A SPECIAL RELEASE

Glyphosate

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Roundup used in an apple orchard in Ciardes, Italy. Despite studies linking it to chronic diseases such as cancer, it is widely used not only in agriculture but in public areas such as parks.

Pesticide Action Network Asia and the Pacific

P.O. Box 1170
10850 Penang, Malaysia

Tel: (604) 657 0271 / 656 0381
Fax: (604) 658 3960
Email: panap@panap.net
Homepage: www.panap.net

Meriel Watts, PhD
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Trade names

Roundup, and many others.

Uses

Broad spectrum (non-selective), systemic, post-emergence herbicide used to control annual and perennial plants including grasses, sedges, broadleaf weeds and woody plants.

It is used for crops, orchards, glasshouses, plantations, vineyards, pastures, lawns, parks, golf courses, forestry, roadsides, railway tracks, industrial areas, and home gardening.

Most used herbicide in the world.

Regulatory status

International

None.

National

Colombia: In 2001, a court order stopped the government aerial spraying of Roundup on illegal coca plantations on the border of Columbia and Ecuador (Antoniou et al 2010).

Israel: A court order stopped aerial spraying of Roundup on Bedouin farmers' crops in the Negev region of Israel between 2002 and 2004, after a coalition of Arab human rights groups and Israeli scientists reported high death rates of livestock, and a high incidence of miscarriages and disease amongst the people (Antoniou et al 2010).

Argentina: In 2010, a regional court in Argentina banned the spraying of glyphosate near populated areas of Santa Fe province. In 2012, a network of 160 physicians, health workers and researchers demanded a ban on aerial spraying of glyphosate and other pesticides in Argentina, based on increases in cancer and a range of other illnesses since the introduction of glyphosate-tolerant GM soybeans. The illnesses affect development, reproduction, and skin; and immune, respiratory, neurological, and endocrine systems (Robinson 2010; Sirinathsinghji 2012).

Manufacture

Monsanto, and many other companies. Global production capacity is 1.1 million tonnes, and global demand is about 0.5 million tonnes. Most comes from China - its capacity is 0.8 million tonnes and it exports 0.3 million tonnes.

Residues in food

Residues analysis is expensive and not often carried out, but residues have been found in bread, flour, wheat, barley, bran, oats, breakfast cereals, cereal bars, polenta strawberries, lettuce, carrots, soy, wild berries, and drinking water.

Health effects

Poisonings

Glyphosate herbicides have been frequently used in self-poisonings with many deaths, especially in Asia. Numerous occupational and bystander exposures have been reported.

In Columbia and Ecuador, widespread human poisonings have been reported following aerial spraying of cocoa crops with glyphosate. Effects included skin problems, abdominal pain, gastro-intestinal problems, acute respiratory infection, conjunctivitis, fever, allergies, kidney disease, lupus, cancer and birth defects. Many fish, cattle and poultry died (Oldham & Massey 2002; Trigona 2009; Valente 2009).

In 2003, 11 year-old Silvino Talavera died after direct exposure to pesticides used on soybean fields. His mother and siblings were hospitalised for 3 months. In 2004, a court convicted 2 men of culpable homicide caused by the irresponsible and criminal use of agrochemicals sprayed on soybean, specifically glyphosate. Three family members had glyphosate residues in their bodies (Williamson 2004).

Residues in people

Residues were found in all samples of urine from people in Berlin, ranging from 0.5 to 2.0 mg/L, assumed to come from food especially crops desiccated

pre-harvest by glyphosate (Brändli & Reinacher 2012).

Residues have also been found in the urine of farmers using glyphosate at level of 0.23 mg/L (Acquavella et al 2004).

Acute toxicity

Signs and symptoms of exposure include:

- irritation, swelling, tingling, itching or burning of the skin, photo-contact dermatitis, recurrent eczema, blisters, rashes;
- numbness in the face, swelling of the eye and lid, face, and joints;
- conjunctivitis, painful eyes, corneal injury, burning eyes, blurred vision, weeping eyes;
- oral and nasal discomfort, unpleasant taste, tingling and irritation of throat, sore throat;
- difficulty breathing, cough, coughing of blood, inflammation of lungs;
- nausea, vomiting, headache, fever, diarrhoea, weakness;
- rapid heartbeat, palpitations, raised blood pressure, dizziness, chest pains (IPCS 1994; Cox 1998; Gallardo 2001; Bradberry et al 2004).

Dr Ricky Gorringe of New Zealand estimated, based on cases presenting to his clinic, that 1 in 20 New Zealanders are sensitive to Roundup. The most commonly occurring symptoms are unnatural fatigue, band-like headache, "spaced-out feeling with loss of confidence", skin rash, and an otherwise unexplainable sudden increase in blood pressure. These problems are thought to largely result from micro-droplet inhalation (Watts 1994).

"Widespread disturbances of many body systems . . . after exposures at normal use levels. These include balance disorder, vertigo, reduced cognitive capacity, seizures, impaired vision, smell, hearing and taste, headaches, drops in blood pressure, body-wide twitches and tics, muscle paralysis, peripheral neuropathy, loss of gross and fine motor skills, excessive sweating and severe fatigue" (Ho & Ching 2003).

Chronic toxicity

Formulated products contain so-called 'inert' ingredients in addition to the active ingredient. Sometimes they can be more toxic than the active, and this is particularly so for Roundup, hence studies are often carried out separately on Roundup and glyphosate.

General: decreased body weight gain, increased incidence of cataract and lens abnormalities, increased liver weight, and degeneration of the liver and kidney at high doses in laboratory trials. Concentrations far below those normally sprayed kill human skin cells, cause aging of the skin, and can lead to skin cancer. (US EPA 1993; Heu et al 2012 a,b)

Genotoxicity: glyphosate and/or Roundup are genotoxic in human lymphocytes, liver cells, and mouth cells; and in mouse bone marrow, liver and kidney cells, bovine lymphocytes, fruit flies, fish, alligators, tadpoles, sea urchins, onion root-tip cells, and bacteria. Epidemiological studies show DNA damage in people exposed to aerial spraying of glyphosate in Ecuador and Colombia. One of the main health implications of genotoxicity is cancer. (Vigfusson & Vyse 1980; Rank et al 1993; Kale et al 1995; Bolognesi et al 1997, 2009; Clements et al 1997, Lioi et al 1998a,b; Peluso et al 1998; Kaya et al 2000; Grisolia 2002; Mueckay & Maldonado 2003; Monroy et al 2005; Siviková & Dianovskỳ 2006; Bellé et al 2007; Çavaş & Könen 2007; Cavalcante et al 2008; Gasnier et al 2009; Guilherme et al 2009; Mañas et al 2009a,b; Poletta et al 2009; Prasad et al 2009; Koller et al 2012)

Other cancer-causing mechanisms: glyphosate or Roundup cause cell division dysfunction, cell-cycle dysregulation at concentrations hundreds of times lower that those sprayed. They inhibit RNA transcription at concentrations 25 times lower than those sprayed; and cause oxidative stress in human lymphocytes and skin cells, bovine lymphocytes, bullfrog tadpoles, pregnant rats and their foetuses, rat liver cells, mouse kidney cells and liver DNA, fish brain, liver and kidney cells, and in rice leaves. Additionally glyphosate enhanced the genotoxic effect of hydrogen peroxide though an oxidative stress mechanism. Roundup caused mild oxidative stress in the brain, liver and kidneys of goldfish. (Lioi et al 1998a; Lueken et al 2004; Pieniążek et al 2004; Gehin et al 2005, 2006; Lioi et al 1998b; Costa et al 2008; Beuret et al 2005; El-Shenawy 2009; Bolognesi et al 1997; Marc et al 2002, 2003, 2004, 2005; Ahsan et al 2008; Lushchak et al 2009)

Cancer: thyroid C-cell carcinomas, liver carcinoma, leukaemia, lymphoma; adenomas of pancreas, liver, thyroid in rodents at high doses. Studies on mice show it has tumour-promoting potential for skin cancer. Both Roundup and glyphosate cause proliferation of breast cancer cells. (US EPA 1993; Hardell & Eriksson 1999; Lin & Garry 2000; Hokanson et al 2007; George et al 2009)

Epidemiological studies indicate non-Hodgkin's lymphoma and multiple myeloma. Doctors and the state government of Chaco report increased incidence of cancer in Argentina following the introduction of GM soy crops that are heavily sprayed with Roundup. (McDuffie et al 2001; Hardell et al 2002; De Roos et al 2003; Robinson 2010; Chaco 2010)

Endocrine disruption: Roundup but not glyphosate inhibits the conversion of androgens to oestrogen, disrupts the production of progesterone, and reduces testosterone levels. Both Roundup and glyphosate dysregulate oestrogen-dependent breast cancer cells, and interfere with aromatase, the enzyme that converts androgens to oestrogen. Glyphosate is anti-androgenic at concentrations 40 times lower than residues permitted in GM soybeans. (Walsh et al 2000; Gasnier et al 2010; Hokanson et al 2007; Clair et al 2012a).

Reproductive and developmental toxicity: Monsanto has known since 1993 that low doses of glyphosate cause malformations in animals. These include reduced ossification and higher incidence of skeletal and organ anomalies; and reduced number of viable foetuses (Antoniou et al 2011).

Rats treated with sublethal doses of Roundup Max during pregnancy had decreased implantation rates, increased resorption of foetuses, and the surviving offspring had decreased skeletal calcification (Gerişlioğlu et al 2010).

Roundup Transorb significantly altered the progression of puberty, reduced testosterone production and altered seminiferous tubules (Romano et al 2010).

Glyphosate, Roundup, the adjuvant POEA, and the metabolite AMPA all cause cell death in human umbilical, embryonic and placental cells, at dilutions far below those used in agriculture. These effects together with the endocrine disrupting effects can result in pregnancy problems leading to abnormal foetal development, low birth weights, or miscarriages. Glyphosate kills testicular Sertoli

cells. (Benachour et al 2007; Benachour & Seralini 2009; Gammon 2009; Clair et al 2012a)

Birth defects are reported in Argentina and Paraguay amongst those exposed to aerial spraying of glyphosate. These are neural tube defects (absence of the majority of the brain, skull and scalp), small head, and craniofacial malformations, strikingly similar to those caused by glyphosate in laboratory studies on amphibia.

There has been a 4-fold increase in birth defects in the Argentinean state of Chaco with the introduction of GM Roundup Ready crops (Benítez-Leite et al 2009; Paganelli et al 2010; Antoniou et al 2010; Chaco 2010). Epidemiological studies have reported miscarriages, pre-term deliveries, and reduced fecundity (Savitz et al 1997; Curtis et al 1999; Arbuckle et al 2001).

Neurotoxicity: Glyphosate inhibits the growth of axons and dendrites in nerve cells. It also depletes the neurotransmitters serotonin and dopamine, and damages the substantia nigra region of the brain, implicating them in Parkinson's disease (Axelrad et al 2003; Anadón et al 2008; Astiz et al 2009).

Immunotoxicity: exposure to glyphosate has been associated with allergic responses; one case developed autoimmune blistering of skin and mucous membranes after exposure to the fumes of burning glyphosate. Immune effects have been found in fish. Immune function effects have been reported from Argentina in areas of heavy aerial spraying of glyphosate over GM crops. (el-Gendy et al 1998; Slager et al 2009; Fisher et al 2008; Sirinathsinghji 2012).

Environmental and agroecological effects

Toxicity

Aquatic: Glyphosate is increasingly found in the aquatic environment at levels that have caused significant effects on species that underpin the entire aquatic food chain. It can alter the composition of natural aquatic communities, tipping the ecological balance, changing clear water to turbid water, giving rise to harmful algal blooms, and reducing species richness. It can have profound impacts on micro-organisms, plankton, algae and amphibia at low concentrations: one study showed a 70% reduction in tadpole species and a 40% increase in algae. Insects, molluscs, crustaceans, sea urchins, reptiles, tadpoles, and fish can all be affected, vulnerability within each group varying dramatically between species. Effects include reproductive abnormalities, developmental abnormalities and malformations, DNA damage, immune effects, oxidative stress, modified enzyme activity, decreased capacity to cope with stress and maintain homeostasis, altered behaviour, and impaired olfaction that can threaten their survival. Amphibians are particularly vulnerable. Roundup is generally more toxic than glyphosate, especially to fish. (Relyea 2005; Pérez et al 2007; Vera et al 2009; Saxton et al 2011).

Terrestrial: Glyphosate at concentrations lower than those used in agriculture inhibited the growth of 3 microorganisms important in food processing. It interferes with key molecular mechanisms which regulate early development in chickens leading to congenital malformations (Paganelli et al 2010; Clair et al 2012b).

Agroecological disruption

Beneficials: Glyphosate has adverse effects on some earthworms; and on a number of beneficial insects useful in biological control, particularly predatory mites, carabid beetles, ladybugs, spiders, and green lacewings. It can also adversely affect other insects that play an important part in ecological balance such as springtails, wood louse, and field spiders (Schneider et al 2009; Benamú et al 2010; Griesinger et al 2011).

Soil organisms: Glyphosate has adverse effects on some earth-worms. Glyphosate is toxic to some but not all soil microorganisms, altering microbial community dynamics in ways that are harmful to plants and to ecological balance. It increases microorganisms capable of metabolising the chemical. It can reduce some beneficial organisms such as saprophytic fungi that decompose dead plant material and are important for soil fertility. Glyphosate is toxic to nitrogen-fixing bacteria, and also increases denitrification contributing to nitrous oxide emissions and nitrogen loss from soil. (Grossbard 1985; Carlisle & Trevors 1988; Tenuta & Beauchamp 1996; Zablotowicz & Reddy 2007; Kremer & Means 2009; Lupwayi et al 2009).

Crop effects: Numerous studies show glyphosate stimulates growth of some fungal pathogens, such as Fusarium, that cause diseases in many crops. The upsurge in use of glyphosate in no-till agriculture has brought about a resurgence of some diseases. Glyphosate binds micronutrients in the soil and causes micronutrient deficiencies in plants that increase their susceptibility to disease, decrease their vigour, and produce micronutrient-deficient food crops. It can reduce the plant's production of lignin and phenolic compounds, which are also important for disease resistance. It can reduce nitrogen-fixation in legumes such as soybean. It causes nutritional changes in soy including reduced iron, linoleic acid and linolenic acid, and increased monounsaturated fatty acids (Ozturk et al 2008; Johal & Huber 2009; Zobiole et al 2010).

Resistance: 23 species of plants in 20 countries are resistant to glyphosate and Monsanto is encouraging farmers to use dicamba or 2,4-D alongside the Roundup (Monsanto 2012; Schiffman 2012; WeedScience.com 2012).

Environmental fate and contamination

Air and rain: Glyphosate and the metabolite AMPA were found in up to 100% of samples of rain and air in agricultural areas in the US; about 0.7% of glyphosate applied in agricultural areas is removed from the air in rain. It was one of the most frequently detected pesticides in rainwater in Belgium in 2001; also measured in rain in Canada, at all sites and throughout the "growing season", at a maximum concentration of 1.51 ug/m^2/day (Quaghebeur et al 2004; Humphries et al 2005; Chang et al 2011).

Soil: relatively persistent (up to 180 days in some soils). The metabolite AMPA accumulates: 20 years after application, 8.5% of the amount applied is likely to remain in soils (Mamy et al 2010).

Aquatic: Runoff from hard surfaces in urban areas is increasingly seen as a source of surface water pollution with glyphosate and AMPA. Residues of glyphosate and AMPA were found in surface water in Argentina, Canada, China, France, Netherlands, Norway, Switzerland, Germany, UK, USA; in wastewater in France and Canada, landfill leachate in the UK, and groundwater in Spain. (Slack et al

2005; Ghanem et al 2007; Peruzzo et al 2008; Hanke et al 2010; Mamy et al 2010; Székács & Davas 2011)

Glyphosate has been found in groundwater and wells in a number of countries, including Canada, Denmark, the Netherlands, and USA (IPCS 1994, US EPA 1992; Cox 1998).

Both glyphosate and AMPA have been found in marine sediment in the Waitemata Harbour and Hauraki Gulf in New Zealand, believed to have come largely from the spraying of urban roadside weeds. The maximum glyphosate concentration detected was 1 ppm, while AMPA had a maximum level of 0.37 ppm (Stewart et al 2009).

Bioaccumulation: Low-level bioaccumulation has been found in snails, fish, and freshwater worm (Wang et al 1994; Contardo-Jara et al 2009; Druart et al 2011).

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