Glyphosate: Addendum 2012*

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Summary

Huge production capacity for glyphosate in China has resulted in the world being oversupplied. Total global production capacity is more than twice global demand, putting pressure on industry to decrease prices and disperse GM Roundup Ready crops.

There are still no national regulations limiting glyphosate, but there are some local court rulings restricting its use because of reported health impacts such as birth defects, cancer and miscarriages. Scientists, doctors, activists and others continue to push for restrictions and bans.

Health effects

Poisonings
Doctors in Argentina report vomiting, diarrhoea, respiratory problems, skin rashes, cancer, infertility, pregnancy problems, and birth defects in association with aerial spraying of GM crops.

Glyphosate has been found in the urine of urban dwellers in Berlin, Germany.

General effects
Glyphosate at low concentrations damages liver, kidney and skin cells; in the latter, it causes aging and potentially cancer. Its ability to penetrate skin increases 5-fold when skin is damaged.

Long-term toxicity
Cancer and genotoxicity
Glyphosate promotes skin tumours in mice. Glyphosate and Roundup caused DNA damage in human mouth cells, and was clastogenic in mouse bone marrow cells, adding to a number of previous studies showing it to be genotoxic. Roundup caused mammary and skin tumours in rats.

Endocrine disruption and reproduction
At low levels, glyphosate is anti-androgenic, decreases production of testosterone and other hormones in testes, and alters the progression of puberty. Roundup kills testicular cells.

Monsanto has known since the 1980s, and the German government since 1998, that glyphosate causes birth defects. New studies show malformation in the heads of frogs that are similar to birth defects amongst people exposed to aerial spraying of Roundup over GM soy crops in Latin America.

Neurological effects
Further evidence is provided for a possible link with Parkinson's disease through the effect of glyphosate products on dopaminergic neurons.

Environmental effects

Aquatic effects
There is further evidence of disruptive effects on aquatic communities, particularly on diatoms and phytoplankton. Other aquatic impacts include effects on crabs, amphibia, reptiles and fish.

Terrestrial effects
Glyphosate inhibits the growth of 3 important food processing microorganisms, alters the composition of soy beans, adversely affects the beneficial predators wolf spider and web orb spider, and interferes with key molecular mechanisms, including endocrine, in birds.

Environmental fate

Air
Glyphosate and the metabolite AMPA were found in 60 to 100% of samples of rain and air in agricultural areas in the US; about 0.7%

*To be read in conjunction with the Glyphosate Monograph published November 2009

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of glyphosate applied in agricultural areas is removed from the air in rain.

Soils
The metabolite AMPA accumulates in soils.

Water
Residues of glyphosate and AMPA were found in surface water in Argentina, Norway, Switzerland and Germany, in wastewater in France and Canada, landfill leachate in the UK, and groundwater in Spain. Both glyphosate and AMPA have been found in marine sediment in New Zealand, believed to have come largely from the spraying of urban roadside weeds.

Resistance
Twenty three species of plants in 20 countries are resistant to glyphosate and Monsanto is encouraging farmers to use dicamba or 2,4-D alongside Roundup.

Bioaccumulation
There is evidence of some bioaccumulation in snails.

Climate Change effects
There is increased tolerance to glyphosate in invasive grasses with increasing carbon dioxide levels in the atmosphere.

Manufacture

Glyphosate was first synthesized in Switzerland in 1950, then developed as a herbicide by Monsanto in 1970 (Brandli & Reinacher 2012). The global production capacity is about 1.1 million tonnes, with China's capacity alone being 835,900 tonnes. Global demand is about 0.5 million tonnes so there is a huge overproduction capacity. China by itself provides more than enough to meet global demand, and exports 0.3 million tonnes. Hence, there is significant pressure to decrease prices and to disperse Roundup Ready GM crops (Szekacs & Davas 2011).

Regulatory status

National regulatory action
In 2001, a court in Colombia ordered the government to stop aerial spraying of Roundup on illegal coca plantations on the border of Columbia and Ecuador (Antonio et al 2010).

A court order stopped aerial spraying of Roundup and other pesticides 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 (Antonio et al 2010).

In 2010, a regional court in Argentina banned the spraying of pesticides, including glyphosate, near populated areas of Santa Fe province (Robinson 2010).

In 2012, a network of 160 physicians, health workers and researchers demanded a ban on aerial spraying of 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 (Sirinathsinghji 2012).

In May 2012, PAN Europe and Greenpeace filed a complaint before the General Court of the European Union, challenging the Commission's decision to delay the reassessment of glyphosate for 3 years despite dozens of recent studies giving cause for concern about health effects such as cancer, DNA damage, endocrine disruption, and birth defects (Mullerman & van Bekkem 2012).

Toxicological Assessment

Absorption and distribution

Glyphosate penetration of damaged skin is about 5-fold greater than that of healthy skin according to Heu et al (2012b).

Chronic toxicity

General effects
Roundup killed embryonic kidney cells at levels 200-fold lower that those recommended for agricultural use. The LC50 was 57.2 ppm (Mesnage et al 2012).

Four Roundup formulations caused cell death in human liver cell lines, at concentrations described as "far below those used in agriculture", and also below those legally allowed as residues in GM food. Whereas legal levels can be 200 ppm, this study was carried out at dose levels of 40-96 ppm. Effects were stronger for the Roundup formulations than for glyphosate alone (Gasnier et al 2010).

Glyphosate, at low doses (15-70 μM), kills human skin cells by inducing mitochondrial membrane potential disruption leading to oxidative stress. Deregulation of the cell death mechanism or an improper removal of damaged cells can lead to cancerous lesions, and the authors warned that their study “confirms the potential public health risk” of glyphosate (Heu et al 2012a). Other studies have also shown that glyphosate induces the death of human skin cells though oxidative stress (Ellie-Caille et al 2010; Gehin et al 2005, 2006 in original monograph). At low, but not high, concentrations it causes damage to skin similar to that of the aging process, i.e. thickening of the skin and induction of subcellular cytoskeleton structures (Heu et al 2012b).

Cancer

Studies on mouse skin showed that glyphosate has tumour-promoting potential, but not tumour-initiating potential, for skin cancer (George et al 2009).

In a 2-year rat feeding study on the effects of GM soy and Roundup, Seralini et al (2012) found that Roundup at low levels of exposure induce severe hormone-dependent mammary, liver and kidney disturbances, at all levels of exposure (50 ng/L, the level in regular tap water; 400mg/kg, the US MRL for glyphosate in some agricultural feed; 2.25g/L, half the minimal agricultural working dilution). When rats were fed non-GM diets but with Roundup in their drinking water, there were 2-3 times more deaths (all treatments) than in the control group, with females being more sensitive than males. In females the main cause of death was large mammary tumours (which impeded breathing and were non-metastatic), and in males mainly liver and kidney problems; large skin tumours also occurred. Additionally all females had mammary hypertrophies and in some cases hyperplasia with atypia – except for one who instead had metastatic ovarian carcinoma. There was also increased incidence of pituitary gland adenomas, hyperplasias and hypertrophies in females.

Genotoxicity/ mutagenicity

Both glyphosate and Roundup caused DNA damage in human buccal (mouth) epithelial cells with short-term (20 mins) exposure to concentrations corresponding to a 450-fold dilution of concentrations normally used in agriculture, prompting the authors of the study to warn that inhalation may cause DNA damage in mouth and respiratory tissues of exposed individuals. Even a 1,350-fold dilution of a spraying solution of Roundup caused acute and genotoxic effects on human cells in this study (Koller et al 2012).

Glyphosate was clastogenic in mouse bone marrow cells, causing chromosomal aberrations and induction of micronuclei. Cytotoxicity was demonstrated by a significant decrease in mitotic index (Prasad et al 2009).

A study reported in the original monograph found that people exposed to aerial spraying of glyphosate in Ecuador had significantly higher DNA damage (Paz-y-Miño et al 2007); a follow-up study 2 years after spraying ceased found that significant DNA damage was no longer present (Paz-y-Miño et al 2011).

Endocrine disruption

Low, nontoxic doses of Roundup Bioforce (1 ppm) and glyphosate (0.366 ppm), similar to the levels found in the urine of those occupationally exposed (0.233 ppm glyphosate), decreased testosterone levels by 35% in rat testes. Endocrine disruption in testicular cells can result in adverse effects, including epigenetic ones, on reproduction, including decreased sperm count and increased abnormal sperm (Clair et al 2012a). The study also found that glyphosate, at doses of 1-10ppm, increased aromatase mRNA in testicular cells, the enzyme that converts androgens to oestrogens.

Reproductive and developmental effects

A report by a group of internationally acclaimed independent scientists (Antoniou et al 2011) found that:

- Industry (including Monsanto) has known from its own studies since the 1980s that glyphosate causes malformations in experimental animals at high doses.
- Industry has known since 1993 that these effects also occur at lower and mid doses.
- The German government has known since at least 1998 that glyphosate causes malformations.
- The EU Commission’s expert scientific review panel knew in 1999 that glyphosate causes malformations.
- The EU Commission has known since 2002 that glyphosate causes malformations, yet approved it anyway.

Antoniou et al (2012) concluded: "a substantial body of evidence demonstrates that glyphosate and Roundup cause teratogenic effects and other toxic effects on reproduction". They analysed industry data on glyphosate as reported in the German authorities 1998 draft assessment report, and found the following birth defects reported: increased heart malformations and abnormalities; absent kidneys; extra, distorted and rudimentary ribs; absent postcaval lobe of the lungs; reduced ossification of cranial centres and sacro-caudal vertebrae; undefined skeletal malformations; and embryonic deaths. The German authorities had dismissed the birth defects on grounds such as a nonlinear dose-response (which is not in accord with current scientific understanding), and that some of the effects only happened at doses toxic to the mother (this is not an unusual situation with industry studies which use low numbers of animals and hence have to use high doses to find a statistically significant effect, in the process obscuring effects that may occur at low or medium frequency). As a result of the dismissal of these effects, the acceptable daily intake (ADI) set by the German regulators, of 0.3 mg/kg is 3 times higher than it should be based on these studies alone, according to Antoniou et al. However, if more recent peer reviewed studies were taken into account, the ADI would be 12 times lower, at 0.025 mg/kg/bw.

Romano et al (2010) described the formulation Roundup Transorb as "a potent endocrine disruptor in vivo" when rats were exposed during the puberty period. They found that it significantly altered the progression of puberty, reduced testosterone production and altered seminiferous tubules.

Low subclinical doses of glyphosate, "indicative of involuntary exposure to residual agrochemicals", (10 mg/kg bw) caused oxidative stress in testicular tissue and decreased antioxidant defence systems resulting in modified hormonal parameters involved in reproductive function, including decreases in testosterone, follicle stimulating hormone and luteinizing hormone levels in the plasma of treated rats. The effects were worse with simultaneous exposure to glyphosate, dimethoate and zineb (Astiz et al 2009). Clair et al (2012a) also found that exposure to Roundup Bioforce and glyphosate "at agricultural levels" kills testicular Sertoli cells.

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 (Gerislioglu et al 2010).

Nervous system

The original monograph reported 2 studies indicating a possible link with Parkinson's disease. A third study has found that glyphosate products (in this case Touchdown) can cause degeneration of the dopaminergic neurons, a hallmark of Parkinson's disease (Negga et al 2012). This study was carried out on roundworms, confirming the previous studies on rats.

Gui et al (2012) lent further support to the epidemiological findings, case reports, and laboratory studies that indicate glyphosate exposure may be causing Parkinson's disease in their study on the neurotoxic effects of glyphosate. They showed that it inhibited viability of differentiated cells in a rat adrenal cell line used to study neuronal differentiation. It induced cell death via autophagy as well as apoptosis, in a dose- and time-dependent manner. Both autophagy and apoptosis are involved in the degenerative processes of Parkinson's disease (Gui et al 2012).

Human Exposure

Non-occupational exposure

A study of people in Berlin, who had no direct contact with glyphosate, found residues in all samples of urine, ranging from 0.5-2.0 ng/ml, which is 5-20 times the level allowed in drinking water of 0.1 ng/ml (0.1 mg/L, or 0.1 ppb). The residues were assumed by the authors to come from food, especially from crops that are desiccated pre-harvest by glyphosate (Brandli & Reinacher 2012).

Health Effects and Poisonings

Acute effects observed in humans

Intentional ingestion

A 56-year old woman ingested about 500 mL of herbicide containing glyphosate isopropylamine salt. Symptoms included hypotension, coma, hyperkaliemia, and respiratory and renal failure. The patient survived the acute phase of poisoning, but she developed vigil coma (a state in which the patient appears awake with eyes open but is in an unresponsive coma) (Potrebic et al 2009).

In a study of case fatalities from intentional ingestion of pesticides in 2 Sri Lankan clinics, glyphosate caused 21 deaths out of 887 ingestions - a fatality rate of 2.4% (Dawson et al 2010).

Occupational and bystander exposure
Doctors in Argentina report acute effects from the aerial spraying of glyphosate to include vomiting, diarrhoea, respiratory problems and skin rashes (Robinson 2010).

Long-term effects observed in humans

Doctors in Argentina have reported a dramatic upsurge in long-term effects in areas where genetically modified soy crops are aerial sprayed with glyphosate. They include cancer, infertility, pregnancy problems, birth defects, and respiratory diseases (Robinson 2010).

Cancer
A report released by Argentina's Chaco state government in April 2010 (Chaco 2010) refers to a significant increase in cancer in La Leonesa, an agricultural town, including a 3-fold increase in childhood cancers, particularly leukaemia, lymphoma, and brain tumours, coinciding with the dramatic increase in transgenic crops such as soy which are heavily sprayed with glyphosate. These effects could be caused by a number of factors including other pesticides, but there is support from epidemiology and laboratory studies to indicate that glyphosate might be contributing to these cancers.

Reproductive
Birth defects in the Argentinean state of Chaco, where GM soy and rice crops are heavily sprayed with glyphosate, increased nearly fourfold over the years 2000 to 2009, according to a report released by the Chaco state government (Chaco 2010). Paganelli et al (2010) also reported that "several cases of malformations together with repeated spontaneous abortions were detected in the village of Ituzaingó [Cordoba], which is surrounded by GMO-based agriculture". Antoniou et al (2012) reported on another study showing higher incidences of spina bifida, microtia, cleft lip with cleft palate, polycystic kidney, postaxial polydactyly and Down's syndrome in the intensive GM soy cultivation area in Cordoba. Similar birth defects were also experienced by 52 women in Paraguay, who were exposed during pregnancy to herbicides (Paganelli et al 2010).

These birth defects, specifically neural tube defects and craniofacial malformations, showed striking similarities to those induced by glyphosate in laboratory experiments (Paganelli et al 2010). The congenital malformations in Paraguay included microcephaly (small head), anencephaly, and cranial malformations (Benítez-Leite et al 2009). Anencephaly occurs when the neural tube fails to close during pregnancy resulting in the absence of the majority of the brain, skull and scalp. In 2009, Argentinean researchers lead by Professor Carrasco showed that 1/5000th of the concentration of commercial glyphosate disrupted the development of the craniofacial skeleton. The malformations occurred at 2.03 mg/kg glyphosate; residues have been found in soybeans up to 17 mg/kg. The glyphosate caused marked alterations in cephalic and neural crest development and shortening of the anterior-posterior axis in tadpole embryos, resulting in deformities in the cranial cartilages at the tadpole stage. Other effects included shortening of the trunk, reduced head size, and eye defects; and the authors concluded their results were "compatible with the malformations observed in the offspring of women chronically exposed to glyphosate-based herbicides during pregnancy" (Paganelli et al 2010; Antoniou et al 2010).

Media items report that, in April 2012, Argentinean tobacco farmers filed a lawsuit against Monsanto and tobacco companies that had asked them to use Monsanto's products, which they knew or should have known cause birth defects. The majority of the small family-owned farms use Roundup. Birth defects and other effects cited in the complaint include cerebral palsy, Down syndrome, psychomotor retardation, missing fingers, blindness, epilepsy, spina bifida, intellectual disabilities, metabolic disorders, and congenital heart defects (Filip 2012).

Environmental Effects

Aquatic effects

Aquatic communities
Glyphosate acts as a nutrient source to some

algae able to tolerate its herbicidal effects, but kills other algae, thus affecting aquatic community structure. In Lake Erie, Canada, glyphosate increased the abundance of the blue-green algae *Planktothrix* spp.; some members of this species can cause harmful algal blooms. It also decreased the abundance of *Microcystis* spp., a cyanobacteria that can also cause algal blooms (Saxton et al 2011).

Glyphosate also modified the structure and function of experimental freshwater ecosystems (mesocosms) in Argentina, producing a long-term shift, and changing clear water to turbid water. It killed diatoms and favoured the growth of cyanobacteria, but the overall biomass production decreased. It also delayed the colonisation of the mesocosms by periphyton, one of the most significant microbial communities forming the base of food webs in shallow lakes, so the delay could have important consequences on the ecology of the whole freshwater system (Vera et al 2009).

In an experiment on amphipods (small crustaceans) in Brazil, all concentrations of Roundup caused significant changes in all biochemical parameters, depressed reproduction and decreased survival rate, indicating a potential toxic effect at very low concentrations. Amphipods are an important link in the food chain and these changes can lead to significant changes in the structure of freshwater environments (Dutra et al 2011).

A single application of the formulated product Glifosato Atanor (mean concentration of 3.45 mg/L) caused increased phosphate and chlorophyll *a* concentrations, and a rapid increase in abundance of bacterioplankton, planktonic picocyanobacteria, and the rotifer *Lecane* spp., resulting in turbidity and rapid deterioration in water quality (eutrophication) (Vera et al 2012).

Aquatic invertebrates

Roundup is toxic to freshwater shrimps with the following values for lethality (96hr LC50 mg/L):

Neonates	Juveniles	Adults
2.5	7.0	25.3

The lethality for neonates is much lower than usual application rates (20-30 mg/L). Survivors, especially neonates, were erratic and slow in their movements (Mensah et al 2011).

Crabs

Estuarine blue crabs in the US treated with levels of Roundup that caused 20% mortality, experienced significantly reduced time to metamorphosis and increased the frequency of juveniles dying within 6 hrs of moulting. Delays in moulting can reduce survival ability. The larvae were 50-fold more sensitive to Roundup than the juveniles (Osterberg et al 2012).

Amphibians

Glyphosate-based herbicides and glyphosate itself interfere with key molecular mechanisms, including endocrine mechanisms, which regulate early development in frogs, leading to congenital malformations (Paganelli et al 2010).

In an experiment on 3 frog varieties in North America in simulated outdoor habitats, “environmentally relevant concentrations” of Roundup induced in surviving tadpoles morphological changes that appeared to mimic the adaptive changes induced by the presence of predators, such as relatively deeper tails. The tadpoles respond to Roundup as if it was a predator, triggering hormonal responses that resulted in tail growth (Relyea 2012).

In a review of effects of pesticides on amphibia, Mann et al (2009) summarised the effects of glyphosate products: lethality, interference with gill morphology, delayed development, or accelerated development, reduced size at metamorphosis, malformations of tail, mouth, eye, head, indications of intersex, avoidance behaviour, and symptoms of oxidative stress.

Reptiles

In an experiment in which caiman eggs were exposed to glyphosate to simulate the likely effect on nests from neighbouring croplands, glyphosate was found to cause genotoxic alterations, delayed growth, and enzymatic and metabolic disorders in caimans (Polleta et al 2011).

Fish

<u>Systemic effects</u>

Glyphosate caused moderate to severe irreversible damage to liver and reduced liver function in a neotropical fish species, probably affecting their ability to detoxify and to repair tissues (Shiogiri et al 2012).

<u>Chronic effects</u>

Exposure to Roundup at sublethal levels causes oxidative stress in the liver, and inhibits acetylcholinesterase in the muscle and brain of fish (Modesto & Martinez 2010). The authors postulate that "the accumulation of acetylcholine due to reduction of enzyme activity may affect the fleeing and reproductive behaviour of fish, interfering directly in the survival of the species".

New Zealand freshwater fish, simultaneously exposed to glyphosate at "environmentally relevant concentrations" and a trematode parasite, experienced reduced survival, and juveniles developed spinal malformations not seen with either the parasite or the glyphosate alone (Kelly et al 2010).

Molluscs

Exposure of freshwater ram's horn snails, *Biomphalaria alexandrina,* for 6 weeks to Roundup at LC_{10} (i.e. the concentration that kills 10% of snails with acute exposures) resulted in 85.6% abnormal egg masses and marked reduction in hatchability after 2 weeks, and 100% mortality after 5 weeks, a week early than for the controls (Barky et al 2012).

Terrestrial ecotoxicity

Food microorganisms

Glyphosate at concentrations lower than those used in agriculture inhibited the growth of three important food microorganisms: *Geotrichum candidum, Lactococcus lactis* subsp. *cremoris* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. The first 2 are important in cheese processing, and *L. bulgaricus* is the starter bacteria commonly used in fermented food. This study, together with others showing effects on microorganisms in the soil and aquatic communities, has raised concern about the implications of widespread glyphosate use on microbial diversity and particularly those available for food culture (Clair et al 2012b).

Plant diseases

Pathogens

In a letter to the US Department of Agriculture in 2011, Dr Don Huber, author of many papers on the effects of glyphosate on plant nutrients and plant diseases, stated that he had found a pathogen new to science that increases in soil treated with glyphosate, is taken up by plants, transmitted to animals via feed and to humans via plants and meat. The identity of the pathogen, or any other details, does not appear to have been released (Wan-Ho 2011).

Other effects on plants

Compositional changes

In greenhouse experiments, glyphosate resulted in significant decreases in linoleic acid and linolenic acid, and significant increases in monounsaturated fatty acids in soy (Zobiole et al 2010).

Beneficial arthropods

Airborne components of Roundup sprayed at normal applications rates interfered with the ability of male wolf spiders, a common predator in US and other agroecosystems, to locate mates, either by affecting their ability to detect or react to female pheromones. This could affect their reproductive success and hence also success at reducing pests (Griesinger et al 2011).

The glyphosate formulation, Glifoglex, had a range of negative effects on the orb web weaver spider, an abundant predator species in Argentina's transgenic soy crops. These effects include reduced prey consumption, delayed and less complex web building, abnormal ovaries and egg sacs, reduced fecundity and fertility, and longer developmental time of progeny (Benamu et al 2010).

A significant decline in the numbers of monarch butterflies overwintering in Mexico is blamed on the widespread use of Roundup in USA's GM herbicide-resistant crops, which has caused a consequent loss of milkweed host plants for caterpillars (Brower et al 2011).

Birds

Glyphosate-based herbicides and glyphosate itself interfere with key molecular mechanisms, including endocrine mechanisms, which regulate early development in chickens leading to congenital malformations (Paganelli et al 2010).

Climate Change

Increased levels of atmospheric carbon dioxide increased the tolerance of 3 out of 4 mature invasive grass species to glyphosate, indicating that as climate change progresses, grasses may become less susceptible to the herbicide. The species were *Chloris gayana, Eragostis curvula, Paspalum dilatatum,* and *Sporobolus indicus* (Manea et al 2011).

Environmental fate

Air

In the first ever report on ambient air monitoring for glyphosate, the herbicide was found in 61 to 100% of samples of air and 63 to 92% of samples of rain in agricultural areas in two US states. The concentrations ranged up to 9.1 ng/m^3 in air and 2.5 μg/L in rain for glyphosate; and for AMPA 0.97 ng/m^3 in air and 2 μg/L in rain. Highest levels were recorded during weeks with rainfall following the application period. It was calculated that about 0.7% of the glyphosate applied in agricultural areas is removed from the air in rain (Chang et al 2011).

Soil persistence and mobility

AMPA accumulates in soil; modelling showed that after 20 years of application, levels of 4.9 kg/ha, or 8.5% of the total amount of glyphosate applied, were expected; and these results are consistent with various field studies (Mamy et al 2010).

Glyphosate residues were found in soil where GM soy is grown in Argentina, at levels up to 4.45 mg/L (Peruzzo et al 2008).

Persistence in water

Residues in surface waters

Runoff from hard surfaces in urban areas is increasingly being seen as a source of surface water pollution with glyphosate and AMPA, especially during storm events or after rainfall. In Switzerland, one study found that urban sources provided more than 60% of the loading in a small catchment with both urban and agricultural sources (Hanke et al 2010).

AMPA is being increasingly found in water in France (Mamy et al 2010).

Glyphosate residues were found in surface waters where GM soy is grown in Argentina, at levels up to 0.56 mg/L and in sediment at 1.85 mg/L (Peruzzo et al 2008).

A one-year monitoring project of three wastewater treatment plants and one composting unit in France detected glyphosate and AMPA in all samples of sludge. The highest level of glyphosate was 2.9 mg/kg and of AMPA 33.3 mg/kg, although some of the later may be attributable to household cleaning products containing aminophosphonates (Ghanem et al 2007).

Glyphosate and AMPA were found in tributaries of the river Ruhr in Germany in the 1990s at up to 590 ng/L; in 54% of surface water samples in Norway in the late 1990s at up to 0.93 μg/l glyphosate and 0.2 μg/L AMPA; and in elevated levels in surface water, soil and sediment samples in Argentina as a result of GM soy cultivation (Szekacs & Davas 2011).

Glyphosate was found in 17.5% and AMPA in 67.5% of samples from 10 wastewater treatment plants in the US; and, in Canada, 21% of samples had concentrations up to 41 μg/L for glyphosate and 30 μg/L for AMPA (Szekacs & Davas 2011).

Landfill leachate

Glyphosate has been detected in landfill leachate in the UK (Slack et al 2005).

Groundwater

Glyphosate was found in the groundwater in 11 different locations in Catalonia, Spain. It was detected in 41% of 140 samples, at concentrations as high as 2.5 μg/L, 25 times the legal limit for drinking water in the EU (Sanchis et al 2012). The authors of the study stated that few monitoring studies have looked for glyphosate in groundwater, or have found it, because it is difficult to analyse. However, their new more sensitive method, carried out in agricultural areas in peak application times, did find it extensively.

Marine sediments and seawater

Detectable concentrations of glyphosate and AMPA were found in marine sediment at a number of sites in the Waitemata Harbour and Hauraki Gulf in New Zealand. The maximum glyphosate concentration detected was 1 ppm, while AMPA had a maximum level of 0.37 ppm (Stewart et al 2009).

Bioaccumulation

Snails placed in a vineyard in France and subject to normal pesticide applications, were found to accumulate glyphosate and AMPA in their tissues 12 days after treatment. The concentration of AMPA was twice that of glyphosate showing that both metabolism and accumulation were occurring (Druart et al 2011).

Two previous papers had demonstrated a low level of accumulation of glyphosate in fish (Wang et al 1994), and a freshwater worm, *Lumbriculus variegatus* (bioconcentration factor 5.9) (Contardo-Jara et al 2009).

Herbicide resistance and weeds

Resistance is now recorded in 23 species of weeds in 20 countries, most notably the USA (WeedScience.com 2012), up from 16 species in 14 countries in September 2009. In 2011, the following indicative figures were published (GM Freeze 2011):

- Palmer amaranth (*Amaranthus palmeri*) in maize, cotton and soy in the US since 2005; estimated at up to 1 million infested sites in North Carolina alone.
- Horseweed (*Conyza canadensis*) in cotton, soy and maize since 2000: up to 100,000 sites are infested in Delaware, USA, alone.
- Johnsongrass (*Sorghum halepense*) in soy in Argentina since 2005: up to 100,000 acres infested.

Resistance to glyphosate continues to grow to such an extent that Monsanto has been forced to accompany its new GM technology with old herbicide packages to try to beat the weeds. For example, the Roundup Ready® Xtend Crop System consists of GM soybean seeds with tolerance to dicamba as well as Roundup (Monsanto 2012).

Resistant weeds in corn have spurred Monsanto to join forces with Dow AgroSciences: Dow has developed a GM corn resistant to both 2,4-D and glyphosate so that farmers can spray both herbicides on their crop (Schiffman 2012).

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Pesticide Action Network Asia and the Pacific (PAN AP) is one of the five regional centres of PAN, a global network dedicated to eliminating the harm caused to humans and the environment by pesticides and promoting biodiversity-based ecological agriculture.

PAN AP's vision is a society that is truly democratic, equal, just, and culturally diverse; based on the principles of food sovereignty, gender justice and environmental sustainability. It has developed strong partnerships with peasants, agricultural workers and rural women movements in the Asia Pacific region and guided by the strong leadership of these grassroots groups, has grown into a reputable advocacy network with a firm Asian perspective.

PAN AP's mission lies in strengthening people's movements to advance and assert food sovereignty, biodiversity-based ecological agriculture, and the empowerment of rural women; protect people and the environment from highly hazardous pesticides; defend the rice heritage of Asia; and resist the threats of corporate agriculture and neo-liberal globalization.

Currently, PAN AP comprises 108 network partner organizations in the Asia Pacific region and links with about 400 other CSOs and grassroots organizations regionally and globally.

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