280 µg/l),[65, 72] these concentrations would not pass the more stringent European drinking water criterion (< 0.1 µg/l).[73] Based on this same European criterion, US citizens have requested improved monitoring after finding glyphosate concentrations up to 0.33 µg/l in their drinking waters.[74]

People Exposed via Food

Glyphosate is also found at trace levels in our food.[75] Studies by the United Nations Food and Agriculture Organization (FAO) have found glyphosate residues in wheat, barley, lentils, soy, peas, sugar beets, corn and cereal-based products (such as beer).[76-78] Glyphosate could also be present in fish and meat.[62] However, the pesticide monitoring program run by the Canadian Food Inspection Agency (CFIA) does not regularly monitor glyphosate in studies tracking coffee, tea and fruit juices,[79] fresh produce sold between provinces,[80] or in food destined for babies[81] despite their enhanced sensitivity to pesticides.[82-84] This lack of monitoring is surprising and worrisome considering that glyphosate is used in several types of orchards, vegetable cultivation intended for human consumption, and in crops grown for livestock.

Besides water and food, certain groups of the general population may also be exposed to glyphosate from other media. For instance, children, especially those living on farms, may be exposed to glyphosate-contaminated house dust,[85] which can lead to exposure when they play on the ground or eat food that has fallen on it.[84] Glyphosate may also be present in low concentrations in medical or feminine hygiene products made of cotton.[86]

Insidious Effects on Animals

Glyphosate is considered moderately toxic to mammals, birds and aquatic animals (Figure 4).[52] On the other hand, it is considered highly toxic for rainbow trout.[52] Independent researchers have demonstrated that it is toxic for amphibians and phytoplankton at levels below regulatory criteria directed at the protection of aquatic life.[87, 88] For instance, glyphosate produces changes in phytoplanktonic communities at concentrations below the criterion for the chronic protection of aquatic life of Québec (65 µg/l).[89] That same criterion has recently been increased by the Canadian Council for the Ministers of the Environment to 800 µg/l)[26] in a review which did not seem to convince Québec specialists.[8] Those specialists worry that only the active substance is being evaluated, in isolation from all the other ingredients, including additives, that are found together in commercial formulations of glyphosate.[90] Additives contained in glyphosate formulations are known to increase the toxicity of the active substance. For example, RoundUp™ is considered 125 times more toxic to human cell lines than glyphosate alone.[91]

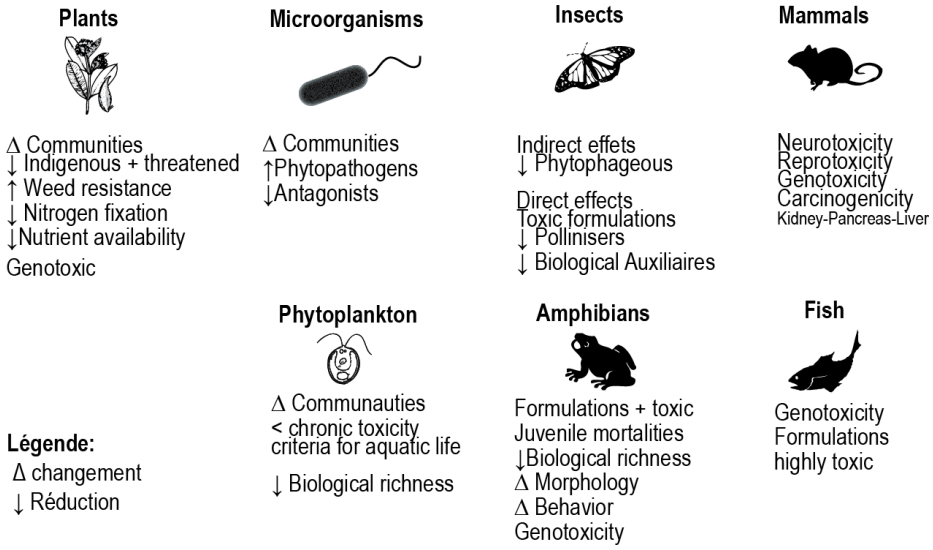

Figure 4: Glyphosate ecotoxicity.

Human Health Concerns

Academic researchers have found that glyphosates may be: endocrine disruptors[92, 93] carcinogenic,[94-98] capable of increasing the risk of spontaneous abortions,[92, 99] associated with congenital malformations,[100] and harmful to human nervous systems.[101, 102] Other scientists worry about its toxicity to fetuses (Figure 5).[103] In 2015, the International Agency for Research on Cancer (IARC) concluded that glyphosate was a probable human carcinogen, based on limited evidence of increased risk of non-Hodgkin lymphoma in humans, sufficient proof in animals (kidney, pancreas and skin cancers), and evidence of a carcinogenic mechanism involving genotoxicity and oxidative stress.[97, 104]

One epidemiologic study suggests that there is a high correlation between the increasing use of glyphosates and several human health problems including hypertension, heart attacks, diabetes, obesity, Alzheimer, senile dementia, Parkinson, multiple sclerosis, autism, inflammatory diseases of the digestive system, intestinal infections, kidney pathologies, as well as cancers of the thyroid, liver, bladder, pancreas, kidney and leukemia.[105] These correlations alone do not prove that glyphosate induces these effects, but another study confirmed a metabolic pathway explaining the potential role of glyphosate in these pathologies.[15]

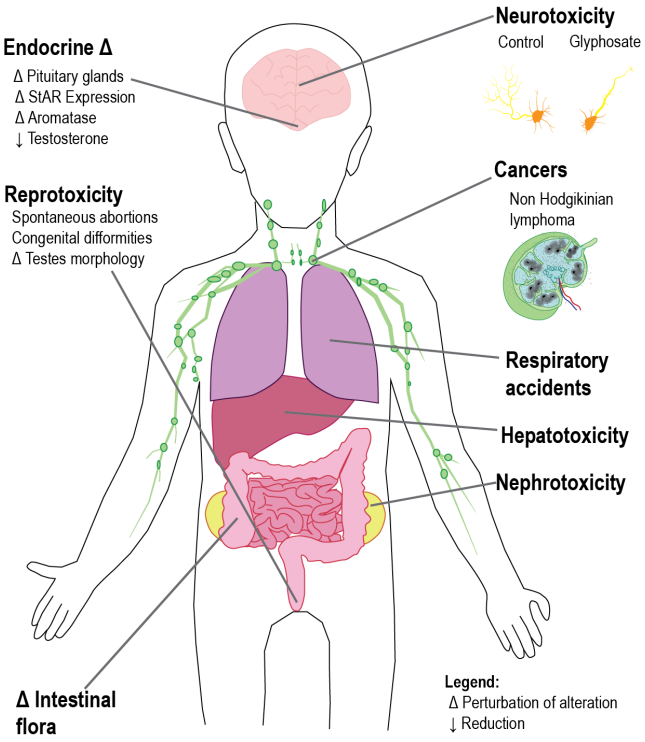

Figure 5: Glyphosate human toxicity.

Glyphosate Is a Hot Topic

Canada, the USA and the European Union are currently reviewing glyphosate registration. This year, it is likely that numerous scientific publications and legislative discussions will be directed at the potential risks and benefits associated with glyphosates. Among other things, it is expected that new findings in neurotoxicity and immunotoxicity, and cumulative or synergistic effects (interactions with other pesticides or chemicals) will be better characterized in studies leading up to the re-registration of glyphosate.[106, 107]

The regulatory agencies' registration processes strongly depend on results gathered by pesticide manufacturers. Unfortunately this casts doubt on the objectivity of toxicological studies.[108] Academic research results published in peer-reviewed journals are often excluded from registration files, restricting the potential of independent science to influence decision-making.[109]

Conclusions

Because glyphosate is the most widely sold pesticide in the world, it is imperative that we pay attention to the numerous potential impacts on human health and the environment suggested by independent studies. Glyphosate is not currently considered to be a highly toxic pesticide. It is not considered highly mobile in the environment, or strongly persistent. However, it is omnipresent in our environment, often moved in surface and groundwaters and more persistent than expected. We suspect that it may be linked to more chronic health effects in humans (cancer, endocrine disruption, neurotoxicity, fetotoxicity, etc.), as well as have a multitude of deleterious environmental effects (threats to plants or animals, aquatic and soil fauna; alteration to flora communities; alteration of nutritive value and disease resistance of plants, etc.) than is currently believed.

In the light of current scientific knowledge, it is essential that Health Canada take into consideration the persistence of glyphosate in cold climates and the risk of groundwater contamination during the registration review. A precautionary approach is essential in the registration review concerning the probable carcinogenesis recognized by IARC[97, 104] as well as the potential negative effects associated with various co-formulants. In

Québec, the risk of glyphosate's carcinogenicity is acknowledged by the provincial government which has found glyphosate in almost all the surface waters in the Saint-Lawrence lowlands.[8] The federal government relies on buffer zones – where spraying is prohibited – to protect surface waters and sensitive habitats. In addition, the provincial government further promotes, via a policy, the implementation of narrow vegetated riparian buffer strips. However, this may not suffice to stop glyphosate from contaminating streams.[110] Although several Québec municipalities restrict the use of pesticides for aesthetic purposes, the product is nevertheless readily available within their jurisdiction, meaning it can be used on private or institutional properties. Municipalities could impose further regulatory constraints to better prevent unwanted health and environmental side effects of glyphosate.

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