

The herbicide glyphosate

Glyphosate (sold under different formulations, among which the most widely known is Roundup) is the herbicide most used all over the world. It's a systemic and nonselective herbicide. Most common formulations contain the active ingredient (glyphosate), which prevents photosynthesis and affects other metabolic processes in plants sensitive to the herbicide; they also contain, among other products, surfactants which allow glyphosate penetrate through the cuticles of plant leaves.

This herbicide was developed in the 1970s, and released in 1974. The company Monsanto held the patents until 2000, and in 2009 it expected sales of 800 million liters of glyphosate-based herbicides, 55% of which were Roundup. Currently several companies produce herbicides based on glyphosate as the active ingredient. Most glyphosate-based products are classified as "dangerous" to the environment, with a "low" toxicity for mammals, "low" for birds, and "moderate" for fish. Some formulations are considered "irritating" and/or "harmful" to humans.

Permission to glyphosate in the European Union should have been revised in 2012. Nonetheless the European Commission adopted, behind closed doors, a directive delaying the review for glyphosate and other pesticides until 2015. Since this same Commission, however, has not yet approved the updating of the testing protocols that the industry should follow so as to request approval for their products, glyphosate has been revised under old, lax and outdated requirements. Therefore glyphosate will likely be authorised until 2030 [1]. Furthermore the review of the authorisation by part of the German government, on behalf of the EU, was conducted by a working group from agrochemical industries, not by independent scientists [2].

Risks to human health

Glyphosate, particularly its trademark Roundup (due to other added components), has been shown to have clear toxicity and/or risks of toxicity to humans, both in laboratory tests and in epidemiological studies.

Epidemiological studies have shown that glyphosate/Roundup:

- It's absorbed through the skin and mucous membranes [3],
- it produces neuromuscular symptoms [4],
- it causes a greater risk of preterm delivery by exposition when combined with other biocides [5],
- it increases the risk of abortion [6],
- it increases the risk of developing non-Hodgkin's lymphomas, by exposure to only glyphosate [7] or to mixtures of pesticides and herbicides including glyphosate [8],
- it could increase multiple myeloma incidence [9],
- it has been related, together with other factors, to chronic kidney diseases [10],

Laboratory studies show several negative effects:

- genotoxic effects [11], mutagenic effects [12], and negative effects on estrogen-regulated gene expression [13].
- changes in the structure and functioning of cells [14], cytotoxicity in human cells [15], effects that are increased when mixing glyphosate with surfactants [16].

- neurodegeneration [17], with a possible incidence on Parkinson disease,
- interferences with steroids synthesis and effects as endocrine disruptors [18], altering as well reproductive development of laboratory animals, reducing testosterone production [19]. It also affects negatively the functioning of male reproductive cells [20], and it has other negative effects on the reproductive performance of male laboratory animals [21],
- possible relationship to adrenal insufficiency problems [22],
- interferences with liver functioning [23],
- congenital malformations [24],
- toxic effects on human placental cells which may affect negatively human reproduction and foetus development [25],
- faster tumor development and higher mortality of laboratory animals [26],
- faster human breast cancer cell growth, with an estrogenic activity which is additive to that of genistein, a soy phytoestrogen. This implies that the consumption of soy products contaminated with glyphosate produces a risk of developing breast cancer [27],
- it has been related to the development of skin and breast cancers [28],
 - consumption of genetically modified maize tolerant to glyphosate-based herbicides or of contaminated water with the herbicide, produces negative effects on several vital traits, it promotes a faster development of tumors and increases mortality in laboratory mice [29].

Even the studies carried out by companies that produce these herbicides and revised by European authorities so as to approve glyphosate use, show evidences of malformations [30], but these authorities systematically minimize these results in order to give their approval.

Glyphosate effects on the biology and reproduction of freshwater snails have been reported as well, and as a result of this, its possible influence on the spread of mammal diseases as fascioliasis [31]. On the other hand, the exposure to this herbicide changes the susceptibility to antibiotics of some disease-producing bacteria, so in some cases these bacteria acquire greater resistance to antibiotics [32].

While also used in gardening and maintenance of railway lines, the use of commercial glyphosate-based products has increased significantly as a result of the commercialization of transgenic varieties of crops resistant to this herbicide. And significantly, the European Union raised the threshold of maximum allowable glyphosate residues in food by 200 % in 1999, to avoid problems with food imports containing genetically modified soybean resistant to glyphosate, and therefore these imports may be highly contaminated with this herbicide [33].

At the beginning of 2012 the maximum threshold of glyphosate in lentils was also increased [34], not because some scientific study had shown that the herbicide was less dangerous as previously thought, but in order to “accommodate the authorized use of glyphosate to dry lentil plants in the United States and Canada” [35], that’s it, for purely commercial reasons.

Glyphosate residues have been detected in the homes of farm workers, demonstrating the risk of exposure to this herbicide [36]. It has also been detected in the urine of populations of farmers and their families [37], in the blood of non-pregnant women in Canada [38], and in the urine of urban populations in Germany with levels between 5 and 20 times higher than the limit established for drinking water [39].

In March 2015, the IARC, the cancer committee of the World Health Organization declared glyphosate as “probably carcinogenic” given the evidences of its danger [40].

Effects on the environment

Glyphosate and its metabolite AMPA have been frequently detected in air and rain [41], as well as in surface water [42] of agricultural regions. A recent study in Catalonia [43] shows that 41 % of groundwater samples analyzed have a detectable glyphosate content, that the average value of all samples is $0.2 \mu\text{g.l}^{-1}$, that values of up to $2.5 \mu\text{g.l}^{-1}$ are reached, and that in 68 % of cases the average concentration of glyphosate along the year is over $0.1 \mu\text{g.l}^{-1}$, the maximum value allowed by the European legislation (Directive 2006/ 118 / EC).

This herbicide, in its commercial formulations, may impact severely and in different ways on aquatic ecosystems [44], “being able to produce extremely high levels of mortality in amphibians that could result in the reduction of their populations” [45]. The POEA surfactant, which is found in many commercial glyphosate-based products, is lethal to fish and amphibians, particularly in waters with basic pH [46]. Recently, the ‘Sociedad de Ciencias Aranzadi de Donostia’ made public the results of their studies on the impact of this herbicide in 10 amphibian species in Europe, showing that the doses recommended by manufacturers are deadly for most of them, and that lower doses affect the biology and behavior of amphibians [47]. On the other hand, it has been shown as well that mussels have great sensitivity to glyphosate-based herbicides [48]. Moreover it has been shown that glyphosate has toxic effects on some fish species [49], and can reduce resistance to other diseases, increasing incidence of infections [50]. Besides, the increased content of nutrients such as phosphorous and nitrogen (indirect effect) can affect trophic relationships in aquatic ecosystems [51].

Glyphosate absorbed by plants is eventually excreted by roots to the rizosphere, into the soil, where it’s toxic to several beneficial fungi and bacteria, unbalancing the soil microbial community [52]. Earthworms are also negatively affected by this herbicide, both alone or combined with other herbicides [53].

Furthermore herbicides containing glyphosate have negative effects on the behavior of bees at doses usual in agricultural environments, with negative consequences for long-term success of the colonies [54].

This herbicide not only affects plants over which it’s applied, or those close to fields affected by drift, but next generations of these plants also show problems of germination and/or of reduced development, “being able to produce important ecological changes” due to this effect [55].

The increasing use of this herbicide as a result of growing transgenic corn and soybean varieties in the United States has resulted in the loss of a great part of the population of some species of wild plants, and therefore, the loss of much of the population of some species of butterflies [56].

In 2009, the French Supreme Court upheld a previous sentence in which the company Monsanto (producer of Roundup, glyphosate main trademark) was condemned for not having told the truth about the security of this herbicide, and for having used misleading advertising when defining it as “biodegradable”. At the end of 2012, the Dutch regulatory committee also decided that an advertising of Roundup which appeared in June 2012 in several newspapers and that said the herbicide “has no effect on the soil”, was misleading [57].

Some effects on agricultural production

As other herbicides, its use has led to the appearance of resistant plants [58]. Worldwide it is estimated that there are 18 species of plants that have developed resistance to glyphosate, and in early May the appearance of a new resistant plant to glyphosate, *Ambrosia trifida*, was

confirmed in Canada [59]. In Spain populations of *Conyza bonariensis* resistant to glyphosate have been found in Andalucía [60].

In 2009 it was estimated that plants of the species *Amaranthus palmeri* resistant to glyphosate appeared in 250.000 ha cultivated in the United States [61]. In 19 states of this country resistant plants to the herbicide have appeared, already producing serious economic problems [62]. In the state of Georgia 40.000 ha are severely infested with plants of *Amaranthus palmeri* resistant to glyphosate, to the point that in the Macon County 4.000 ha had to be discarded in 2007 [63].

A study carried out in the US in 2012 shows that the area infested by plants resistant to glyphosate is already 24 million hectares, and about 50% of the farmers interviewed have resistant weeds in their fields [64].

Moreover this herbicide produces many problems to the crop in which it's applied and to next crops [65].

- In soybean crops, the application of glyphosate reduces poly-unsaturated fatty acids content and increases that of mono-unsaturated fatty acids. However, it decreases mineral concentration and crop biomass production [66],

- It increases sensitivity to fungal attacks and to diseases in crops in which the herbicide is applied [67], and in later crops in the same field as well [68],

- It decreases the viability of pollen, and under certain conditions, it also decreases pollen production, in transgenic maize varieties resistant to glyphosate [69].

Besides, severe negative effects have been proved on terrestrial insects which are important in the biological control of pests in soybean [70].

Roundup also produces negative effects on much of the beneficial bacteria in the digestive tract of chickens, while highly pathogenic bacteria, such as several species of genera *Salmonella* and *Clostridium*, are highly resistant to this herbicide [71]. As a result, Roundup would act as a factor favorable to the development of gastrointestinal diseases in these animals [72].

Studies in Denmark show that glyphosate is toxic to the metabolism of dairy cows. When cows are exposed to these herbicides, they show clear signs of toxicity in kidneys, and general cytotoxicity [73].

The company Monsanto itself, in its contracts with farmers that buy transgenic rape seed resistant to Roundup, recommends not graze these crops because, "right now, there isn't enough information that enables recommendations about appropriate and safe grazing" [74].

The commercial product Roundup, unlike glyphosate, also has negative effects on microorganisms used in dairy industry [75].

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