



Viewing evidence of harm accompanying uses of glyphosate-based herbicides under US legal requirements



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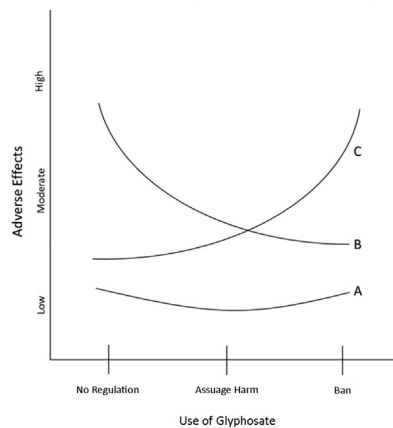
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HIGHLIGHTS

- The use of glyphosate is related to potential health problems.
- Agricultural producers use glyphosate to increase crop yields and reduce production costs.
- US law requires only allows pesticide residues in food if no harm will result from aggregate exposure.
- Epidemiological experts feel that glyphosate use is related to non-Hodgkins lymphoma.
- Registrations of glyphosate uses need to consider both the adverse effects of human health and food insecurity.

GRAPHICAL ABSTRACT

Social cost curves for possible regulatory options for glyphosate.



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ABSTRACT

Some epidemiological experts feel there is sufficient proof that glyphosate use adversely affects human health, and glyphosate has been labeled as probably carcinogenic by the International Agency for Research on Cancer. Federal law in the United States provides two major options under which health concerns about glyphosate use might be addressed. First, registrations of glyphosate-based herbicides (GBHs) need to be cancelled if the costs are greater than its benefits. Since the cancellation of GBH registrations in the United States would lead to higher maize and soybean prices that would adversely affect food security, further analyses are needed. Second, US law requires consideration of the human dietary risk from pesticide residues, and tolerances of allowable amounts of glyphosate residues allowed to remain in or on food items have been established. Social cost curves depicting three options for regulating GBHs show preferred strategies dependent upon the magnitude of adverse effects on human health and food insecurity. Measures to reduce harm to humans can be identified to ameliorate health damages to allow some uses of GBHs to continue, but only if the evidence supports the conclusion that “no harm will result from aggregate exposure to the pesticide chemical residue.”

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1. Introduction

Considerable concern is being voiced about the use of glyphosate-based herbicides (GBHs) in the production of agricultural foodstuffs (Carvalho, 2017; EFSA, 2017a, 2017b; Vandenberg et al., 2017).

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Glyphosate is a phosphonomethyl amino acid herbicide developed by Monsanto. Various GBHs are registered by the United States Environmental Protection Agency (EPA) to control weeds in agricultural and non-agricultural settings (US EPA, 2016a). In 2014, an estimated 825,000 kg of GBHs were used for the production of crops around the world (Statista, 2018). Glyphosate is the most heavily used herbicide in the world and is manufactured by more than 90 producers in 20 countries (WHO, 2014; WHO, 2017).

Monsanto and other companies also developed genetically modified crops that are glyphosate resistant. The resistant crops can be sprayed with GBHs and they survive while nonresistant weeds are killed. Fifty-six percent of glyphosate use in the world is on herbicide-resistant crops, including soybeans, maize, cotton, canola, and sugar beets (Benbrook, 2016; Brookes, 2014).

As with any herbicide, there are costs and benefits related to the use of glyphosate (Table 1). The costs that are most problematic are related to its occupational hazards to applicators and residual levels in food (Myers et al., 2016). Applicators face risks of inhalation, dermal exposure, and eye and skin irritation. As for exposure via residual levels in food, concern exists that possible long term effects of exposure may be linked to cancer (Gillam, 2018; WHO, 2017). Numerous groups have analyzed human safety data and reached different conclusions. The major health concern is whether GBHs are implicated in heightened risk of developing non-Hodgkin's lymphoma, a type of cancer originating in a person's lymphatic system. Some experts feel that glyphosate is currently causing this type of cancer in humans (In re: Roundup Products Liability Litigation, 2018a, b, pp. 165, 167, 405, 617).

From an environmental viewpoint, concerns exist about the cost associated with glyphosate-resistant weed species (Myers et al., 2016). For glyphosate, the International Survey of Herbicide Resistant Weeds (2018a) lists 42 resistant species, of which 17 are a problem in the United States (Heap and Duke, 2018). However, alternative herbicides, such as atrazine used in the production of maize, have greater numbers of resistant weed species (International Survey of Herbicide Resistant Weeds, 2018b). Another concern is that glyphosate may suppress some microorganisms and adversely affect plant uptake and transport of micronutrients (Schütte et al., 2017).

Positive environmental attributes may offset weed resistance. By eliminating or minimizing cultivation through no-till or conservation tillage, producers using herbicides can markedly reduce erosion (Brookes, 2014; Vogel et al., 2016). Producers also need less equipment, reduce fuel usage, and have lower labor costs for controlling weeds (Gianessi, 2013). By ridding crops of weeds, producers have higher yields per acre and less land is needed to grow the same amounts of food (Brookes et al., 2017; Teasdale and Cavigelli, 2009). In some areas, the use of GBHs allows the production of two crops a year that augments production on tillable acreages (Brookes and Barfoot, 2017). For weed control in developed areas, glyphosate use replaces noisy mechanical control, enhances safety, extends the life of paved surfaces, contributes to visual appeal, and reduces weed control costs (Benvenuti, 2004; Rask and Kristoffersen, 2007).

The EPA has concluded that glyphosate uses do not create unreasonable adverse effects on the environment. This conclusion was reached

due to the conclusion that chance and/or bias may explain the “positive carcinogenic potential of glyphosate” (US EPA, 2017, p. 47). However, some scientists disagree as to the merits of the various studies evaluating the carcinogenicity of glyphosate through animal models. Because glyphosate is often used with co-formulants, there are gaps in the biomonitoring data and epidemiological studies (D'Bryant, 2014; Vandenberg et al., 2017). Individuals and some organizations are calling for banning the use of GBHs (Ho and Sirinathsinghji, 2013; Sirinathsinghji et al., 2015), and some countries have banned GBHs (Baum et al., 2018). Yet, glyphosate use is important because it lowers food insecurity. Producers use GBHs to reduce production costs and increase crop yields (Brookes et al., 2017). These features contribute to lower-cost commodities and foods that are marketed around the world.

All uses of GBHs in the United States are pursuant to registrations granted by the EPA. To limit or cancel uses, the EPA would need to reevaluate the economic, social, and environmental costs, as well as food production, prices, and the agricultural economy (US Code, 2016, tit. 7). This would involve the alleged health costs associated with the use of GBHs being balanced with food insecurity and other benefits.

Litigation in the United States provides insights into the evidence connecting GBHs with risks of cancer to raise serious doubts about compliance with federal law. More than 400 lawsuits have been filed against Monsanto Co. in a US district court alleging exposure to their Roundup herbicide caused persons to develop non-Hodgkin lymphoma (In re: Roundup Products Liability Litigation, 2018a). In March of 2018, testimony from several witnesses disclosed evidence that scientific studies showed a relationship between glyphosate use and non-Hodgkin lymphoma, a type of cancer.

With respect to the litigation against Monsanto, the issue focuses on whether there is evidence that it can cause cancer. Studies concerning exposure of animals to various levels of glyphosate exposure showed in some cases that it can cause cancer. With this finding, it's biologically plausible and accepted in the scientific community that glyphosate is probably a human carcinogen. The next issue is whether humans are being exposed to levels of glyphosate that lead to harm. The experts are divided on this issue. However, the plaintiffs in this litigation had several experts who testified that glyphosate-based formulations were causing cancer in people (In re: Roundup Products Liability Litigation, 2018a, pp. 167, 207, 405, 617). In July 2018, the district court found that the testimonies of several experts were admissible so that the case can go to trial (In re: Roundup Products Liability Litigation, 2018b).

Other research raises additional issues. Research from South America found significant DNA damage to persons exposed to glyphosate by aerial spraying that suggests a genotoxic effect on the exposed individuals (Paz-y-Mino et al., 2007). Studies looking at co-formulants suggest that the addition of an adjuvant to glyphosate causes it to be more toxic (Coalova et al., 2014; Defarge et al., 2016). Another study found that acute exposure to GBHs causes molecular changes in the reproductive function (Cassault-Meyer et al., 2014), and data from several studies suggest that GBHs may adversely affect humans and the environment (de Araujo et al., 2016; Kwiatkowska et al., 2017; van Bruggen et al., 2018).

Given evidence of health concerns and the requirements of US law, further analyses for cancelling or curtailing glyphosate uses are needed. Employing existing data, we look at crop production, crop prices, and food security to identify factors that would be balanced by the EPA in considering whether to cancel registrations. We offer several measures to reduce to minimize harmful effects of glyphosate use so that most glyphosate uses could continue, thereby maintaining production. These measures can also reduce residues of glyphosate in drinking water and in or on food so that the tolerance levels meet the requirements of the Food Quality Protection Act of 1996 (US Code, 2016, tit. 21).

2. Safety analyses

Numerous studies analyzing glyphosate have attempted to evaluate the potential carcinogenicity of GBHs. It is generally admitted that GBH

Table 1
Benefits and costs associated with the use of GBHs.

Issue	Benefit	Cost
Applicator exposure	Fewer mishaps involving cultivation equipment	Possibly harmful
Exposure by residues in food	Cheap food	Residues may be harmful
Glyphosate-resistant weeds	Less cultivation, erosion, fuel, and labor	Herbicide purchases
Cropland needed for production	Less cropland needed	More herbicide residues in food
Weed removal in populated areas	Less costly, fewer mechanical accidents	Potential harm from residues in food

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