

GLYPHOSATE

A Chemical to Understand



Glyphosate: A Chemical to Understand

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About the Invasive Species Council

The Invasive Species Council was formed in 2002 to advocate for stronger laws, policies and programs to keep Australian biodiversity safe from weeds, feral animals, exotic pathogens and other invaders. It is a not-for-profit charitable organisation funded by donations from individuals and philanthropic organisations.

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Introduction

The herbicide glyphosate is very controversial. In 2015 the International Agency for Research on Cancer (IARC) determined that it was a probable carcinogen. Several countries (but not Australia) have since announced bans on glyphosate. In three American court cases, juries have awarded massive damages to people who blamed it for their cancer.

These events are very concerning. But government agencies have responded in divergent ways to the IARC report. The European Food Safety Authority announced that glyphosate 'is unlikely to pose a carcinogenic hazard to humans' (European Food Safety Authority 2015). Similar conclusions have been reached by regulatory authorities in Australia, the US, Canada, Japan and New Zealand (Connolly et al. 2018). Organisations representing Australian farmers – the National Farmers' Federation,

Agforce, Victorian Farmers Federation, WAFarmers – have strongly rejected the IARC finding.

Glyphosate is the main herbicide used on crops in Australia – the active ingredient in Roundup and many other weed-killers. It is also the main herbicide used against weeds invading native vegetation. Aside from cancer concerns, it is controversial for its link to genetically modified crops, such as the GM corn grown widely in the US. Many GM crops have been designed to survive glyphosate so that they can be sprayed to kill associated weeds.

The Invasive Species Council has produced this report in an attempt to reconcile the conflicting findings, and to consider the outcomes if Australia bans glyphosate. The Invasive Species Council is an independent environmental organisation that works for better

policies to reduce the environmental impacts of invasive species. The views expressed in the report are those of its author, Tim Low, not those of the council.

The first two sections of the report consider why agencies have reached divergent or apparently divergent conclusions. The third asks what it means for glyphosate to be a carcinogen, and the fourth explores what a world without it might look like.

About the author

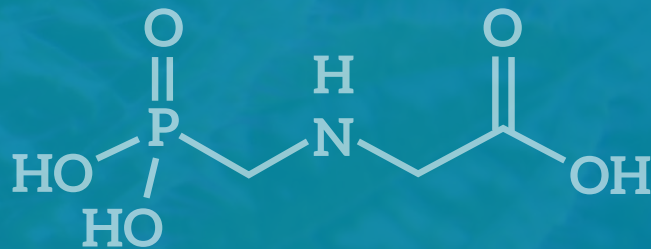
Tim Low is an ecologist, consultant and writer who helped found the Invasive Species Council in 2002.

He is author of the best-selling book *Feral Future*, which The Australian newspaper called a wake-up on the dangers of McDonaldising world ecology, and regularly speaks about pest issues at conferences in Australia and internationally.

Tim's most recent book was *Where Song Began*.

Tim became very interested in reptiles as a teenager and discovered several new species of lizard. He named the chain-backed dtella (*Gehyra catenata*) and had the dwarf litter-skink (*Menetia timlowi*) named after him. His interests expanded to include plants, birds, mammals, fish and invertebrates. He has written journal articles that caution about the weed threats posed by biofuel crops, agroforestry trees and pasture plants.





BOX 1



What is Glyphosate?

Glyphosate is an organophosphorus compound widely used for weed control that kills growing plants by blocking synthesis of enzymes. It interferes with the shikimate pathway, used by plants to produce some amino acids.

Glyphosate is absorbed through foliage and transported to growing leaves. Animals lack the shikimate pathway, obtaining these amino acids in the foods they eat. This means glyphosate cannot harm people or animals in the way it harms plants.

The Monsanto Company discovered the impacts of glyphosate in 1971, obtaining a patent over its production, which long ago expired, freeing other companies to engage in its manufacture. Since the 1970s it has been the world's most popular herbicide, used in many different products, of which Roundup is the best known. China is currently the world's largest producer.

1. Hazard assessment versus risk assessment

The danger posed by a chemical can be assessed in two ways. A hazard assessment simply asks if a substance is capable of causing harm. A risk assessment asks if it can cause harm under conditions of normal exposure.

The IARC determined that glyphosate may be capable of causing cancer, but did not specify the circumstances, since that is beyond the IARC remit.

In Australia, decisions about pesticides are the responsibility of the Australian Pesticides and Veterinary Medicines Authority (APVMA), an independent statutory authority. When the IARC report came out, the APVMA commissioned a review from the Office of Chemical Safety within the Department of Health. This review led the APVMA to restate a previous finding that glyphosate is safe to use if the safety instructions are followed.¹ The safety instructions include advice to wear the likes of 'safety shoes, overalls, gloves, safety glasses' for concentrates and 'Wear gloves and wash hands after use' for home garden mixes.

In reaching this conclusion the APVMA drew a distinction between the hazard assessment performed by the IARC and the risk assessment it performed:

'A hazard assessment considers only the potential to cause harm. It does not determine whether or not the harm will occur. It also does not determine the likelihood of the harm occurring in real-world situations.'

The IARC has stated that its 'Monographs identify cancer hazards even when risks are very low at current exposure levels, because new uses or unforeseen exposures could engender risks that are significantly higher.'²

Under questioning in the Australian Senate, the Chief Executive Officer of the APVMA, Chris Parker, said he agreed with the IARC that glyphosate was probably carcinogenic (Rural and Regional Affairs and Transport References Committee 2019). Dr Jason Lutze, Acting Executive Director of Scientific Assessment and Chemical Review of the APVMA, also said he agreed with the IARC hazard finding.

Some cancer victims mention being drenched in glyphosate, indicating exposures well outside those advised in current safety instructions.³ A common complaint is that safety instructions were lacking in the past.

Since the first glyphosate court case in America, some experts on chemicals and cancer have repeated the view that glyphosate is not harmful if used according to instructions. Dr Ian Musgrave, a pharmacologist at the University of Adelaide, has said:⁴

'Science is not besotted by court cases and the actual scientific evidence we have shows that that link [to cancer] is not apparent at the concentrations humans use, under the conditions human use it.'

Dr Joshua Mylne, a biochemist and herbicide expert at the University of Western Australia, expressed a similar view to newsGP, the news hub of the Royal Australian College of General Practitioners:⁵

'The overwhelming opinion of experts is that glyphosate is safe. People forget "the dose maketh the poison".

'The scary data sheets that come with herbicides are for the concentrated compound, plus all the chemicals

needed to dissolve it, plus the detergents needed to allow the chemical to penetrate the leaf – the concentrate is a toxic cocktail, to be sure.

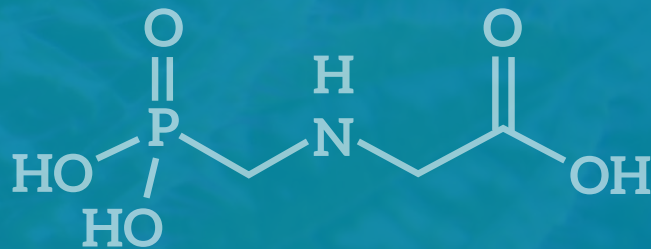
'However, the concentration at which what's in the bottle is applied is usually 1000 times less, or even more dilute than that.'

Toxicologist Dr Ian Musgrave, from the University of Adelaide, was also critical of over-reactions:

'In fact, if you tried to get the concentrations we see in animal studies, you'd have to eat something like a half a kilogram of glyphosate a day.'

After the IARC report appeared, the risk of glyphosate in food was reassessed. Animals develop health problems if they eat glyphosate, although the amounts in experiments far exceed those detected in foods. A joint meeting of United Nations and World Health Organization panels (JMPR) found no cancer risk to people from traces in food (World Health Organization 2016). Even though the IARC is also a World Health Organization agency, there is no contradiction between the two WHO findings because one assessed hazard and the other the risk in food. WHO explained this on its website:⁶

'IARC reviews published studies to identify potential cancer hazards. It does not estimate the level of "risk" to the population associated with exposure to the hazard. In contrast, JMPR reviews both published and unpublished studies to assess the level of health risk to consumers associated with dietary exposure to pesticide residues in food.'



Weed control for thistle and bindweed in Canada.

Photo: Bear Paw Battlefield | Flickr | CC BY-NC-ND 2.0

Safety instructions for the use of glyphosate include to wear safety shoes, overalls, gloves and safety glasses for concentrates. For home garden mixes it is to wear gloves and wash hands after use.¹

The JMPR decision was not especially controversial. The studies that had swayed the IARC were about cancer sufferers exposed directly to glyphosate, not about people imbibing traces in food. None of the court cases have been about food. Cancer Council Australia advises that 'consumption of foods most commonly associated with pesticide use

– fresh vegetables and fruit – can help to prevent cancer'.⁷

The difference between hazard and risk is only one reason for differing opinions. It does not explain why some countries have moved to ban glyphosate while others have pronounced it safe.

2. Reliance on different research

Causation in cancer is difficult to establish, as Cancer Council Australia noted about pesticides:⁸

'Finding evidence of carcinogenicity in humans is difficult as studies need very large numbers of people followed for decades, with detailed information about specific pesticide exposure including how much pesticide and length of time of exposure. Animal experiments can provide some indication of potential carcinogenicity of pesticides, but their results are not always applicable to humans.'

Research papers that report evidence of cancer or a lack of it are not always accepted as reliable by agencies reviewing risks. Different conclusions can be reached if more weight is placed on some papers than others.

Controversy erupted in 2012 over a much-hyped paper in the respected journal *Food and Chemical Toxicology*. It reported that rats fed genetically modified corn and glyphosate developed 'very significant chronic kidney deficiencies' (Séralini et al. 2012). No previous studies had reported findings like this. Criticisms came from many quarters, including the European Food Safety Authority, the Société Française de Pathologie Toxicologique, the UK Food Standards Agency and the Brazilian Biosafety Association (Williams et al. 2016). Scientists criticised the use of too few rats and a strain that readily develops tumours no matter what. There were criticisms of the lead author, Professor Gilles-Eric Seralini, for not disclosing a role as president of an advisory board opposed to GM foods. The editor-in-chief of the journal chose

to retract the article, explaining that 'A careful and time-consuming analysis found that the data were inconclusive, and therefore the conclusions described in the article were unreliable' (Wallace Hayes 2014). He rejected claims he was influenced by Monsanto, the company that developed glyphosate. A slightly amended version of the article then appeared in the journal *Environmental Sciences Europe*, with a brief introduction by the journal's editor, Winfried Schröder, saying that (Séralini et al. 2014):⁹

'any kind of appraisal of the paper's content should not be connoted. The only aim is to enable scientific transparency and, based on this, a discussion which does not hide but aims to focus methodological controversies'.

The Séralini paper is ignored in glyphosate assessments, but there are many other such studies about which questions can be raised. When eight scientists checked the quality of 73 epidemiology studies in leading journals (but not focused on glyphosate), they concluded that 'Overall, there is a serious risk that some epidemiological publications reach misleading conclusions' (Pocock et al. 2004). Their review, published in the *British Medical Journal*, looked at research mainly on cancer and cardiovascular disease. They warned of a publication bias towards exaggerated claims, noting that 'Particularly in small studies, apparently strong associations may be spurious and not supported by subsequent studies.'

Ideally, a rejection of poor papers would mean that agencies all use the same high-quality papers, but in practise it

has led to some reliance on different glyphosate papers. The APVMA accepted several papers disregarded by the IARC for reasons such as 'limited experimental data' (IARC 2017) while the APVMA disregarded 174 studies cited by the IARC because they 'utilised non-conventional species or methodology for evaluating human toxicity (eg fish)' (APVMA 2016).

The US Environment Protection Agency (EPA) also discounted some papers accepted by the IARC, for reasons such as they 'did not collect information on glyphosate exposure from all subjects' (EPA's Office of Pesticide Programs 2017). When an independent panel reviewed the EPA report its members were strongly divided about one matter, whether glyphosate is a rodent carcinogen, but they agreed there is no link to human cancers (FIFRA Scientific Advisory Panel 2016).

For those agencies that have endorsed use of glyphosate, the pivotal study has been the Agricultural Health Study (Alavanja et al. 1996), a very large, ongoing study in the US investigating why farmers are so prone to a range of cancers. Determining the causes is difficult because farmers are exposed to many carcinogens, which include sunlight, animal viruses, dust, fuels, oils, engine exhaust and fertilisers. The longitudinal survey of 90,000 farmers, pest control operators and other pesticide users (and their spouses) in Iowa and North Carolina began in 1993, and has included periodic interviews of participants and controls. These have assessed pesticide use, other cancer risks, lifestyle factors, and cancer incidence (Alavanja et al. 1996). It is the world's largest study

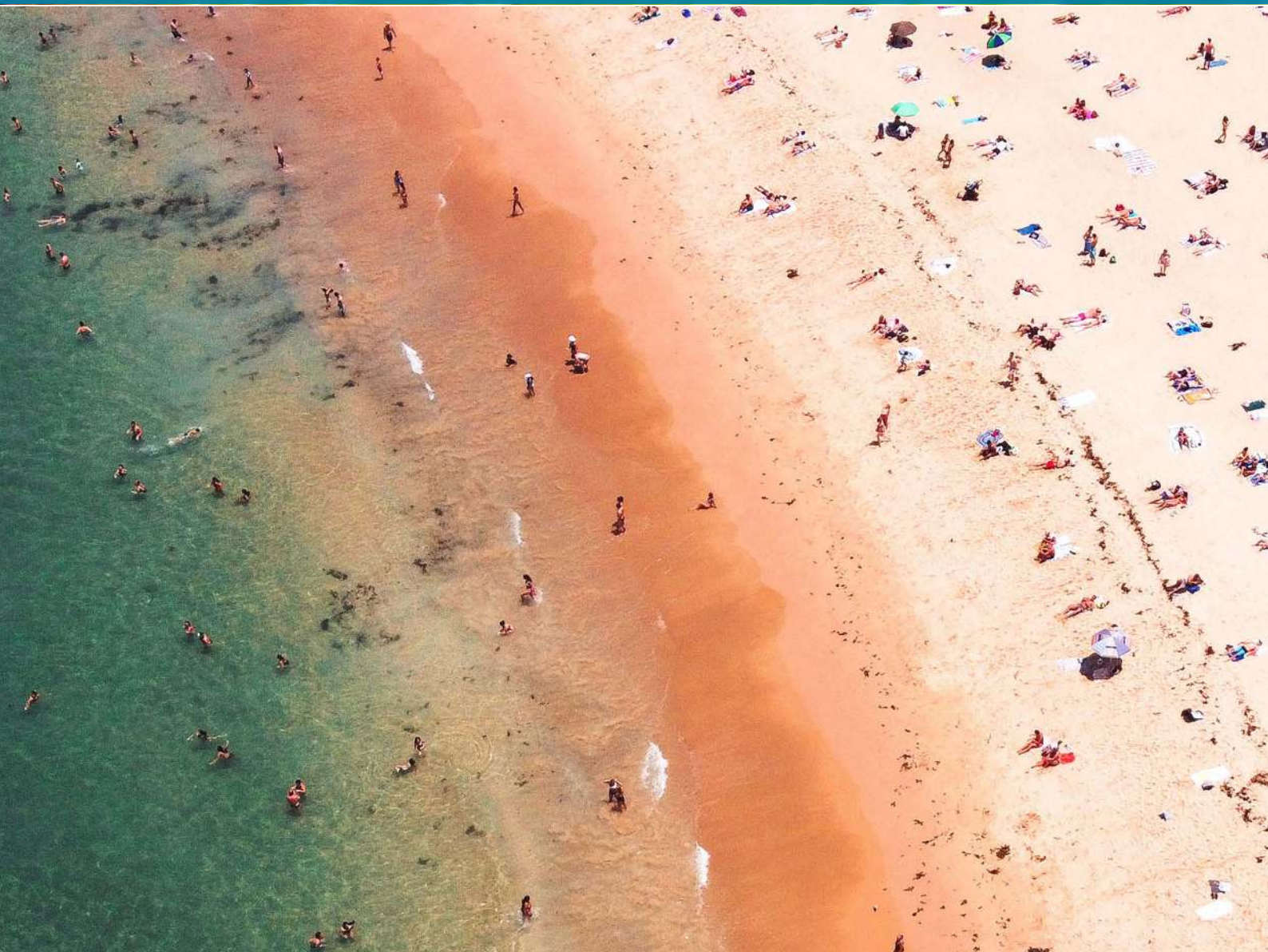
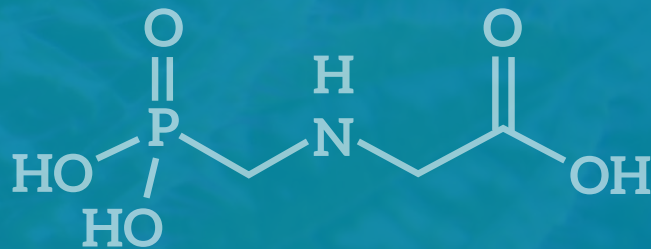


Photo: Coogee Beach, NSW | Manny Moreno | Unsplash

Those who use it glyphosate according to safety instructions are likely to face greater risks from other carcinogens such as sunshine, alcohol and salami.

of its kind, a collaboration of four agencies – the National Cancer Institute, National Institute of Environmental Health Sciences, the U.S. Environmental Protection Agency and the National Institute for Occupational Safety and Health.

Importantly, it is a cohort study, which means participants are asked about chemical use before any cancer is acquired. Most studies of cancer are retrospective, taking matched groups of people with and without cancer and asking them to recall past use of possible carcinogens. A problem with

these studies is recall bias, whereby people with cancer reflect more on their past than those without, upping the chances they will recall and emphasise use of pesticides, while those without cancer may underestimate past pesticide use (Germany 2015, Williams et al. 2016). Another concern is selection



Glyphosate is often used to spray the weeds growing beneath grape vines. Photo: Jill Wellington | Pixabay

bias; if the controls in a study are not from the same population as the cases, their exposures to many substances are different.

The Agricultural Health Study has yielded many published papers, and the one about glyphosate relied on by the IARC and other agencies did not find a link to cancer (De Roos et al. 2005).

The IARC acknowledged the high quality of this study and its 2005 finding, but put emphasis on three smaller retrospective studies that did find a cancer connection (Guyton et al. 2015, IARC 2017) – to non-Hodgkin

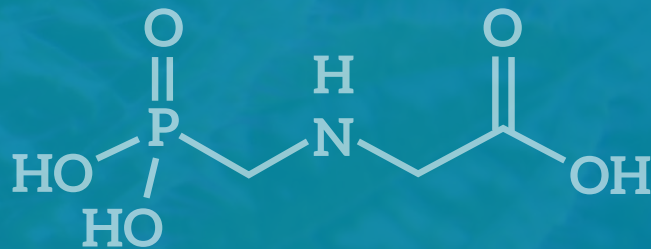
lymphoma, a cancer that originates in white blood cells and is often fatal.

However, the APVMA questioned the worth of these three papers. It criticised the statistical methods in two and discounted their conclusions. Although it accepted that one study found a slightly higher rate of non-Hodgkin lymphoma, it said the increase was not statistically significant (APVMA 2016). About the third paper (Eriksson et al. 2008), the APVMA questioned the IARC's description of this as a large study. It entailed 910 non Hodgkin lymphoma patients, of whom 29 had had exposure

to glyphosate, and 1016 controls (people without cancer), of whom 18 had had exposure to glyphosate. The APVMA suggested that some of the 29 lymphoma patients may have encountered another herbicide (MCPA or 2-methyl-4-chlorophenoxyacetic acid), also associated with non-Hodgkin lymphoma (APVMA 2016). The IARC had acknowledged 'possible confounding from use of other pesticides including MCPA', but said this was considered (IARC 2017).

The IARC came to this conclusion:

'There is limited evidence in



humans for the carcinogenicity of glyphosate. A positive association has been observed for non-Hodgkin lymphoma.'

The body of evidence allows for this conclusion. But the evidence also allows other agencies to doubt a link to non-Hodgkin lymphoma, by emphasising the largest and best-designed study.

The IARC also concluded that there is 'sufficient evidence in experimental animals for the carcinogenicity of glyphosate.' Animal studies use very high dosages, and have their own limitations, allowing agencies such as

the APVMA to decide that glyphosate is safe with precautions such as gloves and masks.

The scientific disagreements are echoed in the legal arena. In the second American court case the jury found Monsanto culpable of cancer and awarded the victim \$289 million in damages (cut to \$78 million on appeal), but the presiding judge, Vince Chhabria, was uncertain noting 'credible evidence on both sides of the scientific debate'¹⁰. In a subsequent ruling he said 'the evidence that Roundup causes cancer is quite equivocal'.¹¹ Court cases are not

scientific rulings.

In 2017, two years after the IARC judgment, an update of the Agricultural Health Study based on newer survey data confirmed a lack of association between glyphosate and NHL (Andreotti et al. 2017). The survey, did however, identify a possible association with another cancer, acute myeloid leukaemia. The highest users of glyphosate showed an elevated risk of contracting this cancer, but this finding was not statistically significant. The researchers called for further research to see if this link can be confirmed.

3. Cancer in perspective

Cancer is such a feared disease that many people might suppose that any cancer risk is reason to ban a chemical. But today's world abounds in carcinogens. IARC hazard assessments (see Table 1) show it is less certain that glyphosate causes cancer than it is about sunshine, alcohol, salami (and other processed meats), salted fish and wood dust.¹²

The Australian Work Exposures Study estimated that 3.6 million workers, or 40% of the working population, are potentially exposed to carcinogens at work (Darcey et al. 2016). That proportion rises to 99% for agricultural workers, with their most prevalent carcinogens being solar (UV) radiation (99%), diesel engine exhaust (94%), benzene (82%), polycyclic aromatic hydrocarbons (76%) and wood dust (71%).

Dr Joshua Mylne, a scientist researching new pesticides that could one day supersede glyphosate, is one who has criticised concern over glyphosate. Noting that alcohol can cause cancer of the oral cavity, pharynx, larynx, oesophagus, colorectum, liver and female breast. He said that 'If you seriously want to lower your cancer risk, keep using Roundup [herbicide] and stop drinking.'¹³

The Australian Cancer Council and the Cancer Council NSW both have web pages about non-Hodgkin lymphoma that do not mention glyphosate or other chemicals as risk factors.¹⁵ The Cancer Council NSW says the risk factors are a weakened immune system, certain viruses and family history. It also says this:

'Most people with known risk

factors don't develop non-Hodgkin lymphoma, and some people who do get it have no known risk factors.'

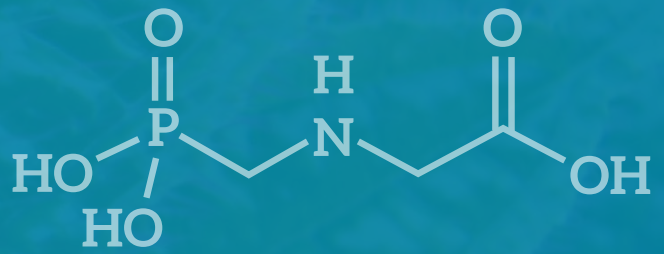
A study of non-Hodgkin lymphoma published after the IARC report found slightly elevated rates in American farmers, hairdressers, cleaners, doctors and spray painters (Chihara et al. 2015). This study was unable to identify risk factors for each profession, and suffered from some of the methodological issues raised earlier.

Pesticides are easy to fear because they are designed to kill something (although glyphosate does so by blocking an enzyme found only in plants¹⁷). The modern conservation movement began with Rachel Carson's *Silent Spring*, an exposé of wanton use of dangerous pesticides. Glyphosate was developed by Monsanto, a company with a reputation among many as a heartless corporation willing to poison for profit.¹⁸ By contrast, alcohol may bring to mind cheerful dinner parties, and sunshine goes with holidays at the beach and is hard to avoid.

Legitimate concerns about glyphosate have been exacerbated by some wildly exaggerated comments. Author and regenerative farmer Charles Massy has claimed 'mounting evidence that it is one of the most destructive chemicals ever to get into the system.'¹⁹ In his acclaimed book *Call of the Reed Warbler* he alleges (page 6) that it 'is now being implicated as a primary causal factor in many of today's major diseases'. Anyone familiar with the IARC report or the court cases would know these claims are preposterous, but they go largely unchallenged because chemicals are so easy to fear.

The IARC cancer conclusion has concerned government weed officers, but other IARC rulings give other workers more to fear, including painters, welders and those exposed to diesel fumes. Hairdressers and night-shift workers also face a 'probable' cancer risk. Night-shift workers might be said to face more risk than users of glyphosate because safety gear can limit glyphosate exposure while night-shift workers, by definition, cannot avoid night shifts. But the IARC's finding on night shifts, like that on glyphosate, has come under question.²⁰

It is well known that some cancer types run through families, showing that risk can be inherited rather than environmental. Cancer often comes down to bad luck, to chance mutations. A study of cancer published in *Science* concluded that 66% of cancerous mutations are caused by random errors in healthy cells rather than by environmental factors (Tomasetti et al. 2017), although that study drew criticism.



BOX 2

What experts have said

Expert opinions about glyphosate are diverse. Here are comments from all the Australian experts who could be found quoted in media articles. The more negative opinions appear towards the end.

Professor Ivan Kennedy is an expert in risk assessment and environmental fate of pesticides at the University of Sydney:²¹

‘The International Agency for Research on Cancer made a bad mistake in claiming glyphosate was a probable cause of cancer. There is no convincing evidence for this and much evidence gathered over 40 years about it as the safest herbicide known. Any replacement will be more likely to be damaging to human health’.

He also said glyphosate ‘is one of the least likely compounds to be carcinogenic that I can think of, because it’s made up of three very simple substances which are common parts of our metabolism’.²²

Associate Professor Nial Wheate is an expert in cancer drugs and pharmaceuticals at the University of Sydney. He was quoted on Scimex website on 4 June 2019:

‘While two related people developing cancer at the same time is clearly worthy of investigation and research, we must be careful not to draw a causal link between their disease and glyphosate. It is important to remember that every year there are many hundreds of thousands of people who use the pesticide, or been exposed to it, who do not develop cancer.’

Emeritus Professor Bruce Armstrong is Professor of Public Health at the University of Sydney’s School of Public Health:²³

‘there is strong experimental evidence that glyphosate can cause cancer. There is also epidemiological evidence that it causes non-Hodgkin lymphoma but this is not conclusive.’

Cancer Research UK is a large British charity that conducts research and develops policy:²⁴

‘There is a small amount of evidence that people who are exposed to the highest levels of glyphosate may have a small increased risk of certain types of cancer. But there’s no good evidence that there’s an increase in risk for people exposed at low levels, such as through using glyphosate as a weed killer in their garden.’

The chief executive of the Australian Cancer Council, Professor Sanchia Aranda, has voiced different concerns on different occasions:

‘The current evidence suggests those who regularly work with the glyphosate may be at risk.’²⁵

‘People should minimise the use of the product if it’s not necessary and those who do work with it should take health and safety precautions.’²⁶

‘The work health and safety aspects of these kinds of exposures aren’t quite as tight as we’d like them to be.’²⁷

‘Studies — which are of variable quality — are mixed. But some definitely show an association with cancer called non-Hodgkin’s lymphoma in people who use these chemicals frequently.’²⁸

But she was reassuring to home gardeners:

‘There is no evidence there is a danger to mum-and-dad gardeners, or kids who play in parks where Roundup is being sprayed.’²⁹

‘[Wear] protective clothing to stop it getting on your skin – it doesn’t need to be industrial protection – just make sure your arms and legs are covered. Wear a mask so you don’t inhale it.’³⁰

Professor Tim Driscoll in the School of Public Health is an expert in cancer, workplace injury and disease at the University of Sydney:³¹

‘As a probable cause of cancer, the most important thing is for those most likely to be at risk to protect themselves according to best practice in occupational health. People should avoid the use of the product if it’s not necessary and those who do need to work with it should take proper health and safety precautions.’

Lin Fritschi is a Professor of Epidemiology in the School of Public Health at Curtin University. She made the following comments to Scimex:³²

‘The International Agency for Research on Cancer has stated that there is suggestive evidence that glyphosate causes cancer, with the strongest evidence for non-Hodgkin lymphoma. We need more information, particularly in relation to people who use glyphosate intensively for a long period.’

‘Anyone who uses glyphosate should consider whether there are other options for weed control in their circumstances.’

‘If you do use it, then you should download the safety data sheet for that product from the internet or ask for the

...continued next page

Table 1. Hazard assessments by the International Agency for Research on Cancer¹⁴

Group 1: Carcinogenic to humans	Group 2A: Probably carcinogenic to humans	Group 2B: Possibly carcinogenic to humans
Benzene	Creosotes	Aloe vera, whole leaf extract
Coal, indoor emissions from household combustion of	Frying, emissions from high-temperature	Carpentry and joinery
Coal-tar pitch	Glyphosate	Gasoline
Engine exhaust, diesel	Hairdresser or barber (occupational exposure as a)	Magnetic fields, extremely low-frequency
Estrogen therapy, postmenopausal	Night shift work	Melamine
Ethanol in alcoholic beverages	Red meat (consumption of)	Pickled vegetables (traditional Asian)
Leather dust	Very hot beverages at above 65 °C (drinking)	
Nickel compounds		
Outdoor air pollution		
Painter (occupational exposure as a)		
Processed meat (consumption of)		
Salted fish, Chinese-style		
Solar radiation		
Welding fumes		
Wood dust		

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safety data sheet where you buy your supply. The safety information is in section 8 and is not on the bottle itself.

'For glyphosate, the manufacturers recommend wearing eye protection, a respirator with replaceable filter, rubber gloves, and cotton overalls buttoned at the neck and wrist.

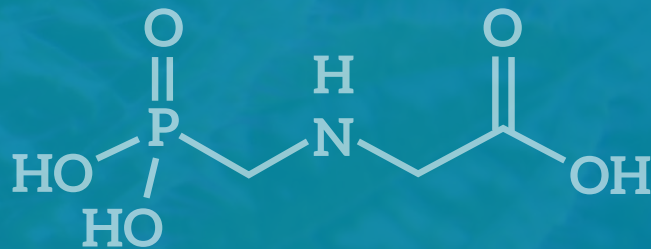
'A strong message from this is that labelling of pesticides in Australia needs to be improved.'

'If you do use it, then you should download the safety data sheet for that product from the internet or ask for the safety data sheet where you buy your supply. The safety information is in section 8 and is not on the bottle itself.

Cancer epidemiologist Bruce Armstrong is emeritus professor at the University of Sydney:²³

'I think they (local councils) should stop using it where, at the moment, there is a practical alternative.'

'And they need to look at all of their uses and ask the question, "Is there a way in which we can avoid needing to use this"?''



BOX 3

Glyphosate lawsuits

Three lawsuits in the United States have resulted in juries awarding four people with non-Hodgkin lymphoma many millions of dollars in damages.³⁴ In each case, a jury found that Monsanto had failed to adequately warn consumers of the risks of glyphosate-based herbicides.

The first, decided in August 2018, involved a former school groundskeeper awarded \$289 million, later reduced to \$78 million. He testified that he had twice been accidentally drenched with a glyphosate herbicide which he was told during training was 'safe enough to drink'.³⁵ In March 2019,

a man who had used Roundup for 26 years on his rural properties, was awarded \$80 million (later reduced to \$25 million) on the basis that it was 'a substantial factor' in the development of his cancer.³⁶ The judge in the appeal stated that there was evidence on both sides about whether glyphosate causes cancer, but that the behaviour of Monsanto showed 'a lack of concern about the risk that its product might be carcinogenic'.³⁷ In the third case, in May 2019, a couple who used Roundup for more than 30 years on residential properties were awarded \$2 billion, later reduced to \$87 million.

4. What would a ban mean?

After the first American court case, Greenpeace urged the Australian Government to suspend sales of glyphosate.³⁸ Many Australian experts have since voiced concerns, but without calling for a ban – although that could change in future.

Weed control officers in some Australian cities have objected to further use of glyphosate and some local governments are using or considering alternatives.³⁹ Fairfield City Council is now spraying sports fields with products whose active ingredients are dicamba, prosulfuron and iodosulfuron-methyl-sodium,⁴⁰ which are not convincingly linked to cancer.

In 2004 the US Agricultural Health Study linked dicamba to lung cancer, but in 2017, with more data, it was concluded no link existed (Bonner et al. 2017). When the APVMA assessed prosulfuron it noted that 'Although an increased incidence of tumours was seen in a rat two-year dietary study, they were considered likely incidental and not treatment related' (APVMA 2012). The forerunner of the APVMA noted that iodosulfuron causes severe eye irritation in rabbits and weight loss when fed to animals but decided it was safe at expected exposures (National Registration Authority & for Agricultural and Veterinary Chemicals 2000). The European Food Safety Authority found there was not enough data to fully assess non-target impacts of prosulfuron and iodosulfuron. The APVMA determined that spraying prosulfuron is acceptable for an operator wearing overalls over normal clothing, chemical resistant gloves and a respirator (APVMA 2012).



Marianne Bate, of the Narrow Neck Bushcare Group in the Blue Mountains, applies glyphosate to a drilled hole in the trunk of a holly tree, a woody weed that is impractical to control without use of herbicides.

Although these chemicals may turn out to be safer than glyphosate, some researchers warn that replacements are likely to be worse. A pesticide expert at the University of Sydney, Professor Ivan Kennedy, says that 'any' replacement is likely to be more damaging to human health⁴¹, and a herbicide expert at the University of Adelaide, Dr Chris Preston, says that glyphosate is safer than the alternatives, and better for the environment because there is no residual toxicity.⁴² For no-till and conservation farming, the obvious alternative is paraquat, says LaTrobe University researcher James Hunt,⁴³ a chemical that is banned in Europe because of extreme toxicity and a link to Parkinson's disease.⁴⁴

The concern here is 'regrettable substitutions', whereby a replacement chemical is no better or even worse. Bisphenol A (BPA) is a controversial compound used in plastics, including in toys, that in some products has been replaced with 'other, less-studied chemicals whose health implications are virtually unknown' (Scherer et al. 2014). In another example, scientists have warned that 'safer' organophosphate ester flame retardants might be no better than those they are replacing (Blum et al. 2019). Glyphosate was embraced as much safer than earlier herbicides such as 2,4,5-T and sodium arsenite, and while newer herbicides may prove safer than glyphosate, only time will tell.^{45,46} New chemicals often

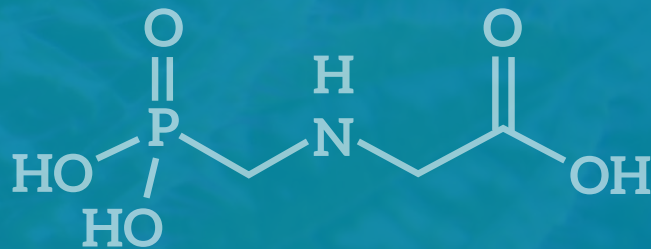


Photo: Stanbalik | Pixabay

On World Heritage-listed Fraser Island glyphosate is used to eradicate bitou bush, one of Australia's worst environmental weeds.

appear to be better because there is less research on their impacts. Glyphosate has been studied far more intensively than the current alternatives because of its status as the world's most widely used herbicide.

The alternatives often do not perform gently. Flupropanate can be used to control African lovegrass, which is fuelling dangerous fires in the Bega Valley, but glyphosate does less harm to nearby native plants such as kangaroo grass (Anonymous 2017). It is also better than flupropanate against Chilean needle grass, because flupropanate is longer-lasting, leaving bare ground that is claimed by thistles and capeweed (Grech et al. 2014).

Diuron is another alternative to

glyphosate, with the disadvantage of very long persistence in the environment. Because it washes down rivers and threatens seagrass and algae on the Great Barrier Reef, the conservation group WWF-Australia gave support in 2012 to a proposal to replace it on farms with glyphosate (Holmes 2012).

A concern for regrettable substitutions is probably a reason why farm groups are vociferous in their support for glyphosate. However, the National Farmers' Federation goes too far in saying that the 'scientific evidence supporting glyphosate's safety is clear and overwhelming.'⁴⁷ This conviction may be fuelled by a concern that alternatives are worse.

Environmental writer Jonathan Latham has confronted the issue of regrettable substitutions in an article called 'The problem is not glyphosate, or DDT, or BPA – we must challenge the entire system!' Environment groups become part of a toxic treadmill, he wrote, when they implicitly treat certain chemicals as rotten apples instead of targeting all pesticides, flame retardants, endocrine disruptors and plastics. He has criticised the limitations of chemical testing and called for a sustainable food movement to reform society.⁴⁸

The extent of risky chemical use was outlined by the US President's Cancer Panel (Reuben 2010):

'With nearly 80,000 chemicals on the market in the United States,



many of which are used by millions of Americans in their daily lives and are un- or understudied and largely unregulated, exposure to potential environmental carcinogens is widespread... The American people—even before they are born—are bombarded continually with myriad combinations of these dangerous exposures.'

Many industrial chemicals are found in trace amounts in our bodies and even in babies. The report noted 'traces of nearly 300 pollutants in newborns' bodies, such as chemicals used in fast-food packaging, flame retardants present in household dust, and pesticides.'

Chemicals also permeate the environment. Organochlorine pesticides have been detected in Antarctic sea

ice algae and krill (Chiuchiolo et al. 2004), and others pervade the waters and sediments of the Great Barrier Reef (GBRMPA 2010). Seven widely used herbicides are cause for concern by the Great Barrier Reef Marine Park Authority, including atrazine, diuron and 2,4-D (but not glyphosate, which has limited environmental persistence).

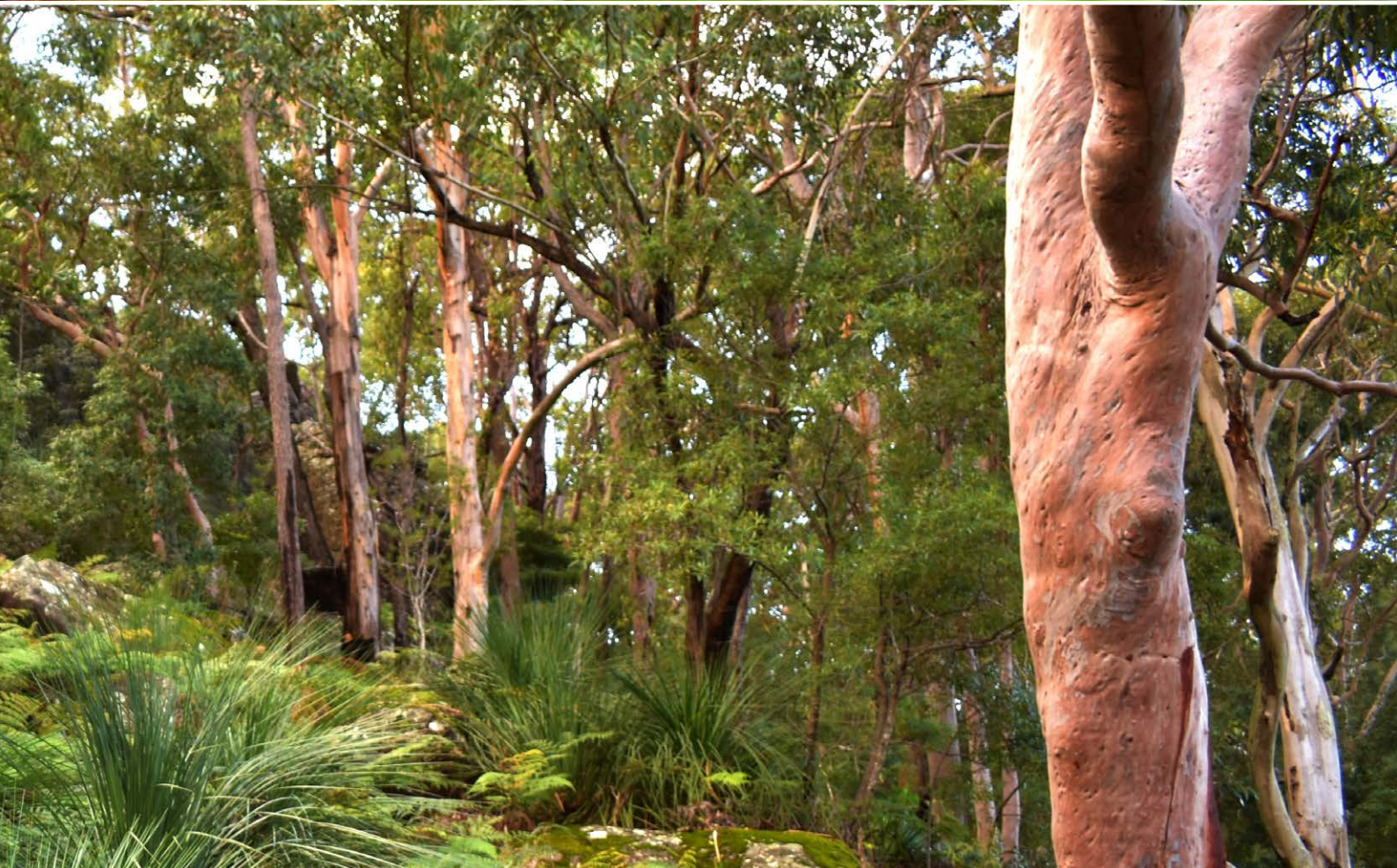
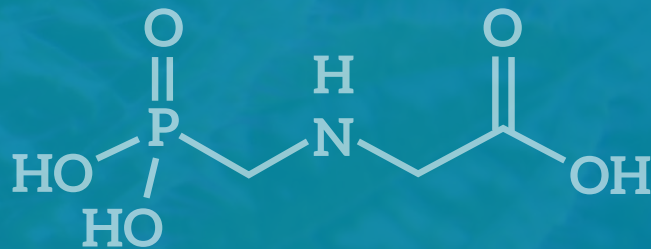
None of these chemicals have been subjected to as much study as glyphosate. Atrazine has caused tumours in female rats but the significance for humans is unknown because, the IARC decided, too little is known about atrazine to assess its carcinogenicity.⁴⁹

Most of those who write about glyphosate do not acknowledge the chemical world we live in. One Guardian article noted that glyphosate 'traces are commonly found in our food and

even our bodily fluids'⁵⁰ as if we should expect otherwise.

Glyphosate concerns extend to the compounds it is mixed with, especially the surfactants that help weed sprays to coat leaves. Polyethoxylated tallow amines (POEAs) are widely used surfactants toxic to frogs, fish and aquatic insects (Howe et al. 2004). The European Food Safety Authority wants further research into their toxicity (EFSA 2015). Some experts fear that POEAs have synergistic toxicity with glyphosate, but this is unconfirmed.

Roundup Biactive is the brand approved for weed control near water, because rather than POEAs it has a non-lethal surfactant (Howe et al. 2004). The APVMA has not assessed POEAs, saying that all glyphosate formulations are different, with many different



Bushland in Georges River National Park, NSW.

Photo: Jim Carroll | Unsplash

Of the many methods to control weeds in bushland reserves, which include fire, mulching, slashing, grazing and scalping, herbicides 'offer the only really effective treatment for removing many of the more tenacious and aggressive invasive species'.

Adam Muyt, Bush Invaders of South-eastern Australia

components, and that other products have POEAs besides those with glyphosate.⁵¹ Jonathan Latham wrote about the impracticalities of assessing the safety of all the chemicals used in combinations, saying the National Toxicology Program found that to study the interactions between 25 chemicals would require 33 million experiments costing \$3 trillion.⁵²

The President's Cancer Panel called for a shift to 'green chemistry' to

find new ways of meeting human needs without contaminating the environment. But they said green chemistry alternatives will need careful long-term study to ensure they are not themselves hazardous. Naturally occurring substances such as cyanide and uranium can be very toxic.

In the chemical world we find ourselves in, genetically modified foods are something else to wonder about. Controversy about glyphosate goes

back to GM crops, many created to survive glyphosate, to enable easy control of associated weeds. A global ban on glyphosate could be seen as a big victory for anti-GM campaigners. But many weeds are evolving resistance to glyphosate, so scientists have bred GM crops to survive other herbicides such as dicamba, glufosinate, triazine and 2,4-D (an ingredient in agent orange), so GM crops would continue to be used. Latham noted that chemical companies could benefit from bans

by charging premium prices for replacement products.⁵³

An ideal world would be one without pesticides. Byron Shire Council moved in that direction in 2013 when councillors passed a resolution aspiring to end pesticide use in highly frequented public places (Byron Shire Council 2019). Council officers stopped spraying roadside weeds in favour of slashing and brush cutting. But roadside weeds increased in diversity and spread, and potholes formed where weeds undermined the road (Byron Shire Council 2019). Current policy is to use herbicides to control priority weeds on roadsides, and strive to replace weedy roadside grasses with low-growing desirable plants (Byron Shire Council 2019).

Byron council has largely eliminated herbicide use in urban areas. The council purchased a steam weeder to blast steam onto small weeds on footpaths, garden beds, playgrounds and picnic areas. Steam will only kill annual weeds, so is unsuitable for most environmental weeds, which are perennial shrubs, trees, vines and grasses that re-sprout when foliage is killed. The Council's Pest Management Strategy states that herbicides retain a role in environmental weed control (Byron Shire Council 2019). One goal is restoration of native vegetation that reduces the need for spraying.

Hobart City Council trialled steam with disappointing results (MacDonald 2019). Weeds often require more than one treatment. Council officers estimated a cost of more than \$1.7 million a year to apply steam citywide, compared to \$114,000 for Roundup (containing

glyphosate), and recommended keeping the latter. Steam has to be used carefully because of the risk of burns, and only suits areas with vehicle access.

In Perth one council trialled alternative methods on clovers and other small weeds growing beside a gravel trail, achieving some success with mulch, steam, pelargonic acid, pine oil, and salt and vinegar.⁵⁴ There was no suggestion that these methods will work against larger weeds. Trials are ongoing.

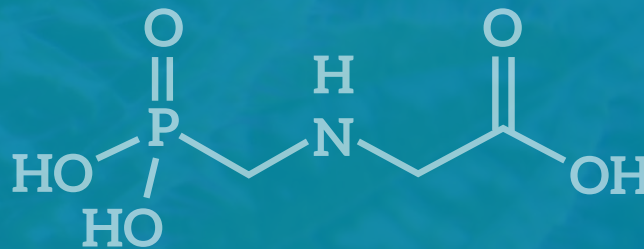
In agriculture, organic farms are chemical free, and a major shift to organic farming would see herbicide use fall. But organic farms produce less food. A South Australian study found that on two organic wheat farms, yields were 17–84% lower than on conventional farms due to phosphorus limitations and weeds (Ryan et al. 2004). One farm at Yenda produced one sixth of the grain of a neighbouring conventional farm and 4.8 times the mass of weeds (Ryan et al. 2004). Use of mineral fertiliser was the main reason but weeds contributed. Differences in yield are typically less than this, with a review of European research finding that organic farming requires 84% more land than conventional farming (Tuomisto et al. 2012). If farmers used synthetic fertilisers but avoided pesticides, the loss in productivity would be less.

Integrated weed management (IWM) is another progressive approach, using less herbicide to curb herbicide resistance in weeds. It employs alternating land uses to break weed cycles. But in IWM in cropping, herbicides remain the backbone of weed control, even though most growers are seeing some herbicide resistance (Preston 2019). Forty weed species in Australia have

developed some resistance, including 17 to glyphosate (Preston 2019), so IWM in future may entail less herbicide use, resulting in lower yields. Sowing crops more densely is one way to reduce weeds without using chemicals, but it leads to more leaf diseases. Every innovation seems to have a downside.

The National Farmers' Federation has said farming cannot survive without glyphosate. Federation president Fiona Simson was presumably alluding to poorer weed control from other herbicides (and lower yields under organic farming) when she claimed that withdrawal of glyphosate would bring on a humanitarian disaster.⁵⁵ She also spruiked the environmental benefits of glyphosate. In 'conservation farming,' farmers spray the weeds that emerge in bare fields rather than killing them by tilling, which disturbs soil structure and soil biota, increases soil erosion and loses moisture.⁵⁶ Defending glyphosate, Simson said 'New practices like low- and no-till cropping have radically reduced our greenhouse gas emissions, improved the quality of our soils, and taken water use efficiency to new heights.' A dramatic reduction in soil erosion in south-eastern Australia is attributed to reduced tillage and stubble retention (Chappell et al. 2012). Rises in glyphosate prices have led to some increases in tillage (Llewellyn & D'Emden 2010), so it seems likely that a ban on glyphosate would increase soil erosion by increasing tillage. This would also increase use of diesel fuel, a known carcinogen.

In those countries that announced glyphosate bans, it is not clear how these will play out. In January 2019, President Macron backtracked on a pledge to



phase out glyphosate in France in two years, citing the harm to agriculture.⁵⁷ An 80% phase-out is expected instead. In Brazil a judge overturned a suspension imposed by another judge because it would damage the economy,⁵⁸ while in November 2019 Thailand reversed a ban imposed one month earlier.⁵⁹ In Sri Lanka, which in 2015 became the first country to ban glyphosate, the ban was partly lifted after reports of 'devastating crop losses' due to overgrowing weeds annually costing 15 to 20 billion rupees (Australian \$12–16 million).⁶⁰

Glyphosate is the main herbicide used against bushland weeds, and a ban would undermine environmental goals. After the American court cases the president of the Australian Association of Bush Regenerators, Dr Tein McDonald, said that bush regenerators 'do not want to discard a highly important tool from our conservation toolbox without sound justification'.⁶¹ Another regenerator, Kate Hughes, has campaigned against organochlorine pesticides, writing the book *Quick Poison, Slow Poison: Pesticide Risk in the Lucky Country* (1994), but she does not oppose glyphosate. In 2016 she wrote about the health concerns, and also about 'the essential role played by judicious herbicide application to protect Australian biodiversity'. Without glyphosate the Macdonald River near her home would, she wrote, be 'virtually over-run' with invasive weeds (Hughes 2016).

Of the many methods to control weeds in bushland reserves, which include fire, mulching, slashing, grazing and scalping, herbicides 'offer the only really effective treatment for removing many of the more tenacious and aggressive invasive

species', wrote Adam Muyt in his book *Bush Invaders of South-eastern Australia* (Muyt 2001). He said that without these chemicals 'there would inevitably be a decline in the quality and quantity of most remaining indigenous vegetation'. Unlike on farms, glyphosate is usually applied in a discrete and targeted way, with stem injection or a cut-and-paint application to individual plants (Hughes 2016), although in some situations it is sprayed on foliage and some spray drift can then occur.

On World Heritage-listed Fraser Island glyphosate is used to eradicate bitou bush (*Chrysanthemoides monilifera* spp. *rotundata*), one of Australia's worst environmental weeds. Large plants are decapitated and the stumps sprayed with glyphosate, and groups of mature plants are sprayed (Behrendorff et al. 2019). The goal is complete eradication from the island by 2027, after which this use of glyphosate will end. Bitou bushes can grow two metres tall and six metres wide so the removal of plants, including rootstocks, without herbicide would be impractical. Two other chemicals are effective against this weed – picloram and metsulfuron-methyl⁶² – and these might be safer than glyphosate but have not received much research scrutiny. When the IARC reviewed picloram back in 1991 it noted one finding of tumours in rats but no research on humans, concluding that 'Picloram is not classifiable as to its carcinogenicity to humans'.⁶³ It has not assessed metsulfuron-methyl.

In the Northern Territory, glyphosate is central to the fight against gamba grass (*Andropogon gayanus*), one of the worst weeds in the Australian tropics. Gamba is an African pasture grass imported

because it grows so tall – up to 4 metres – that it provides far more feed for cows than any native grass. But if it goes uneaten, it fuels much hotter fires. These are up to eight times more intense than the hottest native grass fires, and gamba has increased the season of extreme fire weather by six weeks (Setterfield et al. 2013). It is killing eucalypts, converting northern savannas into African grasslands. Around Darwin, where it is rampant, fire-fighting costs have risen nine-fold (Setterfield et al. 2013). Like bitou bush, gamba grass is one of 32 'weeds of national significance' and has been declared a key threatening process under national law. Control of this weed currently hinges on glyphosate, the only herbicide known to give good control. To help landholders, the Northern Territory government was for 10 years giving away free glyphosate.

Gamba grass will never be eradicated. In most national parks and reserves, eradication is impossible and the goal is weed reduction to aid return of native plants, which then hinder the return of weeds, allowing for less herbicide use. Sprays have one advantage over manual removal. Weeds are seldom killed by decapitation, and have to be excavated if chemicals are not used. Most environmental weeds have very substantial root systems so large holes have to be dug, disturbing the soil profile. Disturbed ground is ideal for weed germination, and often unsuitable for seedlings of native plants, and detrimental to soil invertebrates. Disturbed ground is also susceptible to wind and rain erosion and desiccation.

5. Some conclusions

The widely used herbicide glyphosate has received intense international criticism, some warranted, some not. Glyphosate plays a major role in the control of agricultural and environmental weeds, but its use carries health risks. It could well be a carcinogen, but if used correctly, current research suggests it is unlikely to cause cancer in humans.

The International Agency for Research on Cancer (IARC) was conducting a hazard assessment when it determined in 2015 that glyphosate is a probable carcinogen. A hazard assessment simply asks if a substance can cause harm. A risk assessment asks instead if a substance can cause harm under conditions of normal exposure. Most organisations that conducted risk assessments after the IARC decision, including the Australian Pesticides and Veterinary Medicines Authority, concluded that glyphosate does not **cause** cancer when used according to safety instructions, and endorsed its continued use. In most of the court actions taken against the makers of glyphosate the cancer victims were

repeatedly drenched, from times before the product came with clear safety instructions.

The risks posed by glyphosate should be balanced against other risks. IARC is more certain that cancer is caused by sunshine, alcohol, salami and wood dust than it is about glyphosate. It linked glyphosate to non-Hodgkin lymphoma, but the Australian Cancer Council does not list glyphosate as one of the risk factors for this cancer. Australians are exposed to many chemicals that pose greater risks but escape much scrutiny. Media articles sometimes mention glyphosate traces found in our bodies as if that is especially alarming, but nearly 300 pollutants have been detected in babies, so the situation is one of many chemicals around us rather than that of glyphosate being unusually pervasive. But that said, glyphosate users should be careful not to inhale it or splash it on their skin.

Chemical substitutes for glyphosate could be no better or worse for human health, and less effective at weed control. Some are harsher on the

environment. One concern is 'regrettable substitutions', by which one chemical is replaced by others that seem safer only because they are newer, so less is known about their impacts. Newer chemicals could prove safer, but only time will tell.

The surfactants incorporated into herbicides can be very harmful to aquatic life. Roundup Biactive is the glyphosate brand approved for use near water, because it has a surfactant considered safe for frogs and other aquatic life.

Non-chemical methods of control, especially steam spraying, can be used against some very small weeds in city parks and ovals. They do not kill larger weeds in parks, nature reserves and on farms. Steam has to be used carefully because of the risk of burns, and only suits areas with vehicle access.

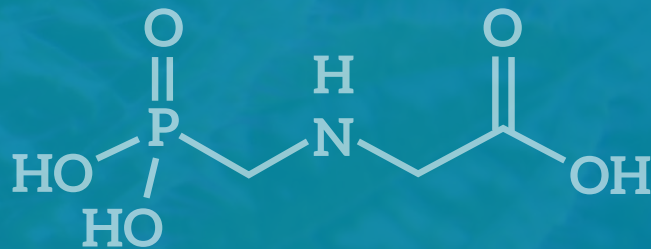
A ban on glyphosate would have serious environmental consequences. Weed invasions would increase in areas of native vegetation including national parks, and erosion would increase on farms.

Sites worth visiting

- APVMA justifying its decision: <https://apvma.gov.au/node/13891>
- A series of Australian experts comment on the first Australian cancer lawsuit: <https://www.scimex.org/newsfeed/expert-reaction-first-australian-cancer-lawsuit-over-herbicide-roundup>
- The World Health Organization explains why different WHO agencies reached different decisions about glyphosate: <https://www.who.int/foodsafety/faq/en/>
- Environment writer and scientist John Latham critiques the chemical world we live in: <https://theecologist.org/2016/may/20/problem-not-glyphosate-or-ddt-or-bpa-we-must-challenge-entire-system>

Articles about regrettable substitutions

- https://www.vice.com/en_us/article/9k5gn3/removing-glyphosate-from-our-food-wont-make-us-safer
 - <https://blog.americanchemistry.com/2017/07/bpa-and-glyphosate-a-cautionary-tale/>
 - Cancer Council Australia addresses pesticides: https://wiki.cancer.org.au/policy/Position_statement_-_Pesticides_and_cancer
 - Countries that have banned and sometimes unbanned glyphosate: <https://www.baumhedlundlaw.com/toxic-tort-law/monsanto-roundup-lawsuit/where-is-glyphosate-banned/>
- Many of the reports cited in this one are publicly available and can be found by searching online with their titles (eg. "Reducing Environmental Cancer Risk – What We Can Do Now").



BOX 4

Sunflowers are a crop for which glyphosate-resistant weeds are becoming a problem. Photo: Rudy and Peter Skitterians | Pixabay

Superweeds

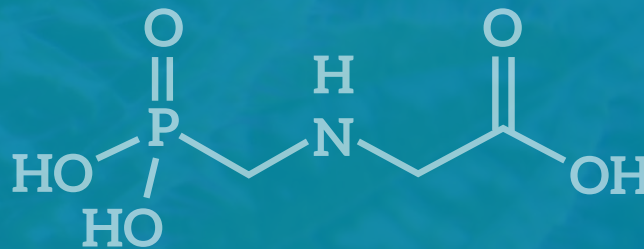
Some media articles warn of 'superweeds', meaning weeds that resist control because they are immune to glyphosate. The word, which suggests armies of triffids, is applied to weeds that in truth are no larger or more vigorous than their forebears, their only difference being immunity to glyphosate. Glyphosate-resistant crops are created by genetic engineering, while glyphosate-resistant weeds arise via evolution, because crop sprays leave behind a small cohort of weeds with some natural resistance to glyphosate, and these eventually multiply

and dominate. They have an advantage over typical weeds only where glyphosate is sprayed. They aren't more likely than other weeds to spread into a forest and there is no evidence of that happening. Most are readily killed with other herbicides.

Farmers in Australia are very concerned about resistance to other herbicides as well, including atrazine, paraquat, chlorsulfuron and trifluralin. Weeds immune to these are not called 'superweeds' only because that word was coined to heighten concerns about GM foods and these herbicides aren't relevant to that.

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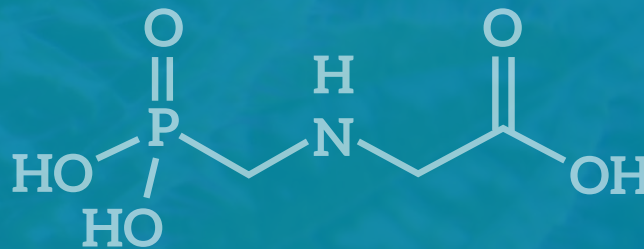
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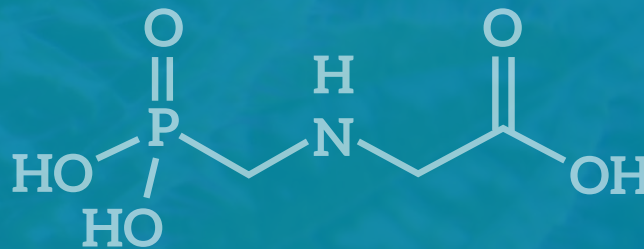
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