

Review

Law and regulations to control pesticide exposure among the general population: Comparing the Australian and the European Union pesticide regulatory system

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Abstract: Pesticides have a vital contribution to the agricultural industry in Australia. However, pesticide applications may not always selective to its target organism. Exposure to pesticide has been associated with negative impacts to human health. One of the ways to reduce pesticide risk to the population and the environment is through government regulations. To put Australia pesticide regulations into perspective, comparisons were made between Australia and other nation's pesticides regulations. The EU pesticide regulatory system was chosen for comparison with the Australian's in the aspect of protecting the population from pesticide exposure. The comparison showed that the assessment to authorize a pesticide in Australia is based on the risk while in the EU, the assessment is based on the hazard of the pesticide. A registered active substance in Australia can be authorized for use indefinitely unless it is nominated for reconsideration while the period of registration of an active substance in the EU lasts for 10 years. In addition, no routine systematic chemical residue surveys are conducted in Australia for food commodities. The results highlight areas for improvement in the Australian pesticide regulatory system from the perspective of controlling undue exposure among the general population.

Keywords: pesticide regulation; pesticide exposure; pesticide policy; non-occupational pesticide exposure; human health; pesticide pollution

1. Introduction

Australia has a well-developed agricultural industry with agricultural land taking up 2% of the total land area (384 million hectares) (for the financial year 2018-19) [1]. There is no public record of the volume of pesticides used in Australia. However, it was reported that A\$20.6 billion worth of crops yielded from the usage of agricultural pesticides, which is 73% of the total value of crops produced in that year in 2015-16 [2].

The use of pesticide is essential in protecting food supply as managing pests and undesirable organism in agricultural scenes increases yields and quality in food production [3]. In the 19th century, an attack of unfamiliar fungus on potatoes in Ireland resulted in famine with one million people died of starvation [4]. The use of pesticides also increases efficiency in crop production. This, in turn, leads to food price reduction [3]. Pesticide applications too had contributed in controlling vector-borne diseases, such as malaria in some part of the world. The widespread use of an

organochlorine insecticide DDT (now banned), in the WHO Global Malaria Eradication Program, resulted in eradicating malaria in Europe, North America, the Caribbean, parts of Asia, and South-Central America in 1955 [5].

There is no denying that pesticide toxicity may not always be selective to its target organism despite the abovementioned benefits. The negative impacts have been observed in humans, animals and the environment. [6–9]. Humans can get exposed to pesticides through occupational route [10–13], indoor exposure via domestic use [14–16], dietary exposure [17–20] and the environment [21–23]. Pesticide exposure has been associated to several acute and chronic health effects along with multiple health conditions (reviewed in Koureas et al. [24] and Reiss et al. [25]). Therefore, there should be controls in place so that the benefits and risks are balanced out, as much as how much pesticides are vital in our lives.

Having controls on the availability, access and use of pesticides can be one of the means to reduce the risks to the population and the environment. The government may restrict the public exposure to pesticides through regulations of several elements, including but not limited to, pesticide approval, labelling, application rates and procedures, post-application harvesting delays, storage and waste disposal. As an example, there was a voluntary elimination of chlorpyrifos (CPF) use at home in the year 2000 when the Food Quality Protection (FQPA) Act signed into law [26]. It was suggested in several studies that even before the complete phase-out of CPF in 2005 [27], the reduction of the use of this pesticide was already observed [14,28,29]. Accordingly, 2006 and 2007 pesticide industry market estimates reported that there was a reduction of 3-5 million pounds of CPF use in the year 2007 for all market sector (not just agriculture and domestic) from 2001 as reported by US EPA [30]. The elimination of CPF domestic use had also suspected to be the cause of the 5-fold decrease of CPF levels in indoor air from homes monitored in 2004 (3 or 4 years of CPF residential ban) than in 2001 in New York [15]. The exposure of pregnant women to CPF in New York had also decreased attributed to the elimination of CPF residential use [16]. This was assessed by the biomarker of exposure measurement in urine, meconium and maternal and cord blood [16]. In the US too, the median level of dialkylphosphorus (DAP) metabolites has decreased by more than half which may imply the decline of human exposure to organophosphorus insecticides since the implementation of the Food Quality Protection Act (FQPA) [31]. In another example in South Korea, herbicide paraquat re-registration cancellation in 2011 has reduced total DALYs (disability-adjusted life-years) due to acute poisoning and intentional poisoning [32]. DALY is a measure of the burden of disease where one DALY represents “the loss of one year of life lived in full health” [33]. While in Israel, regulations restricting agricultural use of organophosphorus (OP) insecticides have been demonstrated to have reduced urinary DAP metabolites between the year 2012 and 2016 among urban pregnant women and their infants [34].

To date, the legislation to control pesticide use is not harmonized worldwide. Regulations can be different from one country to another in various aspects such as the decision to ban a pesticide and the permissible maximum pesticide residue level in food and feed. This is mainly because the assessment of a pesticide by regulatory authority bodies in different countries differs markedly. For example, Australian Pesticides and Veterinary Medicines Authority (APVMA) reported in *Chlorpyrifos Toxicology Supplementary Report* that “there is no evidence to indicate potential neurodevelopment effects reported in some studies to occur at or below doses that inhibit acetylcholinesterase (AChE) activity” [35] while US EPA concluded that “there are neurodevelopmental effects occurring at chlorpyrifos exposure levels below that required for AChE inhibition.” [36]. In addition, the maximum residue levels of pesticide on food sold in a country may be lower or higher in another country [37].

As such, there is no “gold standard” of pesticide policy and regulations. To put Australia pesticide regulations into perspective, comparisons can be made between Australia and other nation’s pesticides regulations. US and EU were once called as the “green giants” because both were the leaders in enacting legislation to control pollution and in promoting agreements in international level to diminish human development impact to on the environment [38]. Moreover, the US and EU are both among the largest global importer and exporter in 2018 [39] and among the largest

agricultural producers in the world [40]. Hence, the US and EU standards are highly likely to be relevant for the rest of the world [41].

In the EU, pesticide approval, restriction and cancellations are in accordance with Regulation 1107/2009. The basis of Regulation of 1107/2009 is to “ensure that industry demonstrates that substances or products produced or placed on the market do not have any harmful effect on the human or animal health or any unacceptable effects on the environment” (Regulation 1107/2009). This means that the industry must demonstrate that the substances or products can be applied/used without giving harm to humans, animals and the surrounding environment. In addition, the EU also put a clear ban in approving and use of pesticides that are categorized as carcinogenic, mutagenic, reproductive toxic, and endocrine disruptor to humans unless the effects are considered negligible [42]. These may be the reason that the EU is said to have the most stringent pesticide regulations globally [43]. In contrast with the EU, the application to get pesticides approved in the US only requires the applicants to show that using the pesticide according to specifications “will not generally cause unreasonable adverse effects on the environment” [44]. “Unreasonable adverse effects on the environment” is partially defined as “any reasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide” [44]. The US EPA’s activities are also subject to heavy political influence as the leadership is appointed by the Federal Government. The current US EPA administration has recently reversed the plan to ban chlorpyrifos despite backlash from the scientific community [45]. This example demonstrates that the US system allows for the regulatory decisions to be made to suit current politics rather than to be solely based on scientific evidence [46,47]. With all these points highlighted for both the US and EU, the latter was chosen to compare with the Australian pesticide regulations.

The objective of this paper is to conduct a comparison between the Australian and the European regulatory systems. The elements that will be compared are 1) pesticide approval, 2) pesticide renewal and 3) pesticide residue in food and commodities. The elements of the regulation process that are covered are related directly to the protection of the public (the end-user) from undue pesticide exposure through legislative instruments. Frameworks for registration, renewal of registration and permissible pesticide residue levels in food in both Australia and the EU regulations will be mainly discussed. Occupational health and safety elements will not be covered in this review.

2. Method

The differences between the EU and Australian pesticide regulations will be examined through the information available in the official websites of each regulatory authority (Table 1), NGOs websites and peer-reviewed articles. All articles and information reviewed and included in this paper are in the English language.

Table 1. Sources obtained from the official regulatory authority websites of Australian and the European Union.

Information	Source of information	Date Accessed
Australia pesticides regulatory system	<p>All information on APVMA and Australia pesticide regulatory system are obtained from:</p> <ol style="list-style-type: none"> 1. Australian Pesticides and Veterinary Medicines Authority (APVMA) from: https://apvma.gov.au/ 2. <u>Federal Register of Legislation from</u> https://www.legislation.gov.au/ 3. Food Standards Australia and New Zealand from https://www.foodstandards.gov.au/Pages/default.aspx 4. National Residue Survey from https://www.agriculture.gov.au/ag-farm-food//food/nrs <p>The list of the webpages visited are also provided in the reference list.</p>	<p>The information was accessed in February 2018 until October 2020. The exact date of the webpages visited is provided in the references list.</p>
EU pesticides regulatory system	<p>Information on EU pesticide regulatory system are obtained from:</p> <ol style="list-style-type: none"> 5. EU law from https://eur-lex.europa.eu/homepage.html?locale=en 6. European Food Safety Authority from http://www.efsa.europa.eu/ 7. European Chemicals Agency from https://echa.europa.eu/ 8. European Commission from https://ec.europa.eu/food/plant/pesticides_en 	<p>The information was accessed in February 2018 until October 2020. The exact date of the webpages visited is provided in the references list.</p>

It is also worth mentioning that Australian regulations and guidelines use the term “active constituent” while the EU uses “active substance” for the active component that primarily against pests/plant disease. These two terms are used interchangeably in this article. The term “pesticides” is also not used in both the EU and Australian regulations. Australia uses the term “agvet chemical” while the EU categorizes pesticides into plant protection products (PPP) and biocidal products (BP).

3. Australia Pesticides Regulatory Framework

Section 6 of the Agricultural and Veterinary Chemicals (Administration) Act 1992 [48] states that the regulation of agricultural chemicals and veterinary medicines (known also as agvet chemicals) in Australia is administered by the APVMA under the regulatory framework referred to as the National Registration Scheme. The regulation shares the responsibility between the Commonwealth and the states and territories under the portfolio of Minister for Agriculture [49]. APVMA has the responsibility to oversee applications, regulations, permits, licenses, chemical reviews, taking on enforcement and conformance activities, and import and export of agvet chemical products according to the agvet code [49]. Once the product is sold, the participating states and territories should oversee the control of the chemical use [50]. Australian pesticide regulatory system comprises of agvet code administration, APVMA establishment as a regulatory body to regulate agvet chemicals, APVMA roles, agvet code regulations, prosecution, collection of levy and prescription of functions in relation to Director of Public Prosecution of the Commonwealth (Table 2). There are also legislative instruments to support the Agvet Code Act [51].

For states and territories, there may be one or more agencies responsible for overseeing the after retail use of pesticides [52]. Some of the activities regulated by states and territories are enforcing

condition of use (according to the label approved), monitoring residue, licensing applications, and record-keeping related activities. To differentiate the federal and states and territories roles, APVMA assesses, registers and develops condition for use and does enforcement and compliance activities under the legislation in Table 2. On the other hand, agencies of states and territories control agvet product use through acts, regulations, codes of practice, guideline and standard operating procedures [52].

Table 2. Legislation of Australian Pesticide Regulations [51].

Legislation	Purpose
Agricultural and Veterinary Chemicals (Administration) Act 1992	To establish that APVMA the responsible authority to regulate agvet chemicals up until the point of sale.
Agricultural and Veterinary Chemicals Act 1994	To allow agvet code to take effect.
Agricultural and Veterinary Chemicals Code Act 1994	Provide detail of APVMA roles that enabled APVMA to evaluate, approve, authorize, renew active constituent and chemical products. Furthermore, this act allowing APVMA to issue permit and license to manufacture chemical products.
Agricultural and Veterinary Chemical Products (Collection of Levy) Act 1994	To enable the collection of levy agvet chemicals product.
Agricultural and Veterinary Chemicals (Administration) Regulations 1995	Provision of controlled chemicals in Schedule 1, information for APVMA to include in the annual report, the prohibition to import certain active constituent and chemical products, and others.
Agricultural and Veterinary Chemicals Regulations 1999	Prescribed function of Director of Public Prosecutions of the Commonwealth.
Agricultural and Veterinary Chemicals Code Regulations 1995	Prescribed matters related to the Agricultural and Veterinary Chemicals Code Act 1994.
Agricultural and Veterinary Chemical Products (Collection of Levy) Regulations 1995	Prescribed the rate of levy.

It is also noteworthy that the agvet chemicals regulatory framework in Australia is currently undergoing a comprehensive review by an independent panel of experts (experts in regulation, agricultural production, veterinary medicine and human health) at the time that this article is written [53]. In September 2019, the then Minister of Agriculture, Bridget McKenzie announced that the appointed panel is doing a review on the structure, aim and operation of the agvet chemical regulatory framework. The review will also include recommendations to ensure the regulatory framework is “contemporary, fit for purpose and reduced unnecessary red tape”. The elected panel is currently requesting feedback from the public.

3.1. Registration and assessment of pesticide in Australia

Fundamentally, the basis of Australian pesticide regulation is that no agvet product can be sold, supplied or used in Australia before being registered by the APVMA unless exempted [54]. The active constituents of the new product must be first approved or exempted from registration. A “registered product” means that it can be sold, supplied and used safely according to the directions on the label. This means that if a new product has a new active constituent which has not been approved before, the applicant must place two applications: 1) approval of a new active constituent; 2) registration of the new product. The process of approval of a new active constituent is similar to the process to register a new product but with two additional criteria to be met other than safety criteria. These two extra criteria are trade and efficiency.

The applicant first must lodge the application for both the approval of an active constituent and the registration of a new product online. Within one month, APVMA must complete the preliminary assessment. If the preliminary assessment passed, the applicant will be notified by APVMA that the application will be evaluated under Section 14 of the Agricultural and Veterinary Chemicals Code Act 1994 [55]. APVMA then must publish a notice in the Gazette (or anywhere appropriate such as APVMA website) engaging anyone (the public) to provide written comments whether to approve the active constituent or whether to register the product with sound justification within at least 28 days (Section 12 and 13 of Agricultural and Veterinary Chemicals Code Act 1994) [55]. Public comments are assessed by APVMA but there is no evidence shown that the public comments have any influence in the decision-making process.

The data required for the applicant to submit during registration and authorization of active constituent are listed on the APVMA website [56]. Some of the data that are relevant to register a new active constituent or a new product are chemistry, toxicology, residues, occupational health and safety, environment, overseas trade, pesticide efficacy and crop safety general guideline and special data of products of gene technology and nanotechnology. APVMA does the assessment of a new active constituent by reviewing dossier of toxicological studies conducted and submitted by the applicants. According to the guideline on toxicology data, applicants may present arguments from data published in the peer-reviewed scientific journals [57]. The applicant's studies must be conducted according to the principle of Good Laboratory Practice (GLP) and other OECD guidelines. "Toxicology data and/or scientific argument" information is vital so that APVMA could formulate recommendations including poison scheduling, ADI (acceptable daily intake), acute reference dose, first aid scheduling and other relevant health recommendations.

The next step in a chemical's journey to the consumer is "Poisons Scheduling". The Poisons Scheduling is a process which it determines the accessibility of the chemicals to the users. It is conducted under the Scheduling Policy Framework for Medicines and Chemicals [58] and intended to determine the classification of medicines and chemicals (including agvet chemicals) according to its potential to cause harm to humans health [59]. For instance, poisons (or chemicals) in Schedule 3 and Schedule 4 listed in the Poisons Scheduling Standard are only be sold by pharmacists or medical, dental and veterinary practitioners. The Schedules (classifications) determine how a product should be 1) stored, 2) labelled, 3) disposed, 4) sold, supplied, possessed or used and 5) record keeping (Table 3). The classifications of chemicals particularly are advised and recommended by the Advisory Committee on Chemicals Schedule (ACCS). The ACCS is a committee comprised of representatives from each state and territory as well as independent experts in toxicology [60]. The ACCS is responsible for making recommendations on what schedule a chemical or a product should be assigned to and at what concentrations. The ACCS bases their recommendations on the review of toxicological dossier submitted by the applicant. At times, the dossiers may be lacking in relevant toxicology data because of the lack of research for a particular chemical/agvet chemical (Babina 2019, pers. comm). Thus, some agvet approved chemicals may not be assigned into any of the schedules. At the moment, this gap seems to create a possibility that such chemicals can be marketed, including to the general public, unscheduled and therefore without appropriate warning labels and other restrictions. This is a significant process gap that creates a potential of undue chemical exposures in the community and it needs to be addressed in Australia.

Table 3. Australia scheduling medicine and poisons.

Schedule 1	This schedule is not currently in use
Schedule 2	Pharmacy Medicine
Schedule 3	Pharmacist Only Medicine
Schedule 4	Prescription Only Medicine Or Prescription Animal Remedy
Schedule 5	Caution
Schedule 6	Poison
Schedule 7	Dangerous Poison
Schedule 8	Controlled Drug
Schedule 9	Prohibited Substance
Schedule 10	Substances of such danger to health as to warrant prohibition of sale, supply and use.

3.2. *Renewal of registration and chemical review in Australia*

In 2014, a bill to remove the requirement for re-approval and re-registration of active constituents and chemical products in Agricultural and Veterinary Chemicals Code Act 1994 was passed through the Australian legislative processes and became a law. This was initiated because the re-approval and re-registration of active constituents and chemical products provisions were said to be redundant because there is already chemical reconsideration process in place [61]. Originally, active constituents and chemical products were required to have a periodic examination every 7 to 15 years for the purpose of re-registration [62]. With the passing of the bill, there is no period of approval of an active substance unless it is cancelled by the APVMA (Agricultural and Veterinary Chemicals Code Act 1994 s. 47) [55]. The licence holder may apply for the renewal of product registration every financial year or a period of 5 years. The process of the evaluation of a chemical product renewal application is not as clear because it is not openly shared with the public as there is no relevant information on the APVMA website [63]. The renewal process is likely a simple administrative procedure without any scientific appraisal.

Pesticides may be re-considered/re-evaluated (in chemical reviews) if there is new scientific information revealed that challenges previously understood risks to human, environment, animal, the safety of crops and trade [64]. To give an example, the reasons of chlorpyrifos review by the APVMA (NRA then) were reported to be “a) its very high toxicity to birds; b) water pollution potential and US restriction imposed to fish, birds, and other wildlife; c) demonstrated potential adverse effects in users; and d) high potential chronic and moderate potential acute toxicity risk” [65]. These facts were not known when chlorpyrifos was first registered for use in Australia.

To trigger APVMA’s process or reconsideration, a chemical must be firstly nominated for reconsideration [64]. The nomination may be triggered if another jurisdiction decides to deregister a chemical or if “a compelling scientific case” challenged the basis of evidence supporting the safe and effective use of the already approved chemical. Some examples of information that may be considered for a chemical nomination for reconsideration cited by the APVMA includes a) regulatory decisions from counterpart authorities in other countries; b) adverse experiences report (which resulted despite the usage of the chemical according to the label); c) pesticide residue violations cases (confirmed cases); d) new reliable scientific information (such as from high quality, peer-reviewed literature or reports from major international jurisdiction and organisations such as WHO); d) product failure or reduced efficiency report; e) information submitted to the APVMA in compliance with the existing statutory obligation; f) information obtained by state and territory authorities related to administration of control-of-use function. APVMA will then assess the available information and decide if reconsideration is justified for that chemical and the chemical be accepted into the Chemical Review Program. Once nominated, the chemical will go through a prioritization

process and then planning and scoping, and then the work plan. The document of the work plan will include significant dates and deadlines and the scope of the assessment. Next, a Notice of Reconsideration will be sent to each approval holder and product registrant and this marks the start of the chemical review process. This is when the actual assessment is initiated. While the whole process of reconsideration presented in **Figure 1** appears linear, it is said to be “a complex iterative process” in practice [64]. The APVMA may need to collaborate with experts nationally or internationally at this phase. The result of the assessment will then be compiled and released as a draft regulatory measure for public consultation. After the period of public consultation is closed, the APVMA and other agencies involved will assess all comments, data submissions, and recommendations. Finally, the APVMA will make a regulatory decision whether to: a) maintain the status quo – the chemical remains as a registered product; b) change, remove or add the label or the condition of approval or registration or c) cancel or put the chemical on hold pending the approval or registration.

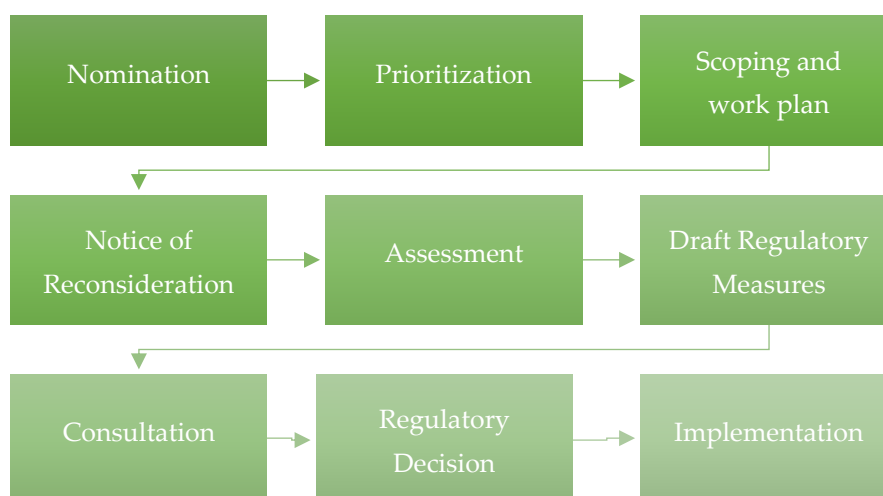


Figure 1. The reconsideration process of agvet chemical in Australia [64].

Overall, there is no systematic process or duration set for a pesticide (active constituent) to be reviewed, re-registered and re-approved. Agvet chemicals re-evaluation and review (the reconsideration process) occurs on an ad-hoc basis because a pesticide can only be reviewed if it was “nominated” [64]. The independent panel elected to review the Australian agvet chemical regulatory framework noted that there is no significant dedicated resources or funding for Australian regulator to hold such periodical reconsideration process unlike in the other countries that has been doing systematic reconsideration or chemical review process [66]. The process of a chemical reconsideration in Australia can take many years (**Table 4**) and, consequently, there is a potential that highly hazardous pesticides will remain in use and thus the regulatory system would be failing to protect the consumer and the environment. The APVMA chemical re-consideration program was also criticized by CHOICE (an NGO) in the past for the lengthy period taken to conclude a review and a minister of agriculture [67]. The extraordinary length of time it takes to review a chemical is due to the lack of accountability as there was no statutory period for a chemical reconsideration process and no cut-off date for the applicants to provide documents and necessary data for reconsideration [68]. Before July 2014, there were no timeframe limit for each chemical review initiated according to the agvet code. For that reason, the time taken to complete a chemical review was highly variable and lengthy (**Table 4**). From 1 July 2014 onwards, chemical review will be completed within the timeframe [69]. The maximum duration to undertake a complex chemical review is 57 months. Despite the prolonged period to complete a review, the regulatory decision does not occur only at the end of the review. Along the period, “interim” regulatory decisions may be enacted multiple times before the final decision was made on the chemical that is undergoing the review. All these decisions are publicly shared in the APVMA website along with the statement of risk assessments and gazettes containing the detail of the regulatory decisions taken for a particular chemical

1 **Table 4.** Some pesticides in Australia that are currently and have undergone the reconsideration process.

Chemical	Reason for review ¹	Period of review	Regulatory actions taken
2,4-D	H; OH&S; E	1995 - 2020	2004- The existing strengthen to minimize spray drift 2006 – Registrations and approvals for high volatile ester forms 2,4-D suspended. New instruction for use issued. 2013 - APVMA cancelled selected active constituent approval, registrations, and associated label approvals for 2,4-D high volatile ester.
Chlorpyrifos	H; OH&S; E	1996 - ongoing	2000 – Modification of garden and domestic pest use and label amendment 2019 – Chlorpyrifos product registration for home garden and domestic pest control cancelled
Diazinon	H; OH&S; E; T	1996- ongoing	2002 – Emulsifiable concentrate of diazinon products without stabilizer posed cancelled 2006- Change of label instruction, modification of diazinon uses, some MRL established
Diquat	H; OH&S; E; R	1995- ongoing	<i>Proposed regulatory decision is expected by August 2021</i>
Fenitrothion	H; OH&S; E	1996- ongoing	2001 – Some conditions introduced to reduce exposure among worker and to reduce contamination for water bodies.
Fipronil	H; OH&S; E; T; A	2003- ongoing	2011- re-entry interval revised and added for many agricultural use.
Malathion	H; OH&S; T	2003- ongoing	<i>Proposed regulatory decision is expected by November 2020</i>
Neonicotinoids	H; OH&S; E	2019 - ongoing	<i>Proposed regulatory decision is expected by April 2023</i>
Paraquat	OH&S; E; T; R	1998 - ongoing	<i>Proposed regulatory decision is expected by July 2021</i>
Procymidone	OH&S; T; R	2004 - ongoing	2017 – New acute reference dose (0.1mg/kg bw) established. Previous dose was 0.3 mg/kg bw
Azinphos-methyl	H; OH&S;E; R; T	1998- 2015	2006- Applications to some crops ceased. The product container was also modified. There are some additions to the labeling of the products too. 2011 – Addition of new restraint element in labeling
Carbaryl	R; H	1995-2012	2007 – Some restrictions applied for domestic and home garden use 2012- Some restrictions applied in agricultural situation
Carbendazim	H; OH&S; R	2007-2012	2010- Label suspensions, discontinued use for pre and post-harvest on certain crops and turf 2012- Label amendments

2 ¹H=health; OH&S= occupational safety and health; E= environment; T=trade; A= animal safety; R=residue in food and feed

3.3. Pesticides residue regulations in Australia (MRL)

In principle, Standard 1.1.1 and Standard 1.4.2 of *Australia New Zealand Food Standards Code* states that food for sale must not contain amounts of agvet chemical (and/or its metabolite and degradation products) in amounts that can harm the consumer [71]. To control this, the maximum residue levels (MRL) of agvet chemicals in commodities are set by APVMA during approval of new active constituents and/or pesticide products [72]. MRL are defined by Food Standard Australia New Zealand (FSANZ) as the highest level/amount of an agvet chemical residue allowed in a food product sold in Australia (imported and produced locally) [72]. Decisions to set the MRLs of a product on agricultural produce are based on the data submitted by the applicants/manufacturers of products. The detail of information needed to determine the value of MRL of pesticides in food items is described in *Residues (Part 5A)* guideline published in APVMA website [73]. Data required includes the pattern of use of the products which include the proposed use pattern of the product. The manufacturers/applicants are also required to nominate the MRL value for the active constituents and the withholding period. Evaluation of data to set the MRL value is said to be conducted through a peer-review process [73]. The details of the peer review, e.g. who is engaged and how the peer review reports are evaluated are not available to the public. However, it is said that APVMA may consider information by other recognized bodies to evaluate the proposed MRL [73]. Comments from the public are sought too, but only if the product contains a new active constituent. The proposed MRLs for other pesticides on food items are listed in *Agvet Chemicals Code Instrument 4 (MRL Standard) 2012* [74] as well as in *Australia New Zealand Food Standards Code—Standard 1.4.2—Maximum Residue Limits 2012* [71].

It is established that the role of APVMA is to review data by applicants (pesticides manufacturer) and make the decision about the MRLs of the pesticides on food items. APVMA also works closely with Food Standard Australia New Zealand (FSANZ) on the assessment of agvet chemical residue in diet. For any variation of MRLs, FSANZ is the responsible body to consider the said requests [72].

3.3.1. Pesticide residue monitoring in food in Australia

MRL monitoring system of food at the point of retail sale and consumption in Australia is “complex” where it involves national, state, industry regulatory regimes that “governs and (sporadically) tests for pesticide residue” [75]. FSANZ conducts the Australian Total Diet Survey (ATDS) of chemical residue in Australian food supply for every two years (Table 6). The fundamental purpose of conducting this survey is to “estimate the dietary exposure” of the public of Australia to the selected substances in food supply [76]. However, pesticides or agvet chemicals are not always included to be part of the survey. Pesticide residue monitoring in food were not surveyed in the 21st, 22nd, 24th (Phase 1) and 24th (Phase 2) ATDS (Table 5). The justification for the exclusion of pesticides was because pesticides residue in food supply tested in the past surveys was well below the Australian and international health standards [77]. It is also stated that the result of pesticide monitoring in the past surveys did not represent public health and safety risk.

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Table 5. ATDS survey conducted from year 2001-2019.

Year of ATDS	Year of sampling	Pesticides included in the survey	Findings related to pesticides residue
19th ATDS (April 2001)	February, April, August and October 1998	Chlorinated organic pesticides Organophosphorus pesticides Carbamates Synthetic pyrethroids Fungicides	The estimated pesticide exposure through dietary route were all within acceptable health standards
20th ATDS (January 2003)	July and November 2000 February and April 2001	Chlorinated organic pesticides Organophosphorus pesticides Carbamates Synthetic pyrethroids Fungicides	The estimated pesticide exposure through dietary route were all within acceptable health standards
21st ATDS (August 2005)	April and May 2003	Pesticides were not tested in this survey	N/A
22nd ATDS (September 2008)	The dates of sampling were not stated in the report.	Pesticides were not tested in this survey	N/A
23rd ATDS (November 2011)	January/February 2008 June/July 2008	Chlorinated organic pesticides Organophosphorus pesticides Carbamates Synthetic pyrethroids Herbicides Fungicides	The estimated pesticide exposure through dietary route were all within acceptable health standards
24th ATDS Phase 1 (April 2014)	May 2011 June-July 2011	Pesticides were not tested in this survey	N/A
24th ATDS Phase 2 (January 2016)	May 2011 August 2011	Pesticides were not tested in this survey	N/A
25th ATDS (June 2019)	May 2013 February 2014	Chlorinated organic pesticides Organophosphorus pesticides Carbamates Synthetic pyrethroids Herbicides Fungicides	The estimated dietary exposure for all pesticide were all within acceptable health standards except for one organophosphorus pesticide (prothiofos).

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There is another industry-funded monitoring called National Residue Survey (NRS) [78]. NRS is part of the Department of Agriculture Australia’s strategy to keep chemical residues in agricultural produce at minimum [79]. This survey monitors residues of chemicals and environmental contaminants in some Australian commodities. This is done to confirm that Australia is a producer of clean food and subsequently to facilitate trade by assisting Australia’s primary producers and agricultural industry to access domestic and international markets. This is different from the ATDS because NRS is not conducted for the purpose of the population health, rather it is performed to encourage good agricultural practice [79]. The information management of the survey data is under the responsibility of the NRS. From the NRS webpage [79], the residue testing datasets are made available to the public. Information of the survey that specifically relates to particular people and property is only released to government authorities or approved individuals [80].

The enforcement and monitoring of MRLs are to be done by the states and territories food regulatory agencies [70,71]. This means that the enforcement and monitoring are not uniform and may vary from one state to another [75]. There is no confirmation for the monitoring activities conducted in each state because of there are no reports on the outcomes of such monitoring that are publicly available except for Western Australia [81].

Other than NGO and government regulators, there are also commercial tests available conducted by FreshTest and other service providers. FreshTest provides services to do chemical residue (MRL) and microbial testing at low cost for Wholesalers and their Growers in Australia [82]. It is the largest and the most comprehensive horticultural residue testing program by the Australian Chamber of Fruit and Vegetables Industry [82]. Coles and Woolworths, the two dominant supermarkets in Australia also require their suppliers of their fresh produce to comply with regulations including the Food Standard Code [83,84]. The monitoring and audits are done voluntarily and paid by the producers themselves and this potentially creates conflicts of interest [75]. This is because in this case, the producers may have full control of the monitoring tests and the results. After all, they are the clients of the service provider/s (FreshTest, as an example). The findings of the agvet chemicals monitoring in their produce are also not made public. Therefore, any problems of the produce/food related to chemical residue that were tested may not be fully revealed.

With these sporadic monitoring of pesticide residue going on in Australia, along with the fact that there is no agvet chemical tested in the latest Total Diet Survey and most reports are not available publicly, we cannot make any formal conclusion on what pesticide residues are consumed by the Australian public.

4. European Union pesticide regulatory framework

Pesticides in EU legislation are classified into two groups: (1) plant protection product (PPP) and (2) biocidal products. By definition, PPPs are "pesticides" that protect crops or desirable or useful plants" [85]; while biocidal products are products that are used to control other organisms. Biocides cover a wide range of products such as disinfectant, parasiticides and bacterial killer. Pesticides are included in both categories (PPP and biocides) [86]. Both groups of products are regulated under different regulations with the same aim to protect humans, animals and the environment. Instead of EFSA, ECHA (European Chemicals Agency) is the authority responsible to make assessments of the biocides products. Biocidal products are regulated under Regulation (EC) 528/2012. This paper will only review PPP because the biocides approval process is similar to PPP approval process.

PPPs are composed of active substances – the active ingredient as main component and other ingredients that are added for different purposes including for stability and to ease the handling and transport of the product. PPPs in the EU market are regulated under Regulation (EC) 1107/2009 together with other regulations (Table 6). Regulation (EC) 1107/2009, however, is essential because it encompasses detailed information on active substances (AS) and PPP approval process in the EU. This regulation covers approval of AS and products, labelling, and monitoring that are applicable in all member state. The main authorities that work with this legislation are the European Food Safety Authority (EFSA), European Commissions (EC) and the member states. EFSA is an independent authority that is responsible for current extensive and comprehensive peer review of the data available for all active substances [87]. Pesticides regulations in the EU is also based on Regulation 395/2006 which administer maximum residue limit in food and feed which will be discussed in *Section 4.3*.

Table 6. Some of European pesticide regulations.

Regulations	Functions
Regulation EC 1107/2009	To get product authorized on the market
Regulation EU 540/2011	List of approved substances
Regulation EU 546/2011	Principle to evaluate and authorize PPP
Regulation 547/2011	Requirement of PPP labelling
Regulation EU 283/2013	Data requirement for active substance approval
Regulation EU 284/2013	Data requirement for PPP product authorization
Regulation 396/2005	Assessing residue in food

99 4.1. Stages to get pesticides authorized in the EU

100 The requirements, procedures, and timeframes for authorization of PPP are described in
101 Regulation (EU) 1107/2009 [42]. The whole procedure to get the AS and its PPP into the market is not
102 simple and it is illustrated in Figure 2.

103 First and foremost, the active substances will be undergoing a cut-off process where the
104 chemicals that are categorized in banned chemical groups in the EU will not be going through any
105 assessment at all [43]. Active substances and other constituents (i.e. safeners (chemical compounds
106 that are added to make pesticide “safer”) and synergists that are carcinogenic, mutagenic, toxic to
107 reproduction or endocrine disruptive to humans cannot be authorised in the EU (Regulation
108 1107/2009, Annex II [42]). In addition, AS, safeners and synergists are not approved if they are a POP
109 (persistent organic pollutant), a PBT (persistent, bioaccumulative and toxic), and/or harmful to bees.
110 This is in line with the aim of EU pesticide legislation: the AS (and its other constituents) must not do
111 harm to human health and the environment. The application for approval of AS that falls into the
112 abovementioned hazard is rejected right away and it will not go through further evaluation.

113 If the AS is identified not in the banned categories, it will proceed in two phases before the PPP
114 is released to the market [87]. First, the manufacturer (applicant) must get the active substances (AS)
115 in the product (formulation) approved by the EC. The manufacturer/company will send application
116 (dossier) to the rapporteur member state (RMS) of choice with required data to support the
117 application. Regulation EU 283/2013 (for PPP) spells out the details of data required for AS approval.
118 Applicants must demonstrate in the dossier that the AS, once it is approved for use, does not put the
119 safety of humans and the environment in jeopardy. A set of mandatory safety studies and the
120 literature review of research done in the last 10 years for adverse effects of the active substance are
121 required to be done by the applicant [88]. There is also a set of mandatory safety studies required for
122 applicants that are funded by the applicants and conducted by a certified laboratory that is subjected
123 to regular audits [88].

124 The RMS will do an initial risk assessment and then prepare a draft assessment report (DAR) to
125 be sent to EFSA. During this process, the RMS may request additional information from the applicant.
126 This process can take 12 months or more if further information is requested by the RMS. EFSA will
127 then do an independent scientific review of the DAR in consultation with other RMSs. The conclusion
128 of the peer review is then sent to the European Commission (EC). Finally, the decision of the AS
129 authorization is done by the EC based on the EFSA’s peer review. The recommendation made by
130 EFSA is not legally binding [89]. An authorized AS is approved for 10 years.

131 The next phase is getting the product (PPP) authorized in the EU countries. This is the role of
132 the EU member states. The basis of PPP authorization is that the applicant shall apply to each country
133 where the product is intended to be used. There are three zones in the EU: North, Central and South
134 [90]. The applicant may select the RMS in the related zone that will examine and assess the
135 application. The data requirements for the application to get PPP authorized are provided in
136 Regulation (EC) No. 284/2013. In this phase too, information on MRLs is required [91]. Whenever
137 necessary, the RMS makes the assessment available to another member state in the same zone because
138 cooperation from other member states in the zone is needed too for peer-review.

139 Finally, the other member states in the zone shall grant or refuse the application of the
140 authorization of the product in countries where it is intended to be used. If authorization is granted,

and if in the future, the applicant would like to place the product (with the same use and comparable agricultural practice) in another member state, an application can be made through “mutual recognition” as explained in Article 40 to Article 42 in Regulation (EU) 1107/2009 [42].

From the description above of the phases involved in getting an AS and its PPP into the market, it is noteworthy that there is a clear-cut separation in the risk assessment and risk management process in getting pesticides authorized in the EU [43]. In other words, the EFSA only makes risk assessment of the AS only while the EC will make the approval of the EC and recommend steps to mitigate the risks [43,92]. In the same context, recommendations made by EFSA is not legally binding [93]. The reason for the distinct role and players in risk assessment and risk management is to maintain independence and objectivity when doing scientific evaluation in the risk assessment process as well as to ensure accountability for the decision made by the decision-makers in the risk management phase [43]. Another feature to highlight is that the EFSA does not make any risk assessment during the PPP authorization. The EU member states make the decision and authorize the products to be used at the national level (Figure 2).

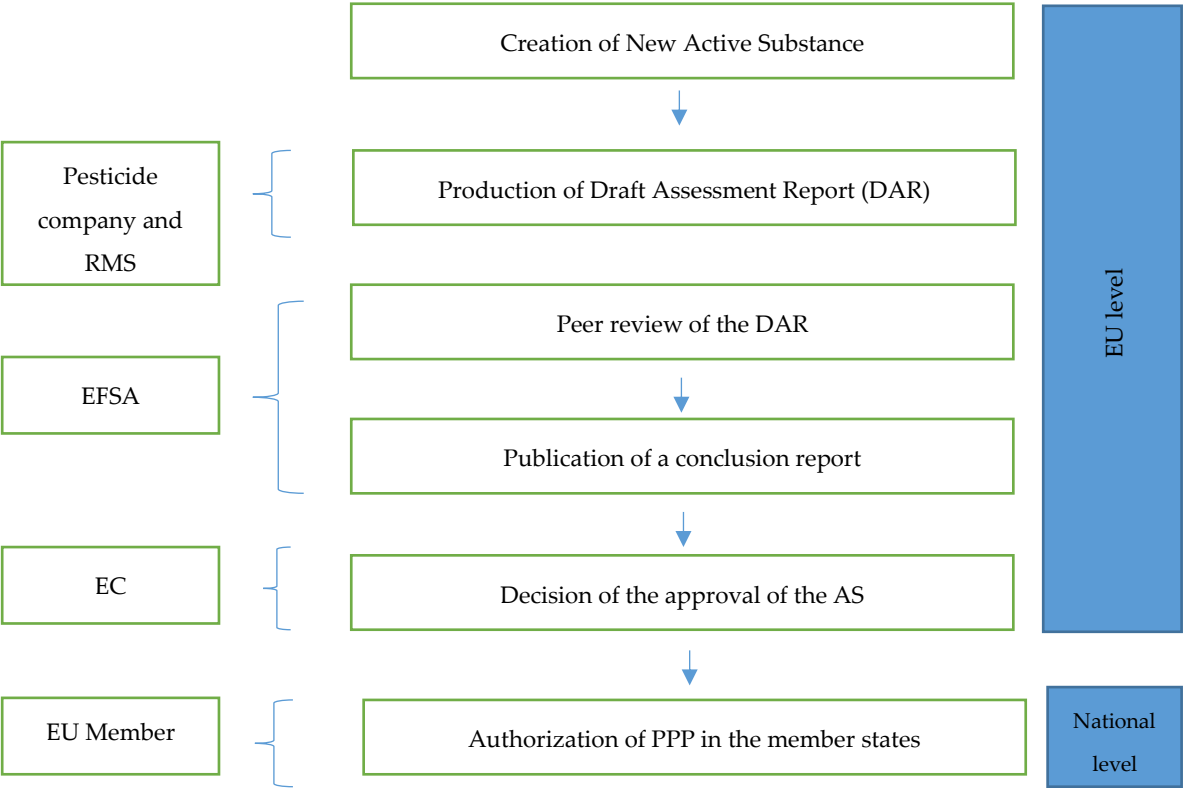


Figure 2. The process of approval of AS and authorization of PPP in the EU.

Although there are claims that the EU pesticide regulatory system is one of the most stringent in the world [43], the process of approval of AS and PPP in the EU are not exempted from criticisms. The first critique of note is having separate authorities in making the decision to approve, authorize and renewal of registration the AS and PPP may cause incoordination of AS and PPP approval [92]. This leads to responsibility issues as exemplified in the case of glyphosate (an herbicide). The EFSA stated that glyphosate (the AS) is unlikely to be carcinogenic and genotoxic [94]. However, the glyphosate as AS and PPP (along with other ingredients) is considered as potentially genotoxic and carcinogenic by the IARC [95]. Since the application of glyphosate in the field is highly likely to be as PPP, it is only logical that the decisions are made based on glyphosate PPP, not as an active substance and the risk assessment of both AS and PPP are done by the EFSA, not by two authorities. Having separate risk assessments and separate authorities to approve AS and authorize PPP lead to “poor coordination and weigh-down authorization process” [92]. Thus, having EFSA as the only authority to do risk assessment in the process to approve the AS and in the process to authorize PPP is

suggested to solve this problem. There are other issues raised during the glyphosate renewal in the EU which will be further discussed in the renewal section.

Secondly, the EU's procedure to get an AS approved is not free from conflict of interest [92]. This is because safety testing and data are provided by the pesticide manufacturer to the RMS. It is later that the EFSA do the risk assessment based on the dossier prepared by the pesticide manufacturer. Although the EFSA may do their review from the peer-review publications, it is important to highlight that the testing done by the pesticide manufacturer may not be independent and free from conflict of interest.

Finally, the lack of transparency of the process of authorization is also criticized by various NGOs as also reviewed by Storck, Karpouzas & Martin-Laurent [92]. Although the conclusion of the risk assessment conducted to approve an AS is published, the details of the studies are not known. The impact of this lack of transparency in reporting the results and process of decision making is said to have hindered the follow-up research of the approved AS and its products [92]. As a result, it usually took years to have the risks to human and environment of the particular AS or PPP disclosed.

4.2. *Renewal of approval of active substance in EU*

The first approval of active substances (AS) is valid for not more than 10 years but the review of approval can be requested by the EC in the light of new scientific and technical knowledge (Article 21 of Regulations 1107/2009) [42]. Having a fixed approval period is important because it will initiate a renewal of approval at certain time and not on ad hoc basis for at least in 10 years since the first approval. This is because in science, not all facts are revealed or concluded in one instance. Having a non-ad hoc basis renewal program also ensures confidence of the consumer in the pesticides market. Applicants may apply for renewal of registration, where the AS still conforms to approval criteria in Article 4 of Regulation 1107/2009. The new period shall not exceed 15 years except the AS that falls into article 4 (7) criteria. This AS (article 4(7)) can only renew for 5 years. The application shall be directed to any member state where the AS is registered along with the submission for notification to other member states, EFSA, and the EC. For the application of renewal, the applicant may submit new data to support the renewal that was not required during registration or last approval. The EFSA will make that information available to the public except for any confidential detail.

The process of renewal in the EU is as rigorous as the process of approval of active substance. The application for renewal is sent to the RMS that provides the initial Renewal Application Report (RAR). EFSA will conduct a peer review of RAR with other member states. The peer-review process includes expert and public consultation. EFSA will then produce a draft conclusion on the renewal of the active substance and the Commission will decide whether to provide renewal of approval of the active substance. This is similar with the authorization process of an AS where the EFSA will conduct the risk assessment while the EC will make the final decision whether to approve the registration or in this case, the renewal of an active substance or pesticide products.

Other than having a fixed period of approval, the Commission may establish work program which is a renewal program by grouping similar active substances to set a high priority on the safety of human and animal health and the environment (Article 18 of Regulation (EU) 1107/2009). To date, there are five renewal programs have been initiated [96]. Having this addition work program demonstrates that renewal program is important in the EU pesticide policy and acknowledges that scientific information of a pesticide may not be known the first time it was approved in the market.

4.2.1. *Controversies surrounding glyphosate renewal in the EU*

Despite the rigorous process prescribed to renew an active constituent or a pesticide product, the EU pesticide regulatory system have been argued to have failed to protect the human and the environment as stipulated as the purpose of the Regulation 1107/2009 [97]. Glyphosate, a widely used pesticide worldwide, has been regularly assessed by many regulatory agencies because of concerns surrounding its risks to human health. In March 2015, the IARC had classified that this herbicide and its products are probably carcinogenic in humans [98]. This carcinogenic classification had the EC mandated the EFSA to consider the IARC findings on the risk assessment conducted for the EU

glyphosate renewal at that time. Despite this, the EFSA came out with a stark contrast of conclusion that “glyphosate is unlikely to pose carcinogenic hazard to human” in October 2015 [94]. Similarly, Joint FAO/WHO Meeting of Pesticide Residues (JMPR) held in 2016 also evaluated the data of acceptable daily intake and acute reference dose for humans of glyphosate (any other pesticides) following the carcinogenic conclusion of this pesticide [99]. The JMPR concluded that “glyphosate is unlikely to pose a carcinogenic risk to humans through dietary exposure”. With the contrasting conclusion of glyphosate risk assessments between the EFSA- JMPR and the IARC, there were so many criticisms surrounded the process of getting glyphosate renewed in the EU.

The EFSA and the German Federal Institute for Risk Assessment (BfR), the RMS for glyphosate renewal the defended the scientific divergence of their glyphosate carcinogenicity evaluation with the IARC's evaluation by explaining the differences of each assessment depending on the evidence in humans and animals, evidence on genotoxicity and other mechanisms of carcinogenicity, the methodology and the overall aim of the assessment [100]. As an example, the association of exposure to glyphosate with non-Hodgkin lymphoma is considered as “limited evidence in humans” by the IARC while it is considered as “very limited and insufficient for triggering the classification” by the EU assessment.

Pesticide Action Network (PAN) Germany then published a peer-review manuscript on the assessments of glyphosate carcinogenicity based on the EU authority's criteria (the CLP regulations-Reg (EC) 1272/2008) in classifying carcinogenic active substance and its products [101]. The EFSA and ECHA were criticized to have violated the applicable regulations [102] as the reanalysis conducted (with the addition of the IARC findings) had led to the said conclusion (“glyphosate is unlikely to pose carcinogenic hazard to human”). Clausen and colleagues [101] argued that the addition data based on the IARC monograph were substantial to conclude that glyphosate is “probably carcinogenic” which corresponds to Category 1B in the European Union. PAN Europe too, had analyzed further the EFSA evaluations and the RAR dossier produced by the RMS as part of the process of glyphosate renewal (Table 7) [97]. It was detected that there were only 52% (76 studies) of the available peer-reviewed scientific literature at the time of reported adverse effects of glyphosate included in the RAR that was prepared by the BfR. This was argued to be a case of scientific misconducts because it involves selective and omission use of scientific data especially the ones that reported adverse effects of a substance, in this case, glyphosate. At the same time, the RAR dossier prepared by the industry dismissed some adverse effects of glyphosate because the study was not conducted according to GLP compliance. The EFSA had published a guideline *Submission of scientific peer-reviewed open literature for the approval of pesticide active substances under Regulation (EC) No 1107/2009* stating that “the fact that a study may not be conducted in accordance with Good Laboratory Practice (GLP) does not imply that the study is irrelevant” [103]. However, as previously mentioned, the EFSA guidelines are not legally binding. There were many more scientific misconducts during the process of glyphosate renewal as analyzed by PAN Europe including the misuse of historical control data, improper use of statistical analytical tools and dismissal of adverse effects because of inconsistency of data. In addition, it was also discovered in February 2020 that there are more than 20 studies submitted to the EU regulators during 2017 glyphosate renewal were conducted by Laboratory of Pharmacology and Toxicology Hamburg [104]. This lab has been accused of committing fraud because some multiple whistle-blowers reported that they regularly falsify study result.

Glyphosate is currently approved for use until 15 December 2022 [105]. The application to renew has been submitted by a group of the industry representatives of applicants (called Glyphosate Renewal Group). A group of RMSs (France, Hungary, Netherlands and Sweden) is currently checking the admissibility of the dossiers submitted which is due on June 2021. The peer review process by the EFSA will commence after this process.

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Table 7. Scientific misconduct conducted during the glyphosate renewal as analyzed by Robinson et al. [97].

Scientific misconduct	Examples during glyphosate renewal
Discrimination use of published data	It was detected that there were only 52% (76 studies) of the available peer-reviewed scientific literature at the time of reported adverse effects of glyphosate included in the RAR.
Dismissal of adverse effects falsely	Not including an epidemiology study reporting reported use of (and other included pesticides) associated with increased incidence of non-Hodgkin lymphoma (NHL)
Historical control data (HCD) use improperly	BfR and EFSA both used HCD from time period up to 17 years (beyond the five-year limit), from 7 different laboratories, and occasionally different sub strain, and used arithmetic mean and range instead of IQR and median. While the ECHA acknowledge the right way to use HCD, the assessment by ECHA did not acknowledge that these HCD supported the observation of increased tumor incidences.
Improper use of statistical analytical tools	The EFSA and BfR claimed the carcinogenic effects was not real because the finding from rodent toxicological studies using trend test (a statistical analytical tool) are “cancelled” because the findings obtained by pairwise comparison (another tool) was not statistically significant.
Dismissal of adverse effects because of inconsistency of data	The risk assessment done by BfR (the RMS for glyphosate renewal) made claim that there was no relation of the findings of malignant lymphomas, kidney tumors, and hemangiosarcomas in male mice with glyphosate because the review of literature found there were inconsistencies in the data. There was no further analysis conducted to support this claim. The EFSA also agreed with this claim.
Improper use of “weight of evidence” approach	There were lack of transparency on how the decision was made as there were no formal description outlining the weight used or how they apply to individual evidence.
Misleading use of research methodology	An epidemiology study that reported association between glyphosate exposure to non-Hodgkin lymphoma was dismissed by BfR because the study is not reliable because there is “no useful information” on confounding factors was reported.
Plagiarism	The RAR prepared by BfR for glyphosate renewal contained several instances of plagiarism. This implies that the regulator does not evaluate the data provided by the industry.

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4.3. Pesticide residue regulations in the EU

Pesticide residue levels in food in the EU were previously not uniform among the member states [106]. It is now harmonized under Regulation EC 396/2005 since the regulation came into force in September 2008. To get a pesticide registered in the EU, the applicant must include in the dossier the scientific information about the minimum amount of pesticides needed to protect the crops and the expected level of residue remaining on the crops after pesticides application [106]. The application is sent to the evaluating member state (EMS) where an initial assessment will be carried out where the report will be sent out to the EFSA [107]. The EFSA will play the role to investigate that these residue levels are safe for consumption for all consumer groups (babies, elder and vegetarian included) based on the toxicity of the pesticides and the maximum levels of residue expected on food and animal feed [108]. The outcome of this assessment is called “reasoned opinion” and it will be published publicly [91] (Regulation (EC) NO 396/2005). The process is consistent with the approval and registration renewal of AS and PPP where the EFSA take charge to evaluate the proposed MRL (i.e. EFSA overseeing risk assessment) while the European Commission will decide whether to approve the proposed MRL. In cases where the residue levels are considered high risk for certain food for any of consumer groups, MRL for the product is rejected and the product will not be registered for application on that crop. In the event where the substantive quantity of a product is lower than the maximum level allowed in that crop, the lower level is set as the MRL to ensure lower application of pesticides.

Generally, there are some of MRL value in the EU is lower than other countries and what the Codex Alimentarius set (see Table 8 for example). The Codex Alimentarius is a committee set up jointly by the FAO and WHO in 1963 that provides international food standards, guidelines and codes of practice [109]. The MRL standard set by Codex may be one of the standards referred to by the exporters [37] because it is included in the World Trade Organization agreement on the Application of Sanitary and Phytosanitary Measures (the SPS agreement) [110]. Even if the Codex MRL standards have been established, “countries routinely reject crops containing pesticide residue levels above their national MRL level” [37]. Since the MRLs of pesticides in the EU are the same for domestic and imported foods in the EU, there are issues raised affecting the international trade. Import restrictions may be imposed on crops from countries that presented pesticide residue more than the EU MRL level. As an example, the low residue limit of thiabendazole imposed by the EU has caused a reduction in Peruvian mango exports. Thiabendazole is a common pesticide to control fungal infection in mango [111].

Table 8. MRL values for the EU, US and Codex. The bold MRL values are the ones that is lower than Codex and the US.

Pesticides	EU MRL [112]	US MRL [113]	Codex MRL [114]
Buprofezin	0.01	0.05	3.00
Boscalid	2.00	10.0	2.00
Acibenzolar-s-methyl	0.30	-	0.30
Deltamethrin	0.20	1.00	0.20
Diphenylamine	0.05	30.00	10.0
Ethephon	0.80	5.00	0.80
Fenamiphos	0.02	-	0.05
Fenitrothion	0.01	-	0.50
Folpet	0.3	5.00	10.00
Fenpyroximate	0.3	-	0.20
Imidacloprid	0.5	0.50	0.50
Indoxacarb	0.5	3.00	0.50
Malathion	0.02	8.00	0.05
Methidathion	0.03	-	0.50
Methomyl	0.01	1.00	0.30

To control the MRLs in food and animal feed among member states in a uniform manner, there are three different instruments introduced by the EC for all member states authorities [106]. Firstly, the EU has a systematic monitoring program called the EU-coordinated Control Program (EUCP) (Article 29, Regulations 396/2005 [91]) which is run by the EU authority with EU member states participation. In addition to the EUCP, there is the National Control Programs (NCP) focusing on the enforcement side where monitoring was done on pesticides residue on products originating from countries that have history of exceedance for each EU member states [115]. Hence, the NCP report does not represent statistically pesticide residue level in the European market food [116]. The EFSA prepares and publishes the comprehensive annual reports on the level of residue from the control activities conducted by the EU member states and the samples randomly taken for the EUCP[108]. The EFSA also make recommendations regarding the future monitoring programs in the annual report. The EU pesticide residue monitoring program is one of the most comprehensive food survey programs in the world as it analyses more than 75 000 food samples for over 600 different pesticides every year [108]. The report of the monitoring program is required to be updated on the internet for the public (Article 30, Regulations 396/2005).

The second instrument introduced by the EC to control the MRL in food and animal feed is having the staff responsible for the residue analysis trained through the Community Reference Laboratories program. To assess the control activities, the EC also introduced inspections in the member state are done by the Food and Veterinary Office (FVO) of the commission [106]. FVO does inspections to member states to ensure compliance with EU food safety and quality legislation. With all these controls in place, there is also a mechanism in place to assist member states to notify the Commission if the level of pesticide residue in a food or feed pose risks to consumers' health [117]. This system called the Rapid Alert System for Food and Feed (RASFF) [118] gives alert or merely notification to all other member states and subsequent necessary actions are taken accordingly for consumer protection.

The effectiveness of the close loop system of pesticide residue monitoring in the EU may have been reflected in the monitoring program reported by the EFSA. In year 2017 and 2018 of the EU report on Pesticide Residue in Food both concluded that the levels investigated for the food commodities analyzed are "unlikely to pose concern for consumer health". The percentage of samples analyzed that fell below the MRL is 95.9% and 95.5% for year 2017 and 2018 respectively [119,120]. PAN Europe, on the other hand, argued that the EFSA had deceived the European people where it was claimed that "the risk of pesticide to consumer remains low" in the EFSA 2015 Pesticide Residue Report [121]. This claim is said to be misleading because there are 28% of the tested food were detected with multiple pesticides residue as the risk of pesticide cocktail to the health of

consumers is not widely evaluated. This is applicable too in what reported in the year 2017 and 2018 where there were 27.5% and 29% (respectively) of food commodities tested with more than one pesticide detected. The effects of exposure to multiple chemicals is not widely investigated. Therefore, the EFSA may not be at the right position to claim that the risk of pesticide to the consumers are low. This action is especially criticized by the PAN Europe where the role of EFSA should be to protect the citizen from the pesticide exposure, not to make everything appear to be alright.

5. Conclusions

The comparisons of the Australian and the EU pesticide regulatory system is summarized in Table 9. The comparison was done for 1) the assessment of the active constituent and products, 2) pesticide re-registration and renewal and 3) the pesticide residue in food and feed regulations.

Table 9. Summary of the comparisons of Australian and the EU pesticide regulatory system.

Aspects	Australia	EU
Assessment for active constituent/product approval	Risk-based - Active constituents and their products are regulated according to their risks which are the likelihood of being exposed to them and the potential effects of exposure.	Hazard-based - The AS will be undergoing a cut-off process first. Chemicals that are carcinogenic, mutagenic, toxic for reproduction, persistent, bioaccumulative, toxic for the environment (PBT), persistent organic pollutants, very persistent and very accumulative or endocrine disruptors are not authorized and not going to the next stage of approval.
Authorities Involved	The APVMA makes assessments and does the approval and authorization of pesticides.	<p>A clear separation of the roles between risk assessment and the approval and authorization of the pesticides:</p> <ul style="list-style-type: none"> The EFSA conducts an independent scientific review of data provided by the applicant. The EC decides the approval of the active substance and the risks mitigation. <p>The decision to authorize the PPP is made by the EU member states</p>
Registration Period	None is set. A product is registered infinitely unless it is cancelled. Review of registration (reconsideration) only happens when nominated.	Registration is set for not more than 10 years. Review occurs every 10 years and there are also multiple review program held in place.
Pesticide Residue Regulation (MRL)	Nominated MRL is reviewed and set by APVMA. Enforcement and monitoring of MRLs in food for health-related concern is not done periodically and systematically.	Nominated MRL is reviewed by EFSA and EC decides to accept proposed levels. Monitoring of residue in food done by EFSA and each member states is reported annually.

The process to get approval and authorization is more complex in the EU than it is in Australia. It is important to acknowledge that the structures of the two regulatory systems are different markedly. Australia is one country, a federation of several states and territories while the European Union is a political and economic union of 28 independent countries. Although EU pesticide regulation is highly harmonized, it has more regulatory authorities involved than in Australia. As an example, authorization of a pesticide product in Australia is only a one-off process to cover the whole nation, while in the EU, an authorized product may need another step if it was to be extended (after authorization) to another zone or even the whole the EU. Therefore, an approach to control pesticides authorization may work for Australia but it will more likely to not work in the EU and vice versa.

It is also important to note that the EU assesses to authorize a pesticide based on *hazard rather than risk* [43]. Hazard is anything that can cause harm while the risk is the likelihood of the hazard will cause harm. In the context of pesticide approval, there are cut off points at the beginning of the process where RMS will ban chemicals that are carcinogenic, mutagenic, toxic for reproduction,

persistent, bioaccumulative and toxic for the environment (PBT), persistent organic pollutants, very persistent and very accumulative or endocrine disruptors (with some exception). On the other hand, the risk-based assessment may allow the above-mentioned chemicals for approval if the likelihood to cause harm is deemed to be low or negligible. Australia (APVMA) performs assessments based on risks to approve active constituents for use [122].

Both EFSA and APVMA relies on the data from the chemical industry (the applicants) to determine the toxicity and the safety of a product/active constituent. This may not be an ideal source because of the potential issue of conflict of interest. As an example, chlorpyrifos had been in use in multiple countries since 1965 [26]. The relation of CPF exposure with neurodevelopmental toxicity was only discovered years after the approval and this was done by the independent academia (as examples [123–125]). Mie, Rudén & Grandjean [126] suggested that the conclusions were withdrawn by pesticide producer “may be misleading”. When the raw data from the original industry-funded studies conducted back in 1998-1999 was reviewed [127], several discrepancies were discovered between conclusions drawn by the test laboratories and the actual observations on the neurodevelopmental toxicity test results for chlorpyrifos. These data were submitted as part of the reauthorization of chlorpyrifos in the US and the EU (the latest in 2015 risk assessment). In addition, Tweedale (2017) suggested that relying on the manufacturers for declaring a product is safe to use may not be wise because investigation on the pre-market toxicity studies of herbicide bentazon indicated that it has a greater hazard than it was claimed in the risk assessment (RA) during the pre-market era. This phenomenon of misinterpreting the data by the applicant has also been seen in drug and medical device pre-market studies as reviewed by Lundh et al. [129] where results are more favorable in industry-sponsored studies than the ones sponsored by other sources.

As for pesticide re-registration or renewal, Australia and the EU do not employ the same policy. An active constituent in Australia is approved indefinitely unless it is nominated for review (reconsideration) because there is no such renewal period set. Reconsideration of an active constituent in Australia occurs on ad-hoc bases, whenever it is nominated or there is new scientific information emerges that may impact the health of human and the environment. On the other hand, an active constituent in the EU is only approved for 10 years. There are also some renewal programs set for active constituent which does not exist in Australia.

In pesticide residue regulations, both Australia and the EU regulatory system require the applicants to propose the MRL values for the new active constituents. During approval of active constituents, the EU involves several authorities (EFSA, RMS and EC) where the EFSA is responsible for the scientific evaluation of the application for approval and then EC will do the final approval. On the other hand, there is not much information about MRL setting processes shared publicly in Australia. The information that is publicly available on the APVMA website implies that evaluation of data to determine MRL are done through peer review [73] and that MRLs are set by APVMA [130]. No further detail, such as who is responsible for peer-review and how many authorities involved in the MRL setting process is provided by the APVMA [73,130].

MRL enforcement and monitoring activities are done by each member state in the EU and the EFSA compiles, analyses and publishes the report (Regulation 396/2005 [91]). Australia is somewhat similar to the EU as food regulatory authorities in each state and territory are responsible to monitor and enforce the Food Standards Code [72]. However, the monitoring data in each of the states and territory in Australia is not published every year. FSANZ also does a national survey through the Australian Total Diet Survey (ATDS). Pesticide residue monitoring is not done systematically and routinely in Australia as pesticides were not included as part of the chemicals surveyed in food every year. Therefore, there is nothing tangible and certain can be said on the actual pesticides that the population being exposed to every year. In contrast, the EU appears to have a closed-loop system where the food and feed commodities are monitored and reported every year. The reports of the EU pesticide residue monitoring are also publicly accessible for at least 5 years back in the EFSA Journal which confirms that there is the monitoring of pesticide residue in food going on annually.

In summary, there are many aspects that the Australian pesticide regulatory system can improve. By comparing with the EU pesticide regulatory system alone, it is suggested that the

Australian pesticide regulatory 1) to have the pesticide registration period, 2) to ensure MRL of pesticides in food and feed are monitored regularly with having the results publicized and finally 3) to re-examine the current system to rely on the data submitted by the manufacturers (the applicants) for the risk assessments in approving and authorizing a new pesticide in the market.

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