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Pesticide Supply Chains From China to Australia: Examining Paraquat Amid the Global Pesticide Complex

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ABSTRACT

Following recent calls to deepen understanding of the Global Pesticide Complex, this article delves into the China-to-Australia supply chain of a single herbicide—paraquat. First released in the United Kingdom in the 1960s, acutely toxic paraquat is now primarily produced in China. It is widely used in Australian broadacre farming, where, in response to the growth of no-till cultivation and rising herbicide resistance, it is used as a 'double knock' strategy with glyphosate. Through interviews and secondary data collection on the China-to-Australia paraquat supply chain, we connect upstream and downstream processes, examining the three nodes of production, distribution and use. We find a complex and at times slippery materialisation of the Global Pesticide Complex enabled by cheap Chinese formulations but also profoundly shaped by Australia's regulatory politics, specific farming practices and environmental conditions.

1 | Introduction

Now banned in the United Kingdom, Europe, China, Thailand, Brazil, Taiwan and elsewhere, the herbicide paraquat continues to be widely used in Australian broadacre farming, particularly on wheat, pulses and canola (Walsh and Kingwell 2021). Paraquat dichloride is a non-selective contact herbicide that is acutely toxic to humans and hazardous to aquatic environments. It is used for the control of weeds, typically in conjunction with glyphosate. As we describe in this article, the paraquat used by Australian farmers is almost exclusively manufactured in China for export. Amid a growing and interdisciplinary body of scholarship on pesticide studies, in this article we delve into the flows of paraquat from China to Australia. Our aim is to examine how the Global Pesticide Complex materialises through this China-to-Australia trade, with a focus on the three nodes of production, distribution and use. Our approach, outlined below, is to connect upstream and downstream processes and to identify the broader dynamics of regulatory politics, power relations and the environment. This enables us to ground the notion of the Global Pesticide Complex and better understand its complex and highly politicised articulation across China and Australia.

An analysis of paraquat begs the not so straightforward question—what *is* paraquat? Paraquat comes into Australia in two forms: as paraquat dichloride active ingredient that is then made into a formulation in Australian facilities or, much more commonly, as a finished, formulated product. These formulations contain active ingredient as well as other raw materials such as surfactants, adjuvants, oils and salts[1] and are produced in multiple forms including granules, concentrates and emulsions. At the time of writing, 20 companies have approval to import and supply paraquat active ingredient into Australia, and 121 separate formulations (products) are registered for sale (APVMA 2024). These come in the forms of paraquat dichloride 250, 300 and 360 g per litre. A small number of these 121 products are paraquat/diquat mixes, while two products are paraquat/amitrole mixes (APVMA 2024).

The other distinction to make is between generic and proprietary products. Generic paraquat formulations are cheaper, while proprietary products attract a higher price (not because they are patented products, but because of their specific mix of raw materials which gives them particular qualities such as rain-fastness) and are offered by the big-name companies such as Syngenta (Gramoxone 250, 360) and Adama (Spraytop 250, 330). Paraquat formulations are available in 20, 100 and 1000-l containers, though there is some suggestion that smaller products will be phased out, leaving only 1000-l drums to be used in boom sprays.

Like all agrochemicals in Australia, paraquat is registered by the Australian Pesticide and Veterinary Medicine Authority (APVMA) for use on particular crops (including hay, sugar cane, cereals, oilseeds, bananas, peanuts and pulses) and for specific purposes. However, as paraquat flows through production, distribution and use, at every step of the way there is a slipperiness that blurs these neat distinctions. Basic ingredients are sometimes unknown (formulations are considered commercial secrets) and paraquat moves through registration and review, production and packaging, shipping and distribution, use and disposal, maximum residue limits (MRLs) and accumulation in the environment and in people's bodies, in highly geographically dispersed ways. As we will describe, what emerges are aspects of the chemical 'slipperiness' described by Hine (2025); in particular, different forms of bureaucratic slippage.

Amid the smorgasbord of chemicals used in Australian farming, paraquat is of particular interest because of the ongoing APVMA paraquat and diquat review. Paraquat has been available in Australia for over 60 years (Walsh and Kingwell 2021), continues to be widely used, and yet assessment by the APVMA has been in progress for almost 20 years. Following a 2023 instruction from then Minister for Agriculture, Fisheries and Forestry, Murray Watt, the latest technical report and draft recommendations were released and public submissions received, with a decision originally planned for late 2025 and then delayed to 2026. Public attention on the review of an otherwise obscure agrochemical has been heightened by a series of media reports on possible links between paraquat use and Parkinson's disease, with Parkinson's Australia formally calling for a ban (ABC 2024a, 2024b). Media reporting prompted responses from Syngenta and the APVMA disputing the Australian Broadcasting Corporation's presentation of scientific findings, while leaked emails from the National Farmers' Federation directed members not to comment on the media story (ABC 2024c). As we discuss in this article, an examination of paraquat exposes some of the fault lines of industrialised agriculture in Australia, in particular, how the widespread shift to no-till farming has led to entrenched chemical dependence and the highest rates of herbicide resistance globally (Peterson et al. 2018).

Our analysis is based on primary and secondary data collection in Australia and China. We compiled secondary sources for understanding production in China, including company websites, trade reports, export data and other government statistics. We also drew on secondary sources in Australia, including the APVMA's paraquat technical report, media reporting, submissions to the Federal Government's food security inquiry, reports from industry peak bodies and publicly available import and pesticide sales data. Our analysis is then informed by 11 semi-structured interviews conducted in 2025 with participants involved in the supply chain. The APVMA's paraquat technical report lists current holders of paraquat active ingredient and formulation registrations in Australia. Starting from this list, we sought interviews with agrochemical suppliers and retailers to map the supply chain and understand the role of different actors. We also interviewed peak body representatives and agronomists to understand where and why paraquat is being used in Australian farming and to delve into the Australian regulatory environment for pesticides. Participants were approached through LinkedIn or publicly available contact details and through chain referral. All interviews were conducted in Australia, in person, online and on the phone, with the all-male participants based in Victoria, New South Wales and Queensland. This geographic distribution reflects some of the main markets for paraquat in Australia: broadacre wheat and other crops in Victoria and New South Wales and broadacre sugarcane in Queensland and northern New South Wales. Interviews were not without challenges: many companies and individuals did not respond despite repeated attempts or declined to participate. Some participants put fairly strict parameters on what they would and would not talk about, a wariness that may be explained by concerns about corporate image or commercial secrecy. While only securing a small number of interviews, these do reflect the different segments of the supply chain; we do not have any major blind spots in this regard. It is important to note that we did not do comprehensive data collection on farms, so what is presented in the 'Use' section is gleaned from interviewees' discussions of farming practices on broadacre farms and secondary material such as field crop guides.

2 | Bringing the Global Pesticide Complex Into Focus

While pesticide studies remain an expansive and somewhat scattered field (e.g., Bohme 2015; Saxton 2015; Suryanarayanan and Kleinman 2017; Williams 2018; Shattuck 2021a), recent scholarship in this area has coalesced to highlight a critical need for research on patterns of production, trade, use and their interrelations, as well as the social drivers of increased pesticide use (Shattuck et al. 2023; Mansfield et al. 2024). To this end, Mansfield et al. (2024, 397) foreground the notion of the Global Pesticide Complex as an analytical tool 'to examine connections between the spheres of production, distribution, and use that stretch unevenly across time and space' and to highlight interactions among agrochemical companies, regulatory bodies, environmental and social justice movements, paradigms of toxicity and the chemical substances themselves. In what follows, we review major threads in pesticide studies, political ecology and chemical geographies to shape our inquiry into paraquat. By reading across different theoretical standpoints and concerns, we refine and operationalise the Global Pesticide Complex as an analytical tool.

First introduced by Galt (2008), the notion of a global pesticide 'complex' sought to understand the global pesticide industry through a materialist political ecology rooted in political economy. Galt's examination unpacks pesticide regulation, production, trade, sales and use, while also centring the environment, arguing that 'all aspects of pesticides' lifecycles from conception to environmental fate' needed to be considered (Galt 2008, 786). Subsequent research on the Global Pesticide Complex has focused quite strongly on political economic concerns and conceptual tools from economic geography. These studies have examined the rapidly changing industry and its dynamics of production, firm networks, trade relations and supply chains, often with an eye to implications for capitalism and geopolitics (see for instance Shattuck 2021b; Werner et al. 2022; Zhao and Rogers 2024; Berndt et al. 2025; Berndt et al. 2026, this issue; Guthman and Werner 2026, this issue). This macro scale of observation has illuminated the emergence of dominant pesticide firms (Clapp 2025), the entrenchment of pesticide dependence globally (Shattuck et al. 2023) and shifting geographies of production, particularly the dominant role played by Chinese firms and generics (Werner et al. 2022; Zhao and Rogers 2024; Xu and Chen 2025; Berndt et al. 2025).

Amidst this scholarship, Mansfield et al. (2024, 398) have called for opening up the 'black box' of supply chains, 'connecting upstream developments with those further *downstream* to better understand what is driving industry restructuring' (our emphasis). These dynamics are by no means straightforward research inquiries. As Mah (2023: 21) notes in her work on the petrochemical industry, there are hierarchies of parent companies, subsidiaries, manufacturing and corporate sites, that are interconnected with upstream and downstream processes: 'even at the level of specific sites, the concentrated geographies of petrochemical industrial complexes operate as highly complex systems'. In this article we seek to better understand the dynamics of production, supply chains and exports by connecting paraquat's upstream and downstream elements between China and Australia. To do so effectively, we need to draw in other insights from the broader pesticide studies literature.

Within pesticide studies there is a collection of studies that look closely at social-ecological relations of agricultural production and social relations of exchange (Andreatta 1998; Galt 2010; Zinda and Kapoor 2019; Rogers et al. 2023; Nichols and Kumari 2026, this issue). These studies draw us to the farm to understand different trajectories of pesticide use and the socio-economic, cultural and environmental conditions that produce chemical dependency. They also situate these dynamics in processes well beyond the farm, in analyses more aligned with political ecology and critical agrarian studies. For example, Rogers et al. (2023) explore China's agrochemical complex and a broader web of state policies and capital. In Luna's (2020) work on Burkina Faso, growing herbicide use in cotton production is explained through global political economic forces and labour shortages but also through the specific set of socio-cultural changes taking place to produce the need for labour-saving technologies. In Ghana, insecure land tenure pushes urban farmers to shorten cropping cycles and prioritise quick returns, making heavy pesticide use less about farming technique and more about social and political pressures (Nyantakyi-Frimpong et al. 2016). Other studies point to the rise of monocultures and non-traditional export crops (Andreatta 1998), as well as pressure by middlemen (Barazza et al. 2011) in driving intensive pesticide use. This work matters in terms of highlighting how particular agrarian contexts and the power relations within them, shape pesticide use.

Pesticide studies scholars have to some degree also engaged with the more-than-human, socio-natures and assemblage thinking, which bring other dynamics and connections into view. Early dialogues on chemical geographies between Romero and colleagues (2017) explored a range of conceptual frames including the more-than-human, chemical assemblages and elemental geographies. From a more-than-human perspective, pesticides are recast as active agents that may play a conditioning role in their entanglements with agricultural technologies, knowledges, production, regulation and markets. Assemblage thinking is perhaps more evident; for instance, Werner's (2022) work draws on Guthman (2019, 17) and others' conceptualisation of socio-natural assemblages to examine 'a constellation of heterogeneous elements and forces that in coming together are consequential'. Assemblage thinking also extends into Werner et al.'s (2022) critical commodity study of glyphosate and Argüelles and March's (2023) study of agricultural assemblages and pesticide use reduction in Spain. Werner et al. (2022, 31) observe glyphosate's agency in a wider 'socio-technical assemblage that arranges specific agricultural production methods and biotechnical knowledges'. From these studies, we understand pesticides to be entangled in related processes of knowledge production and regulatory politics (beyond the supply chain) and are alerted to the need to consider how nature and pesticides themselves may shape the materialisation of the Global Pesticide Complex in certain places.

Galt's provocation to examine pesticides from conception to environmental fate has therefore elicited a strong and still evolving response from scholars investigating the Global Pesticide Complex. If we look at chemical geographies more broadly, much work has been done in recent years on the material dimensions of pesticides, no longer taking for granted 'what they are, where they are made, how they change, and how they move' (Balayannis 2018, 23). This includes Guthman's (2019) study of chemical fumigants in California's strawberry industry, Romero's (2022) historical geography of arsenic, cyanide and other early waste products-turned-pesticides, Balayannis' (2020) geography of hazardous waste removal and Boudia et al.'s (2018) conceptualisations of residue. This work is important because it starts to tease out the specificity of particular chemicals and formulations and points to just how different pesticides are from other, more fixed and easily knowable, commodities. In this article we aim to make sense of an acutely toxic active ingredient as well as formulations (commercial secrets) that have many different labels, and a substance that is typically used *in conjunction* with other chemicals and can then remain in soil, water, food and bodies. To do so, some further conceptual refinement is needed in how we approach pesticide supply chains and the governance of particular chemicals. Hine's (2025, 819) notion of chemical slipperiness is useful here in that it identifies specific characteristics: how chemical substances may evade notice and knowability, may move through space with no regard for conceptual or constructed boundaries, may persist in specific spaces across time and may routinely fall through the gaps of different regimes of management. These four characteristics should not be assumed to be inherent to all materialisations of the Global Pesticide Complex; what we suggest is that they should be actively examined as part of understanding how this Complex materialises in specific places, through specific products and their supply chains.

To summarise, we argue that to effectively examine the materialisation of the Global Pesticide Complex in the China-to-Australia paraquat supply chain (and elsewhere) it is necessary to conceptually connect upstream and downstream processes, to consider how particular agrarian and environmental contexts shape pesticide supply chains and to look at the broader 'assemblage' beyond the supply chain, namely knowledge production and regulatory politics. Given the nature of pesticides, it is also important to allow for chemical slipperiness within and beyond the supply chain. Methodologically, the nodes of production, distribution and use guide us in our data collection and analysis, and it is to the first of these nodes that we now turn.

3 | Production

The British company ICI (now Syngenta) first introduced paraquat (in Chinese 百草枯 *bai cao ku*) into the Chinese market in 1984, obtaining temporary registration in China more than 20 years after the product was first launched (Werner et al. 2022). Shandong's Pesticide Research Institute in cooperation with Nanjing Red Sun (南京红太阳股份有限公司) then built the first large-scale production facility in 2001, with a capacity of 2000 t per year (CCPIA 2011; AgroPages 2012). By 2010, production capacity had reached over 100,000 t per year, in both active ingredient (paraquat dichloride content of ≥ 42%) and formulations, and since 2011, China has been the largest producer of paraquat, accounting for more than 70% of global production (Sino Agri 2012a; AgroPages 2013). In the 2000s, domestic use of paraquat in China increased significantly, from 1560 t of active ingredient in 2001 to 9080 t in 2011 (Wang 2016). China has long been a major exporter of paraquat, supplying paraquat active ingredient and formulations to global markets, but particularly Asia, Latin America and Australia. From the 2000s, production was already export-oriented, and by 2010, well before the ban discussed below, China was exporting approximately 80% of the paraquat it produced (Sino Agri 2012b).

Following thousands of cases of paraquat poisoning, including suicides, Chinese medical professionals proposed a ban on the use of paraquat to the National People's Congress (Zhang et al. 2010; Wang 2016). A series of regulatory measures then followed, with production of aqueous paraquat solutions banned for use from 2014 and the domestic sale of paraquat banned from 2016 (Ministry of Agriculture and Rural Affairs 2012). Production and sale of soluble paraquat granules and gels (which posed less of a poisoning risk) continued until 2018, made by companies such as Shandong Luba and Nanjing Red Sun, but sustained public pressure led to further restrictions (AgroPages 2016). The Ministry of Agriculture upgraded the toxicity classification of paraquat to highly toxic in 2015; by 2018 the registration certificate for remaining products had expired and was not renewed, and by 2020, domestic sales were not permitted to continue in any form (Ministry of Agriculture and Rural Affairs 2015, 2016).

These measures did not apply to paraquat produced for export: registrations and production licences for export overseas were retained. Indeed, China's paraquat production continued to increase between 2016 and 2018, peaking at approximately 130,000 t of active ingredient in 2018, in response to sustained global demand (AgriBusiness Global 2012).[2] Gradually though, with the loss of the domestic market and the increased market share of alternative products such as glufosinate (a broad-spectrum herbicide), from 2019 production began to decline substantially. By 2023 China's paraquat production had reduced to 48,520 t (see Figure 1; Donghai Securities 2023). Nonetheless, paraquat remains China's second most valuable pesticide export following glyphosate (AgroPages 2020) and Australia remains one of its key customers: when in 2020 the Ministry of Agriculture and Rural Affairs implemented new 'export-only' pesticide registrations, the first approved registration certificate was designated for Australia (CCPIA 2021).

Partly in response to the domestic bans, production in China is undergoing major restructuring. In 2025, the number of companies authorised to produce paraquat for export has shrunk to six—Red Sun, Jiangsu Noon, Shandong Luba, Shijiazhuang Baofeng, Hebei Shanli and Syngenta China (see Table 1) with smaller companies closing down. Note that this is six *companies*, some of whom have many different manufacturing *facilities* in different locations and engage third party manufacturers as well. Our interviewees described a huge shift in production in the past decade, from China as a producer of active ingredient that was then formulated in Australia, to China as the dominant supplier of both active ingredient and formulations: 'it just removes the ability for our local formulators to compete' (COMP08). While Taiwanese companies also feature in the list of paraquat registrations in Australia, paraquat is no longer produced in Taiwan. Sinon (興農股份有跟公司 *Xingnong*), for instance, produces paraquat in its mainland China facilities, which is distributed in Australia by its Australian subsidiary Sinon Australia. Only a small number of companies now hold the necessary production licence and export registration, effectively barring newer entrants (Ministry of Agriculture and Rural Affairs 2020).

The broader pesticide production landscape in China is highly diffuse: hundreds of facilities produce hundreds of active ingredients as well as formulations and sell these to a plethora of customers. As one Australian company representative said 'You can't buy agchem unless it comes from China … you can go to any number of Chinese manufacturers and say: "Make this recipe and I'll buy x quantity of it"' (COMP01). Rainbow, a major player in pesticide exports, has nine separate production facilities in China and also buys from other Chinese companies, both through exclusive arrangements with companies

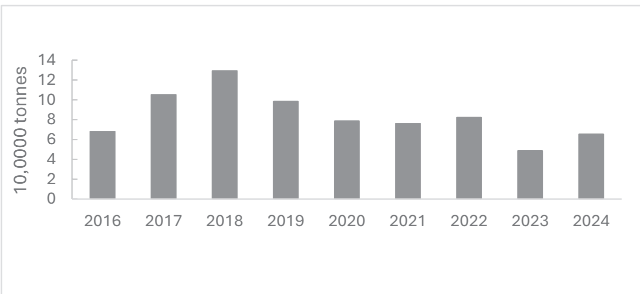

FIGURE 1 | Paraquat active ingredient production in China 2016–2024. *Source:* Wind (2023) and BAIINFO databases (2024).

TABLE 1 | Remaining export registered paraquat producers in China.

Company name	Parent company and ownership	Factory locations and subsidiary company	Registration certificates and expiry	Content	Production capacity (active ingredient) 2021 (tonnes)	Actual production of AI 2021 (tonnes)
Nanjing Red Sun 南京红太阳股份有限公司	Private company Major shareholders: Nanjing First Pesticide Group (南京第一农药集团有限公司); Red Sun Group (红太阳集团有限公司)					
		Nanjing Biochemicals Nanjing Jiangbei Industrial Park, Jiangsu	EX20240254 (2029); EX20240253 (2029); EX20230089 (2028); EX20230091 (2028); EX20230062 (2028)	Aqueous solution (200 g/L; 250 g/L) Concentrate (30.5%) Soluble concentrate (20%)	Nanjing 8000 – 10,000	Suspended
		Anhui Guoxing Red Sun Life Science Industrial Park, Dangtu Economic Development Zone, Ma'anshan, Anhui	EX20210171 (2027); PD20102088 (2025)	Concentrate (30.5%) Soluble concentrate (250 g/l)	Anhui 20,000	20,000
		Shandong Kexin Henyuan Development Zone, Dezhou, Shandong	EX20240065 (2029); EX20240064 (2029); EX20230159 (2029)	Concentrate (42%) Aqueous solution (200 g/l; 250 g/L)	Shandong 2000	2000
Shandong Luba 山东绿霸化工股份有限公司	Private company	Weifang Luba Lingang Industrial Park, Shandong	EX20240072 (2029); EX20240071 (2029); EX20220145 (2027); EX20200002 Only for sale to Australia (2026)	Concentrate (32.6%) Soluble concentrate (200 g/l; 250 g/l)	10,000	7000
Shijiazhuang Baofeng (石家庄宝丰化工有限公司)	Private company Major shareholder: Taiwan Guanxiong Technology (台湾冠雄科技有限公司)	Douyu Industrial Zone, Shijiazhuang, Hebei	EX20240019 (2029); EX20230157 (2029)	Aqueous solution (200 g/l) Concentrate (42%)	5000	Unknown

(Continues)

TABLE 1 | (Continued)

Company name	Parent company and ownership	Factory locations and subsidiary company	Registration certificates and expiry	Content	Production capacity (active ingredient) 2021 (tonnes)	Actual production of AI 2021 (tonnes)
Hebei Shanli 河北临港化工有限公司	Private company Major shareholder: Hebei Chengxin (河北诚信集团有限公司)	Lingang Development Zone, Cangzhou, Hebei	EX20220255 (2028)	Concentrate (42%)	5000	3500
Syngenta China 先正达集团中国	State-owned Syngenta Group, a subsidiary of Sinochem (中国中化控股有限责任公司)	Syngenta Nantong Crop Protection Pty Ltd. Nantong Economic Development Zone, Jiangsu	EX20240256 (2029); EX20240255 (2029); EX20240212 (2029)	Concentrate (360 g/L) Soluble concentrate (200 g/L; 250 g/l)	10,000	5000
Jiangsu Noon 江苏诺恩作物科学股份有限公司	Private company	Xuzhou Industrial Park, Jiangsu	EX20240258 (2030); EX20220243 (2028) EX20240110 (2029)	Concentrate (42%) Aqueous solution (200 g/l)	12,000	10,000

Sources: Compiled by the authors from ICAMA (2025), Wind Economic Database (2023), BAIINFO (2024) and corporate websites.

that produce solely for them and with others at the right price. Rainbow has one paraquat formulation registered for sale in Australia but also produces finished goods under other labels and sells these through 15 to 20 wholesale customers. One interviewee explained some of the market fragmentation in Australia as follows:

> Well, we'll separate the house brands, so that would be Four Seasons, Nutrien under Genfarm label, Elders Titan label, then they would have a couple of the bigger customers ... Adama is probably one of their bigger customers in that regard. But then there's a pile of small generic companies that would buy: Sabakem ... Farmalinks ... They will be exactly the same product with a different label
>
> (COMP01).

This quote suggests that one Chinese producer might be producing for some of the big-name companies under their labels as well as selling the *same* formulation to smaller players for reselling under a different label, all at a negotiated price.

The concentration of pesticide production in China has occurred for specific political-economic reasons. As described by others, China has come to dominate the market in low-cost pesticide formulations, particularly generic glyphosate (Berndt et al. 2025; Shattuck 2021b; Werner et al. 2022) and through industry upgrading and stricter environmental controls, now has the sophisticated supply chains, transport logistics and reputation needed to be a reliable trade partner. There was mention of India stepping into a larger manufacturing role, but our interviews revealed major differences in the way China and India are perceived:

> So the factory that's making ingredient A that needs to be mixed with ingredient B to make pyroxasulfone are next to each other. So as I said, you're only a forklift or a conveyor belt away as opposed to, can you get it from India or can you ship it from somewhere else ... What they have the facilities [for] is to improve production ability and increase scale of existing products
>
> (COMP01)

> India say they're getting better at it, but their logistics are all way behind China. China do everything very well. They say it's going to be on a boat Tuesday next week and it'll be here on a date - it pretty much is. India says it's going to be on a boat and two weeks later, 'ah yeah, we missed the boat. The truck, the truck got stuck behind a cow on the highway'. So ... when you talk about the importance of China and chemicals, ag chemicals coming into Australia, that's my read of it
>
> (COMP04)

What our interviews also pointed to is the web of connections developed between some of the major Australian players and their Chinese suppliers; connections that articulate the Global Pesticide Complex between China and Australia:

> ... it's based on relationships. So that, that team, they spend a lot of time over there, heading around all the major producers, attending the conferences [the annual China International Agrochemical and Crop Protection Exhibition] when they're on, building relationships to those suppliers ... That's a lot of my time researching the sites, getting on site, seeing how they operate ... [my colleagues and I] go and see these factories early on to understand where it's coming from and to be confident that we've got a good product.
>
> (COMP06)

> It takes a long time ... building out those relationships. A pretty key part beyond meeting the factory and the president is to travel to the factory and physically press the flesh with the operators that run the factory ... the Chinese are really big on relationships
>
> (COMP08)

These connections of course rest on the provision of high-quality products. But processes such as testing and quality assurance through a 'certificate of analysis' (COMP08) and retaining samples from each batch to allow for tracing, appear to be inconsistent. This was mentioned only by the bigger corporate players who had sustained relationships with particular Chinese suppliers focused on specific products – 'the safest people to deal with' (COMP08). In contrast, the suppliers offering to produce 20 to 30 products at the annual Exhibition could simply be trading companies buying from many smaller outlets: 'beyond not knowing who you're talking to at the other end of the line ... you have no idea what's in the drum' (COMP08).

What these different aspects of the China-to-Australia trade reveal is that production is a set of nested and at times opaque processes. For paraquat, the majority of products come in as finished formulations. Within China, Chinese companies produce raw materials using their own facilities or buy from other Chinese manufacturers and export active ingredient and formulation. However, on a much smaller scale, Australia-based companies do import active ingredient from China to then formulate into their own product, adding specific surfactants, adjuvants, salts etc. (though many of these are also produced in China). Some companies combine these strategies:

> We buy that product [paraquat] in from China ... fully packed. We *formulate* for another supplier to the recipe [IP], we're just the manufacturer for hire ... we do sell it, that's why we've got a registration, but we don't make ours, we actually bring ours in, because it's cheaper to bring ours in from China than to make it ourselves
>
> (COMP02).

There is yet another arrangement that complicates production. One of the major corporate retailers in Australia uses multiple supply partners in Australia to formulate products on its behalf, an arrangement called 'third party tolling' or toll manufacturing. These toll manufacturers might have several arrangements:

> In our industry, it basically means you're being contracted to make someone else's recipe to their specification and using their method. There's two parts, it then divides into two more sort of things – one where they supply all the ingredients and possibly the packaging. And that … if you did get a job with Syngenta to do something like that or Bayer, that's how they'd like to run it. The other one is that the toll manufacturer supplies everything. And then there's a sort of a hybrid in between where - and that's the most common in Australia is the hybrid - where the toll manufacturer supplies the non-active ingredient, raw materials, and packaging and the client supplies the technical material, the active ingredient, which is usually sourced out of China
>
> (COMP07)

These nested processes of raw material production, formulation, adjuvant production, product testing and repacking present a far more complex picture than that of listed paraquat registrations, bringing two characteristics of chemical slipperiness to the fore. The first is moving through space with no regard for conceptual constructed boundaries. Production is not singular, nor is it necessarily coherent; rather, it comes about through a set of hard-to-trace processes that stretch from the chemical parks of Ningxia Province to the outskirts of Melbourne and is shaped by specific China-Australia trade relations. Understanding production is by no means a straightforward exercise and we have likely only presented a partial picture of how paraquat is produced in China. The second is how chemical substances may evade notice and knowability, given how difficult it is to trace production of even a single active ingredient.

4 | Distribution

There are currently 20 paraquat active constituent approvals in Australia. As we have already described, the vast majority of this active ingredient is produced in China. Then, there are 121 registered agricultural chemical *products* containing paraquat as a soluble concentrate, held by some of the big names such as Syngenta, Adama and Nufarm, as well as a host of smaller traders such as Sinon, Sanonda Australia and others (see Table 2). Despite the dominance of two retailing companies—Elders and Nutrien, with 245 and 385 retail sites respectively (Australian Financial Review 2025)—distribution in Australia is highly fragmented and needs to be understood in terms of the divide between proprietary products, 'white labels' and other generics, as well as a divide between suppliers, big retailers and independent retailer networks.

One company representative described the industry as composed of traditional suppliers such as Bayer and Syngenta who incorporate field representatives, technical officers, research and development in their costs, versus non-traditional suppliers with low-cost models simply buying from China and selling at competitive prices. However, this is not a simple distinction between companies because the big retailers play both sides of a competitive market, selling both their flagship products and their own branded 'white-label' generics:

> So every company has to have a second string to their bow to compete. Because Genfarm [Nutrien's generics brand] came along, with their own label, and started winning all the big tenders and stuff, so then Elders said 'well, we better have our own label' [Titan] and then companies like [our] members couldn't compete, so we better go to the best trader we can find, the lowest, lowest cost we can find. So it goes from features and benefits and why a product's good to 'what's your price?' … we've got very good relationships with companies like Nufarm and Bayer and Syngenta, but they're under pressure. Because more and more stuff [is] coming out of China, and it's good quality and it's low cost
>
> (COMP04).

What this interviewee is suggesting is that white labels are growing in importance as these big retailers effectively take a link out of the supply chain and move into the supplier space: 'They can buy in China into their own label to the farmer instead of buying from, say Nufarm - so Nufarm buy from China at a margin sell to Elders, sell to the farmer' (COMP04). Companies such as Nufarm with manufacturing capability will therefore try to maximise their manufacturing assets by bidding to manufacture white labels for the big retailers while retaining control over distribution of their own branded Nufarm products (both high performance and generic 'fighting' brands).

The rise of cheap Chinese generic formulations has profoundly reshaped agrochemical availability, retailing and use in Australia. These formulations have become widely available and are imported by all actors in the Australian supply chain. Many smaller players have also entered the market. Importantly, this is understood to have been enabled not just by the availability of cheap formulations but also by Australia's regulatory environment:

> It's very easy to register a product in Australia, it doesn't cost you much at all. Once it's off patent, I think it's like $800[3] you can register a product … It's not much at all. And you can just register it and the company has done all the R&D and developed it, you just have to compete with that company. That company might have small staff and buy straight from China, China makes it, so yeah, it's interesting how it plays out
>
> (COMP04).

TABLE 2 | A selection of paraquat products currently registered by the APVMA.

Registration holder	Company ownership	Product type and name	Distribution channel
Nufarm	Australia	Shirquat 250	Wholesale to corporates and independents
Nutrien (Genfarm)	Canada	Paraquick Force 350 Relyon 250 Relyon 360 Genfarm paraquat 250 Genfarm paraquat 360 Genfarm Di-Par 250 (diquat)	Nutrien's retail network
Elders (Titan)	Australia	Titan paraquat 250 Titan paraquat 360 Titan Eos (diquat) Apparent paraquat 250 Apparent Weedy Seedy (diquat)	Elders' retail network
Syngenta Australia	China (Sinochem)	Gramoxone 250 Gramoxone 360 Sprayseed (diquat)	Supplies corporate retailers
Adama	China (Sinochem)	Spraytop 250 Spraytop 330	Supplies corporate retailers
Conquest	China (Jiangsu Sevencontinent)	Explode 250 Explode 300 Scorcher (diquat)	Unknown
Rainbow	China	Rainquat 250 Rainquat 360 Rainbow Diqu-Para 250 (diquat)	Wholesale to corporate retailers
OzCrop	China (Rainbow)	OzCrop paraquat 250 OzCrop paraquat 360 Red Dog 250 Blowout (diquat)	Wholesale to independent retailers
Sinochem	China	Kelpie ParQ 250 Kelpie P-Quat 250 Kelpie P-Quat 300	Via Syngenta
Sinon Australia	Taiwan	Sinmosa 250 Paradox 250 Combik 250 (diquat)	Wholesale to corporates and independents

Source: Compiled by the authors from APVMA (2024) and interviews.

> It's not a massive barrier to get a product registration. There's certainly hurdles that have to be passed, and the regulator is robust … the regulator do their job, it's just that our regulation is not sort of in such a way that it would sort of be a barrier to someone bringing a generic product into the country.
>
> (COMP05)

The China–Australia Free Trade Agreement (ChAFTA), signed in December 2015, further accelerated this process. Prior to ChAFTA, herbicides from China were subject to either a 9%, 6.5% or 5% tariff (DFAT 2015): these were progressively removed by January 2019.

The China-to-Australia supply chain is smoothed by a favourable import and registration environment. A sophisticated logistics operation delivers them to farmers. To anticipate demand, the big retailers rely on forecasting by state managers who will estimate a volume of each product that is needed in a particular region for that year. The aim is not to have much product sitting in warehouses by the end of the season. If there are shipping delays, companies will go to third party suppliers to not leave farmers waiting for specific products: 'there's plenty of other options out there, so we had to go and source it elsewhere' (COMP06). One company was preparing for a scenario where paraquat and diquat were banned by the end of 2025: 'we need to make sure that we don't have, we don't have a big oversupply of product in the sheds … that we can't do anything with' (COMP06).

Transport from China to port in Australia is an 8 to 9-week process, with clearing at port typically taking another week. Paraquat formulations are then moved from port into distribution to retail facilities (another week). Smaller traders will use subcontracted facilities to get their product on shelves: 'Our supply chain management people, they choose which shipping line they want to use … they choose the timing … the first I see it – and a lot of times I don't even see it – it arrives in our warehouse' (COMP03). This particular company contracts a logistics company for clearance work at the port and to arrange transport to the warehouse. From the warehouse the product is delivered to individual retailers' trucking yards and shipped around the country (see Figure 2), noting that paraquat must be trucked by drivers with a dangerous goods licence. Nufarm ships its products out through its distribution centres and also delivers directly to retailers such as Aglink (a network of independent rural retailers) and Elders, from which farmers can buy directly.

The characteristic of chemical slipperiness that emerges most strongly here is how chemical substances may fall through gaps in management. First, the highly fragmented nature of distribution, a result of the rise of generics and the entrance of new and smaller players into the import and retail market, makes it difficult to trace how paraquat moves within Australia. Second, Australia has a loose regime for registering formulations with already approved active ingredients that are similar to other products on the market. This further fragments the supply chain and enables deep dependence on cheap chemicals.

FIGURE 2 | Paraquat for sale at a rural supply store in Western Victoria (first author, 2025).

5 | Use

Paraquat is still widely used in specific farming systems in Australia to control summer and autumn weeds prior to crop sowing (Walsh and Kingwell 2021) and for pre-harvest desiccation (APVMA 2024). It is typically used in conjunction with glyphosate in what is known as double knock application: 'the sequential application of two different modes of action, the first herbicide is translocated (e.g., glyphosate) and the second is a contact herbicide (e.g., paraquat) intended to control survivors of the first application' (Cornish et al. 2020, 524). Paraquat is only approved for use in specific crops, including hay, sugar cane, cereals, oilseeds, bananas, peanuts and pulses (APVMA 2024, 64–65; Rosic et al. 2020).[4] Agronomy textbooks advise that total desiccation occurs after 4 to 7 days and that farmers should not graze or cut for stock feed for 1 day after application and not graze horses for 7 days after application (Chambers and Dean 2004). Before delving into the farming practices described by our interviewees, we first look at some of the regulatory and testing regimes for pesticides in Australia.

The APVMA manages chemical registration and approvals at the national level, while state governments are responsible for enforcing safe use through accreditation. For example, in Victoria, an Agricultural Chemical User Permit is required to buy paraquat as a Schedule 7 poison: these permits are valid for 10 years and are required to purchase restricted use chemicals (Agriculture Victoria 2025). In Victoria, users of all agrochemicals are required to keep an agricultural chemical use record (or 'spray diary'), including the product trade name, location and crop information, wind speed and name of applicator for at least 2 years. In practice, it appears that there is limited auditing of these records, and they are not used to collate state or national-level data on pesticide use.

While product labels specify maximum use rates for different crops, there is no consistent tracking of how much paraquat is being used on Australian farms, meaning we do not have statistics on what volume of paraquat is being used on Australian farms nor where it is being applied. It is commonly used though as part of a double knock in Victorian broadacre agriculture. One interviewee described the process as follows:

> So, there's one crop per year per paddock … everyone will actually do a final spray before they seed, therefore, there is a *massive* amount of volume that gets applied at that time, right? Because everyone does that pre seed knock down. Everyone. Every farmer … And then post-harvest, what we call our fallow control period … what the farmer is trying to do in Australia is retain soil moisture content and retain nutrients, right? So if you've got a wet summer where there's a lot of seed, a lot of weed around, they're going to actually spray during summer in order to actually ensure the weeds aren't sucking up all the water or aren't sucking up all the fertiliser cause they don't know how the rain is going to actually play out in the future towards

> seeding time, right? So that volume is quite erratic. It depends whether it rains or not
>
> (COMP02)

Surveys of farm practices provide some more insights into use on farms. Concern about the potential banning of paraquat led Sugar Research Australia (2024) to undertake a survey of sugarcane growers in Queensland and northern New South Wales to understand how they use paraquat and the impacts that a ban would have. Of the self-selected sugarcane growers who responded to the survey, most growers were using 0.9–1.2 L per hectare regardless of product concentration. Most (59%) apply paraquat twice in plant cane and about two-thirds (68%) also then apply it to ratoon crops. Survey respondents emphasised their professional competency and accreditation to safely handle and apply chemicals.

While in industry submissions to the APVMA paraquat-diquat review there is a strong and fairly coherent industry narrative about the highly controlled and safe use of paraquat in Australia, interviews revealed further slipperiness in its use. The first is off-label or otherwise unregistered use. While pesticides are only registered by the APVMA for use in particular crops, farmers in Victoria can apply for temporary 'minor use' permits for using either unregistered pesticides or for unapproved uses. One company representative described this arrangement as being introduced 25–30 years ago, when active ingredients had been registered for particular uses following safety and regulatory work but were also found to have broader utility. Since then, 'off-label' use has been enabled to some degree by minor use permits, while some agronomists are also understood to push the boundaries. As one company's crop protection manager in Victoria noted:

> It was brought in for horticulture, but snuck into the broadacre scene as well, where they will go a little bit off label on actives to fix a problem … It's a real grey area, one that we struggle with from a compliance point of view … There's a lot of agronomists out there looking, cutting hairs, trying to see the next thing they can do to save their farmers' money, to get on top of a problem. They'll look international, they'll look into Europe as [to] what registrations are on products, they'll look to New Zealand and Brazil as well to see what they can see; anything new coming [in that] might have been done internationally, but it hasn't been applied here in Australia, and then they'll tentatively try and find a way around it
>
> (COMP06)

Nor do use permits consider how different chemicals might be mixed on farms, as explained by a Melbourne-based company representative:

> There's no restriction on what you can mix. You can mix whatever you like, the restriction is usually, usually applies to the maximum rate. So [in] Victoria, you can use any chemical whatever you want, just don't have any residues in your food. So, I can use something that's registered on strawberries across my wheat crop, provided there's no residues … what you're not allowed to do in any circumstances is exceed residue levels.
>
> (COMP01)

Then there are weaknesses in Australian testing regimes, both in terms of the contents of imported formulations and maximum residue limits (MRLs[5]) on crops post-harvest. On the former, one interviewee noted that the APVMA has testing and auditing capacity (where an official will draw a sample directly from an unopened drum and test the contents) but as he described 'in our 20 years, we've only been through that process once' (COMP08).

On the latter, MRL's are administered through the National Residue Survey and funded by farmer levies—in the case of grains, 1.02% of sales to grain traders. MRL testing is mandatory for agricultural *exports*, but voluntary for the domestic market. Withholding periods (i.e., time from spraying to harvest) differ by crop and are included on product labels. The MRL for vegetables, cereal grains, hops and sugar cane is 0.05 mg/kg, while for potatoes it is 0.2 mg/kg, where paraquat can be applied directly to the crop 4 to 5 weeks pre-harvest for desiccation. No statement of withholding period is required 'when used as directed' (APVMA 2024, 41). While some of these MRLs are revised down in the APVMA's paraquat review, Australian standards can still differ markedly from other places: the paraquat MRL for lupin grains being imported into Europe, for instance, is 0.02 mg/kg, 50 times lower than the Australian MRL of 1 mg/kg that applies to lupins, broad beans, chickpeas, field peas and lentils (CBH Group 2021; APVMA 2024). Compared to export markets, domestic testing is loose[6] and done on a voluntary basis by wholesale markets and the two major supermarkets. These results are not publicly available. These differences are illustrated in the following three quotes: the first is from a peak body representative discussing grain exports, while the second and third are a company representative and agronomist discussing domestic production:

> … once it gets into that export market, well, they can reject it and say oh well, it's got you know a little trace of bugger all, but if that's on their list, then … they're entitled to block that cargo … But there's a lot of trust in the supply chain that those active ingredients are what they say they are, and once they are used in the paddock, because like I said, the MRLs, it has to go back … if that's something other than what you've described it as, then you hold the legal liability
>
> (PEAK01)

> … that's generally the tricky one. Unless you're going export, there's no MRL. We just can't do it and they just don't do it
>
> (COMPO6)

> And of course, our grower declaration forms … they haven't really … some of our crops like mungs and soy and all that stuff they're really adhered to, but certainly in our other crops, our broadacre crops, our cereal crops, they're not so well … governed
>
> (AGRON01)

To understand the widespread use of paraquat in Australian broadacre production, we need to look more closely at farming practices. Prior to the wide availability of herbicides in Australia, weed control primarily involved removing weeds by hand or hoe, burning stubble, multiple rounds of cultivation, harrowing or setting sheep on fallow fields (Thompson and Chauhan 2022). The development of selective herbicides in the 1940s, growth in the range of herbicides available by the 1970s, alongside advances in spray equipment and machinery (Cornish et al. 2020) made herbicides an attractive option and helped farmers address declining availability of labour (Thompson and Chauhan 2022), increased fuel and machinery costs (Thomas et al. 2007) and concerns about soil erosion (Cornish et al. 2020; Higgins et al. 2019). Private and government agronomists alike encouraged farmers to transition towards no-till, herbicide-intensive farming systems (see Figure 3; Fulwood 2021; Higgins et al. 2019; McRobert and Rickards 2010). Extension activities included chemical agribusiness demonstrations (Thomas et al. 2007).

This intentional investment in and promotion of herbicides through a shift to no-till farming systems was explained by one Queensland-based agronomist as follows:

> I was a product development officer with a chemical company … they saw profit potential to do this and volume in the market if they could pull it off. And so my objective were [sic] to go and develop no till.
>
> (AGRO02)

The dominant narrative, which was consistently and at times emphatically emphasised by our interviewees, is that no-till or 'conservation agriculture' is beneficial for soils, yields, water security and climate change mitigation (Whitfield et al. 2015). This narrative is also expressed by farmers. As one sugarcane farmer noted in the SRA (2024) survey, 'The alternative is to return to tillage like my grandfather used to do … removal of paraquat would have a negative impact both environmentally and economically' while another warned if paraquat was banned, 'creeks and waterways will fill with sediment … leading to coral bleaching.'

There are few that challenge this narrative and disadoption of no-till practices is said to be rare (Llewellyn and D'Emden 2010; cf. Kirkegaard et al. 2014). However, an overreliance on herbicides in no-till systems has resulted in the growing prevalence of herbicide resistance, with Australia long being one of the countries with the highest number of cases of herbicide-resistant weeds (Thompson and Chauhan 2022). As weeds become resistant to specific herbicides, farmers rotate which group of herbicides they apply, but many weeds are now showing resistance to multiple herbicides, including paraquat (Thompson and Chauhan 2022; Walsh and Kingwell 2021). This helps us understand why paraquat is so deeply embedded in broadacre agriculture and why the APVMA's review of paraquat and diquat has produced such a strong response from industry, as illustrated by the following quotes:

> I feel like growers are backed into a corner at the moment as far as options go … there's not that many options in what we call the 'knock down' space there alongside glyphosate and to a much lesser degree, glufosinate, as that broad spectrum total control type product. Yeah, paraquat is one of a few options and has been a vital tool in breaking resistance
>
> (COMP05).

> Absolutely terrifying. If we lose paraquat [because of the APVMA review], we'll find ways to cope, but we're really gonna have to push every button from new tech
>
> (AGRO02)

Alongside the rise of no-till farming and herbicide resistance has been a decline in public agronomist advice, an increased reliance on private agronomists and increasingly technical knowledge being held by agronomists rather than growers (Kuehne and LLewellyn 2017). There are now two main types of agronomy in Australia: independent and corporate. Farmers are typically reliant on at least one agronomist for advice about weed control and while there are some concerns

FIGURE 3 | A no-till farm in Western Victoria: canola crop in early spring (left) and crop residue the following autumn (right).

about corporate agronomists having vested interests in selling their company's herbicides, mostly agronomists are seen as trusted and knowledgeable advisors (Campbell et al. 2023). Agronomists certainly emerged in interviews as key actors mediating use: providing farmers with advice on specific products and their efficacy and working with farmers and industry on solutions to herbicide resistance:

> Agronomists now are pretty much managing crop rotations. What to plant, what not to plant … And these chemicals, so they'll put in a budget that says, given the history of the paddock, it looks like it'll be product A, B and C … given the standard usage and rainfall patterns, you probably have to apply this one three times and that one once. And hopefully at the end of the year, you'll get four and a half tonnes of wheat
>
> (COMP01)

> … herbicide resistance exploded up here in the last five to ten years and of course I've been assisting farmers and agronomists and teaching them about resistance … now it's coming up with solutions to the resistance with using the WeedSmart Big 6[7] and going to talk to people about resistance and how they can get past resistance and still maintain our minimum till, zero till farming systems that we so much desire up here in the north with our summer and winter cropping on our black-er soils
>
> (AGRON01).

Agronomists, not just farmers, are therefore critical players in materialising the Global Pesticide Complex in Australia. Beyond the supply chains and logistics that move herbicides from China to Australia, they play a key role in shaping pesticide use patterns and managing the increasingly intransigent issue of herbicide resistance.

In the downstream use of paraquat, several characteristics of slipperiness emerge, shaped by conditions on farms (herbicide resistance, labour saving and agronomist advice) and Australia's regulatory environment. The first is paraquat's ability to evade notice and knowability, sharply evident in the lack of publicly available information on how much paraquat is being used and where, possible unregistered use and the mixing of chemicals on farms. The second, and related characteristic, is how paraquat routinely falls through gaps in management, both in terms of drum testing and MRL testing. The third is how paraquat persists in specific spaces across time, but given the lack of information on MRLs and soil and water health, it is difficult to draw firm conclusions here.

6 | Discussion and Conclusion

To understand how the Global Pesticide Complex materialises through a particular supply chain and in a particular place, this article demonstrates how important it is methodologically and conceptually to connect upstream and downstream processes from production, to distribution and use. Following Berndt et al.'s (2026) analysis of the agrochemical industry in Argentina, we see Australia's articulation with the Global Pesticide Complex as composed of limited domestic production capacity and deep integration with and dependency on Chinese supply chains, mediated by fragmented and loose state regulation. By outlining how the Global Pesticide Complex is articulated in the China-to-Australia paraquat supply chain, we offer several insights for pesticide studies scholars examining other materialisations in other places.

First is the importance of examining how chemical dependency on the farm relates to environmental conditions. Australian farmers variously grapple with drought, intense rainfall events—or ‘gully rakers’ (AGRON02) in northern growing regions—and soils that require significant chemical inputs to support intensive agricultural production. No-till was presented as a solution to soil erosion and water insecurity: whether no-till practices achieve all that they are said to achieve is another matter, but farmers at the time were clearly responsive to new practices. The presence of weed species that can rapidly develop resistance to different groups of pesticides further challenges farming. These environmental dynamics are critical to materialising the Global Pesticide Complex in Australia. Without them, there would be no market for China's cheap, generic formulations and at times acutely toxic pesticides: paraquat would simply not flow from Chinese chemical parks to Australian broadacre farms.

Second is the role of the wider socio-technical ‘assemblage’, or how pesticides are entangled with regulatory politics and power relations beyond the farm and beyond the supply chain. Australia's agrochemical regulation appears weaker compared to the EU, US and Canada (Gabriela et al. 2022). Several interviewees raised issues about the APVMA that were in line with a recent Clayton Utz (2023, 3–4) review that called for more careful examination of the APVMA's level of engagement with industry stakeholders:

> The APVMA's hidden rule is: whatever you do don't make it more expensive to farmers. They won't advertise that one, but anytime that it looks like … if they sat down and said we really wanna ban paraquat, the Minister potentially can ring up and go ‘I need you to find a reason not to.’ And they'll flurry around [to] potentially find a reason.
>
> (COMP01)

There was also evidence of staff movement between peak bodies, companies and the APVMA, which raises concerns about potential regulatory capture and conflicts of interest (see also Harrison 2011). Future research could expand on the pressing issue of the politics of pesticide regulation in Australia (see, for instance, Jansen 2017) and how to strengthen it.

Third is allowing for chemical slipperiness within and beyond the supply chain. In this article we have used Hine's (2025) four characteristics of chemical slipperiness—stealth, dynamism, persistence and slippages—to add depth to our analysis of flows of paraquat between China and Australia. All of these characteristics were evident but at different points from production to distribution and use: at times, paraquat evades notice and knowability, moves through space with no regard for conceptual or constructed boundaries, persists in specific spaces across time and falls through gaps in different regimes of management. Our analysis demonstrates that conceptually, chemical slipperiness can be generative, as it helps to pinpoint the complexities and uncertainties of pesticide supply chains. Agricultural chemicals are re-labelled, renamed, reverse engineered, mixed with co-formulants and sometimes other chemicals, shipped, trucked, stored, handled, sprayed and can remain in soil, in water, on food and in bodies. Analyses of the Global Pesticide Complex need to continue to grapple with the complex material nature of pesticides, and chemical slipperiness offers one tool for doing this.

While all four characteristics of chemical slipperiness defined by Hine (2025) are evident in our analysis, what we wish to emphasise is not slipperiness as an innate feature of pesticides, but how characteristics of chemical slipperiness are produced through particular political-economic conditions, politics and vested interests. Critically, this means they can be changed. Two key points of intervention arise from our analysis of the China-to-Australia paraquat supply chain, the first of which is Australia's regulatory environment. The current regulatory regime for pesticides is lax, as evident in the lack of systematic data on pesticide use, the lack of enforceable maximum residue limits for nonexport crops and the inconsistent application and enforcement of chemical user permits across different state jurisdictions. Reforms are needed in how the Australian Bureau of Statistics or the Australian Bureau of Agricultural and Resource Economics and Science collect data on pesticide use in Australia, so that we can better understand what volume of what formulation is imported and how it is used, where, when and for what purpose. Monitoring of soil and waterways for contamination is lacking (done routinely only around the Great Barrier Reef), as is regular monitoring of MRLs for domestically consumed products and public updates by an independent body. Paraquat evades notice and knowability through these specific weaknesses.

The second point of intervention is the APVMA's paraquat review. Across our data collection, we were presented with a strong and coherent narrative of the global benefits Australian agriculture brings, what threatens those benefits (for instance, ‘anti-chemical activists’

PEAK01) and the high standards and technical proficiency of Australian farmers and agronomists. The review could be understood as a critical juncture for Australian farming practices, but the industry is working proactively against this. Werner et al. (2022, 22) discuss ‘how key agents work together to stabilize the global glyphosate assemblage at a time of crisis’. The work of stabilisation in Australia is ongoing, including in narratives about the lack of viable alternatives to paraquat, the benefits of no-till (including in a changing climate) and the strict and informed chemical use of farmers. Beyond these narratives, interviewees suggested that farmers would simply continue to use paraquat at current allowable rates, even if these rates were reduced by the APVMA. Against the power of industry stabilisation and relatively entrenched farming practices, we nonetheless pose Romero et al.'s (2017, 159) question: what would a chemically just future look like? The paraquat review remains a point of potential destabilisation. Public and media attention will again be heightened once a decision is announced, and informed public advocacy may yet open up a wider-ranging discussion of how we produce food in Australia and how entangled we want that food to be with the Global Pesticide Complex.

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Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Endnotes

[1] Studies suggest these co-formulants, which are not always included in health risk assessments by regulatory agencies, can be highly toxic in their own right (Mesnage and Antoniou 2018).

[2] There were other factors at play here too. Apart from possible panic buying by importers (following China's domestic ban), remaining paraquat producers such as Nanjing Red Sun worked to grow their market share and protect their market position to seize overseas opportunities while others exited production (AgroPages 2017).

[3] This was a guess, not an exact amount. But the cost of registering products containing already approved active constituents and that are similar to other existing products, therefore not requiring full assessment, is between $AUD2000–3000.

[4] With the exception of bananas, these are grown on very large broadacre cropping farms (thousands of hectares). In Australia, the number of broadacre farms continues to decline as land is concentrated, farms grow in size and agri-corporate ownership expands (see Pritchard et al. 2023; ABARES 2025).

[5] Outside the scope of this paper is a discussion of the safety of current MRLs. Some toxicologists argue that acceptable daily intakes (ADIs) for widely used herbicides such as glyphosate are far too high, given both effects on the kidneys and livers of rats, and the role of adjuvants in human toxicity (see Mesnage et al. 2013; Mesnage, Defarge, et al. 2015; Mesnage, Arno, et al. 2015).

[6] Food Standards Australia and New Zealand's Australia Total Diet Study is the primary monitoring survey of foods consumed within Australia and uses MRLs as its measure of food safety. Its 2019 study looked at 1500 food samples and found no paraquat residues; the only samples exceeding current MRLs were cucumber and green beans (chlorpyrifos) and broccoli (dithiocarbamates) (FSANZ 2019).

[7] These are: Rotate crops and pastures; Increase crop competition; Mix and rotate herbicides; Optimise spray efficacy; Stop weed seed set; Implement harvest weed seed control.

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