



Australian Government

**Australian Pesticides and
Veterinary Medicines Authority**



Paraquat Review Technical Report

July 2024

© Australian Pesticides and Veterinary Medicines Authority 2024

Ownership of intellectual property rights in this publication

Unless otherwise noted, copyright (and any other intellectual property rights, if any) in this publication is owned by the Australian Pesticides and Veterinary Medicines Authority (APVMA).

Creative Commons licence

With the exception of the Coat of Arms and other elements specifically identified, this publication is licensed under a Creative Commons Attribution 4.0 Licence. This is a standard form agreement that allows you to copy, distribute, transmit and adapt this publication provided that you attribute the work.



A [summary of the licence terms](#) and [full licence terms](#) are available from Creative Commons.

The APVMA's preference is that you attribute this publication (and any approved material sourced from it) using the following wording:

Source: Licensed from the Australian Pesticides and Veterinary Medicines Authority (APVMA) under a Creative Commons Attribution 4.0 Australia Licence. The APVMA does not necessarily endorse the content of this publication.

In referencing this document the Australian Pesticides and Veterinary Medicines Authority should be cited as the author, publisher and copyright owner.

Use of the Coat of Arms

The terms under which the Coat of Arms can be used are set out on the [Department of the Prime Minister and Cabinet website](#).

Disclaimer

The material in or linking from this report may contain the views or recommendations of third parties. Third party material does not necessarily reflect the views of the APVMA, or indicate a commitment to a particular course of action. There may be links in this document that will transfer you to external websites. The APVMA does not have responsibility for these websites, nor does linking to or from this document constitute any form of endorsement. The APVMA is not responsible for any errors, omissions or matters of interpretation in any third-party information contained within this document.

Comments and enquiries regarding copyright:

Assistant Director, Communications
Australian Pesticides and Veterinary Medicines Authority
GPO Box 3262
Sydney NSW 2001 Australia

Telephone: +61 2 6770 2300

Email: communications@apvma.gov.au.

This publication is available from the [APVMA website](#).

Contents

Preface	1
About this document	1
Further information	1
Contact details	1
Introduction	2
Purpose of review	2
Product claims, use patterns and mode of action	3
Chemistry	5
Active constituent	5
Active Constituent Standards	6
Statutory considerations under the safety criteria – active constituents	8
Formulated products	9
Statutory considerations under the safety criteria – formulated products	17
Recommendations	17
Toxicology	19
Evaluation of toxicology	19
Biochemical aspects	19
Major toxicological mode(s) of action and key events	19
Acute toxicity	19
Acute toxicity in humans	20
Repeat dose toxicity	20
Special studies	22
Health-based guidance values	23
Poisons scheduling	25
Recommendations	26
Worker health and safety	27
Worker exposure assessment	27
Ground-based application	28
Re-entry to treated areas	30
Recommended label changes	30
Residues and Trade	33
Metabolism	33

Analytical methods and storage stability	33
Analytical methods	33
Stability of pesticide residues in stored analytical samples	34
Residue definition	34
Residues in foods	34
Plant commodities	35
Fruit crops	36
Pome fruit	36
Citrus fruit	37
Stone fruit	37
Berries and other small fruits	37
Tropical fruits – inedible peel	38
Tropical fruits – edible peel	38
Tree nuts	39
Vegetable crops	39
Bulb vegetables	40
Root and tuber vegetables	40
Leafy vegetables	41
Brassica vegetables	42
Stalk and stem vegetables	42
Fruiting vegetables, cucurbits	42
Fruiting vegetables, other than cucurbits	43
Legume vegetables	43
Pulses	43
Cereals	45
Oilseeds	45
Cotton	46
Peanuts	46
Oilseeds other than cotton and peanuts	46
Sugar cane	47
Hops	47
Herbs and spices	48
Processed commodities	48
Vegetable oil	48
Residues in animal feed commodities	49
Animal feeds derived from grasses	49

Legume animal feeds	49
Cotton trash	50
Almond hulls	50
Other animal feeds	50
Animal transfer studies and required animal commodity MRLs	50
Poultry	50
Pigs	52
Ruminants	53
Crop rotation	55
Spray drift	55
Dietary risk assessment	56
Chronic dietary exposure assessment	56
Acute dietary exposure assessment	56
Trade	57
Conclusions from the residues and trade assessment	60
Consideration of proposed APVMA chemical review outcomes for paraquat	64
Aid to cultivation; crop, pasture or fallow establishment (supported use: 231 g ac/ha)	65
Bananas (supported use: 175 g ac/ha)	66
Peanuts (supported use: 231 g ac/ha)	66
Spray topping to reduce seed set (Field peas, Lupins, Lentils, Chickpeas, Faba Beans. Supported use: 149 g ac/ha)	66
Rice	67
Required animal commodity MRLs	67
Trade	68
Revised dietary exposure assessment	69
Chronic dietary exposure assessment	69
Acute dietary exposure assessment	69
Revised MRL recommendations	69
Environmental safety	72
Assessment scenarios	72
Fate and behaviour in the environment	73
Effects on non-target species	75
Risks to non-target species	78
Terrestrial vertebrates	78
Aquatic species	80
Bees	83

Other arthropod species	84
Soil organisms	85
Non-target terrestrial plants	86
Combination toxicity	86
Assessment scenarios	86
Effects on non-target species	86
Risks to non-target species	88
Recommendations	91
<hr/>	
Spray drift	94
Storage and disposal	97
Storage	97
Disposal	97
<hr/>	
Appendix A – Summary of assessment outcomes	99
Appendix B – Listing of environmental endpoints	108
Appendix C – Terrestrial vertebrate assessments	119
Appendix D – PBT and POP assessments	123
Persistence criterion	123
Bioaccumulation criterion	123
Toxicity criterion	124
Potential for long-range environmental transport	124
Conclusion	124
<hr/>	
Acronyms and abbreviations	125
Glossary	128
References	132

List of tables

Table 1: Paraquat product groups	3
Table 2: Nomenclature and structural formula of the active constituent paraquat dichloride.	5
Table 3: Key physicochemical properties of the active constituent paraquat dichloride	6
Table 4: Current paraquat active constituent approvals	9
Table 5: Currently registered agricultural products containing paraquat	10
Table 6: Points of Departure for Human Health Risk Assessment	23
Table 7: Acceptable daily intake for paraquat	25

Table 8: Acute reference dose for paraquat	25
Table 9: Assumptions used in modelling exposure for professional use of paraquat	27
Table 10: Risk assessment outcomes for liquid paraquat products	28
Table 11: Risk assessment outcomes for liquid paraquat plus diquat products	29
Table 12: Calculation of poultry broiler dietary burden of paraquat	51
Table 13: Calculation of poultry layer dietary burden of paraquat	52
Table 14: Calculation of beef cattle dietary burden of paraquat	53
Table 15: Calculation of dairy cattle dietary burden of paraquat	53
Table 16: Health Standards established for paraquat	56
Table 17: Overseas MRLs established for major export commodities (December 2023)	57
Table 18: Amendments to Table 1 of the MRL Standard	62
Table 19: Amendments to Table 4 of the MRL Standard	64
Table 20: Paraquat uses supported by human health, environment, and residues and trade risk assessments	64
Table 21: Paraquat and diquat combination uses that are supported by human health, environment and residues and trade risk assessments	65
Table 22: Amendments to Table 1 of the MRL Standard	69
Table 23: Amendments to Table 4 of the MRL Standard	71
Table 24: Paraquat – Environmental risk assessment scenarios	72
Table 25: Paraquat – Key regulatory endpoints for exposure assessment	74
Table 26: Paraquat – Toxicity endpoints for primary producers used in SSD analysis	77
Table 27: Paraquat – Post-emergent toxicity endpoints for non-target terrestrial plants used in SSD analysis	77
Table 28: Paraquat – Regulatory acceptable levels for non-target species	78
Table 29: Paraquat – Summary of risk assessment outcomes for terrestrial vertebrates	79
Table 30: Soil exposure estimates for paraquat	82
Table 31: Assessment of runoff risks to aquatic species	83
Table 32: Screening level assessment of risks to bees	84
Table 33: Assessment of risks to other non-target arthropods	85
Table 34: Screening level assessment of risks to soil organisms (worst-case scenario)	85
Table 35: Diquat/paraquat combination products: environmental risk assessment scenarios	86
Table 36: Diquat/paraquat combination products - Predicted toxicity endpoints for non-target terrestrial plants (post-emergent exposure) used in SSD analysis	88
Table 37: Diquat/paraquat combination products: regulatory acceptable levels for non-target species	88
Table 38: Diquat/paraquat combination products: crop groups for terrestrial vertebrate assessment	90
Table 39: Diquat/paraquat combination products: acute risks to terrestrial vertebrates	90
Table 40: Summary of risk assessment outcomes for risks of combination products containing 115 g/L diquat and 135 g/L paraquat to terrestrial vertebrates	90
Table 41: Screening level assessment of risks of combination products containing 115 g/L diquat and 135 g/L paraquat to bees	91

Table 42: Assessment of risks of combination products containing 115 g/L diquat and 135 g/L paraquat to other non-target arthropods	91
Table 43: Supported uses from the viewpoint of environmental safety	92
Table 44: Uses not supported from the viewpoint of environmental safety	92
Table 45: Regulatory acceptable levels of paraquat resulting from spray drift	94
Table 46: Regulatory acceptable levels of paraquat and diquat resulting from spray drift of chemical products co-formulated with both active constituents	94
Table 47: Paraquat - buffer zones for boom sprayers	95
Table 48: Diquat/paraquat co-formulated product buffer zones for boom sprayers	96
Table 49: Risk assessment outcomes for products containing paraquat	99
Table 50: Risk assessment outcomes for products containing paraquat and diquat	102
Table 51: Risk assessment outcomes for products containing paraquat and amitrole	106
Table 52: Paraquat – Dissipation in animal food items	108
Table 53: Paraquat – Fate and behaviour in soil	108
Table 54: Paraquat – Fate and behaviour in water and sediment	109
Table 55: Paraquat – Fate and behaviour in air	109
Table 56: Paraquat – Monitoring data	109
Table 57: Paraquat – Laboratory studies on terrestrial vertebrates	110
Table 58: Paraquat – Monitoring data on terrestrial vertebrates	111
Table 59: Paraquat – Effects on aquatic species	111
Table 60: Paraquat – Effects on bees	112
Table 61: Paraquat – Laboratory studies on other arthropod species	112
Table 62: Paraquat – Field studies on other arthropod species	113
Table 63: Paraquat – Laboratory studies on soil organisms	113
Table 64: Paraquat – Field studies on soil organisms	113
Table 65: Paraquat – Effects on non-target terrestrial plants	114
Table 66: Diquat/paraquat combination products: short-term effects on terrestrial vertebrates	114
Table 67: Diquat/paraquat combination products: short-term effects on aquatic species	115
Table 68: Diquat/paraquat combination products: short-term effects on bees	116
Table 69: Diquat/paraquat combination products: effects on other terrestrial arthropods	117
Table 70: Diquat/paraquat combination products: short-term effects on soil organisms	117
Table 71: Diquat/paraquat combination products: effects on non-target terrestrial plants (post-emergent exposure)	118
Table 72: Seasonal exposure estimates for paraquat in animal food items	119
Table 73: Acute risks of paraquat to wild mammals (RAL 6.1 mg/kg bw)	120
Table 74: Acute risks of paraquat to birds (RAL 5.7 mg/kg bw)	121

Preface

The Australian Pesticides and Veterinary Medicines Authority (APVMA) is the independent statutory authority with responsibility for the regulation of agricultural and veterinary chemicals in Australia. Its statutory powers are provided in the Agricultural and Veterinary Chemicals Code (the Agvet Code), which is scheduled to the *Agricultural and Veterinary Chemicals Code Act 1994*.

About this document

This Technical Report is intended to provide an overview of the assessments that have been conducted by the APVMA and of the specialist advice received. It has been deliberately presented in a manner that is likely to be informative to the widest possible audience, thereby encouraging public comment.

This document contains a summary of the assessment reports generated in the course of the chemical review of an active ingredient, including the registered product and approved labels. The document provides a summary of the APVMA's assessment, which may include details of:

- the toxicology of both the active constituent and product
- the residues and trade assessment
- occupational exposure aspects
- environmental fate, toxicity, potential exposure and hazard
- efficacy and target crop or animal safety.

Further information

Further information can be obtained via the contact details provided below. More details on the chemical review process can be found on the APVMA website: www.apvma.gov.au

Contact details

Chemical Review Team

Australian Pesticides and Veterinary Medicines Authority

Email: chemicalreview@apvma.gov.au

GPO Box 3262

Sydney NSW 2001

Phone: +61 2 6770 2400

Introduction

Paraquat is a non-selective contact herbicide belonging to the bipyridinium class of compounds which also includes the related herbicide diquat. Paraquat and diquat have been registered for use in Australia since 1964. Both compounds share a similar mode of herbicidal action which involves the inhibition of photosynthesis (specifically photosystem I) thereby generating superoxide, leading to lipid peroxidation and membrane damage. Plants die rapidly after treatment and exposure to light.

Purpose of review

Paraquat and the related bipyridinium herbicide diquat were placed under reconsideration by the APVMA (then NRA) in the third cycle of the Existing Chemicals Review Program, in a notice published in the NRA Gazette on 2 December 1997.

The reconsideration covers all aspects of the active constituent approval, product registration and label approval to evaluate whether the continuing use of paraquat:

- would not be an undue hazard to the safety of people exposed to it during its handling or people using anything containing its residues
- would not be likely to have an effect that is harmful to human beings
- would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment
- would not unduly prejudice trade or commerce between Australia and places outside Australia
- would be effective in accordance with the instructions for its use

The following aspects of active constituent approvals and product registrations for paraquat have been assessed:

- Toxicology, including a detailed assessment of the potential for neurotoxic effects
- Worker health and safety (OHS)
 - Risks arising from exposure during handling and application
 - Re-entry exposure risks
 - Determination of appropriate personal protective clothing requirements
- Residues and trade:
 - Residues in treated produce arising from application in accordance with label instructions
 - MRLs to underpin the assessment of dietary and trade risk for all commodities on which paraquat is used
 - Determination of dietary exposure resulting from the consumption of produce treated with paraquat
- Environmental safety, including spray drift

The APVMA has also considered information pertaining to chemistry (impurities of toxicological concern).

Although paraquat and diquat are structurally related, their relative risk to human and environmental safety, and trade, have been assessed separately.

A summary of the combined risk assessment outcomes for each use pattern, and whether it is supported for continued approval, is presented in Appendix A.

Product claims, use patterns and mode of action

Paraquat is an active constituent in 141 products registered for use in Australia by the APVMA. These products can be divided into 3 groups based on the presence of a second active constituent, as indicated in the table below. Paraquat products containing paraquat as the only active constituent (group 1 below), products that contain both paraquat and diquat (group 2 below) and products that contain paraquat and amitrole (group 3 below). This report includes complete assessments of the risk posed by products containing paraquat as the sole active constituent, products containing both paraquat and diquat. Products containing paraquat and amitrole have been reassessed with respect to the risk posed by paraquat only, as amitrole has not been placed under reconsideration.

These 3 groups can be further divided based on the concentration of paraquat and the secondary active constituent as shown in Table 1. Paraquat products are used as herbicides against broadleaf and grass weeds in a variety of situations, including treatment of weeds in seed beds before sowing, as well as post-emergence inter-row weed control and pre-harvesting operations of a number of crops. Paraquat products often include instructions for use as a tank-mix with diquat or other herbicides to improve efficacy against particular weed species (e.g. capeweed), or to provide residual activity (e.g. diuron used for control of annual grasses and broadleaf weeds in lucerne (*Medicago sativa*)). Paraquat is also used as a crop desiccant, for hay freezing, accelerating the drying of seeds and desiccating weeds to facilitate crop harvesting. A detailed list of use patterns considered in this assessment is provided in Appendix A – Summary of assessment outcomes.

Current permits for use of paraquat are not within the scope of this reconsideration.

Table 1: Paraquat product groups

Group	Active constituent(s)	Active constituent concentration
1a (59 products)	Paraquat	250 g/L paraquat
1b (8 products)		300 g/L paraquat
1c (1 products)		330 g/L paraquat
1d (1 product)		334 g/L paraquat
1e (1 product)		350 g/L paraquat
1f (9 products)		360 g/L paraquat
2 (39 products)	Paraquat/diquat	135 g/L paraquat; 115 g/L diquat
3a (1 product) 3b (1 products)	Paraquat/amitrole	250 g/L paraquat; 10 g/L amitrole 300 g/L paraquat; 12 g/L amitrole

Paraquat is a non-selective, contact herbicide, absorbed by foliage. Paraquat belongs to the herbicide mode of action group 22¹ and acts by accepting electrons from photosystem I (PS-I, electron diversion) resulting in reduction of the herbicide and producing a radical; the radical generates hydroxyl radicals and other reactive oxygen species that destroy unsaturated lipids and chlorophyll. Treated plants die rapidly after exposure to light.

¹Mode of Action tables maintained by Croplife are available at the link below (accessed May 2024)
<https://www.croplife.org.au/resources/programs/resistance-management/>

Chemistry

Active constituent

Paraquat dichloride in its pure form is a colourless to off-white crystalline solid with a slightly ammoniacal odour. Paraquat dichloride is an extremely hygroscopic material and is commercially supplied as a technical concentrate (manufacturing concentrate) consisting of an aqueous solution with a typical concentration of 50% w/v (500 g/L). As well as being extremely soluble in water, paraquat dichloride is soluble in methanol while being practically insoluble in most other organic solvents and has an extremely low octanol-water partition coefficient and will not partition into fatty or other hydrophobic matrices. It has very low volatility and is generally stable to hydrolysis and aqueous photolysis. Further information about the identity and physicochemical properties of paraquat are provided in Table 2 and Table below. There are currently 20 active constituent approvals for paraquat dichloride listed in Table 4 below.

Table 2: Nomenclature and structural formula of the active constituent paraquat dichloride.

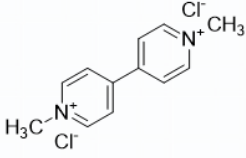
Common name (ISO):	Paraquat dichloride Please disregard and delete my comment if not relevant. Paraquat (ISO approved name for the cation)
IUPAC name:	1,1'-dimethyl-4,4'-bipyridinium dichloride
Chemical Abstracts name:	1,1'-dimethyl-4,4'-bipyridinium dichloride
CAS registry number:	1910-42-5 (dichloride) 4685-14-7 (cation)
Molecular formula:	C ₁₂ H ₁₄ Cl ₂ N ₂ (dichloride) C ₁₂ H ₁₄ N ₂ (cation)
Molecular weight:	257.2 g mol ⁻¹ (dichloride) 186.3 g mol ⁻¹ (cation)
Structural formula:	

Table 3: Key physicochemical properties of the active constituent paraquat dichloride

Appearance	Paraquat dichloride technical substance is a colourless to off-white hygroscopic crystals with a slightly ammoniacal odour. Paraquat dichloride is supplied commercially as an aqueous solution (technical concentrate) typically containing 500 g/L paraquat dichloride
Melting point	Approx. 340°C (decomposes)
Density	1.12-1.15 g/mL as dichloride salt. At room temperature paraquat dichloride is a solid. The technical concentrate (manufacturing concentrate) is usually formulated as an aqueous solution
Solubility in water	620 g/L (20-25 °C)
Organic solvent solubility (20 °C)	143 g/L in methanol, <0.1 g/L in acetone, dichloromethane, toluene, ethyl acetate and hexane
Octanol/water partition coefficient (Log K _{ow})	-4.5 at 20°C (log K _{ow})
Vapour pressure	<0.01 mPa (25 °C)
Stability	Stable in neutral and acidic media, but readily hydrolysed in alkaline media. Photochemically decomposed by UV irradiation in aqueous solution (75% loss in 96 h in UV light).
Henry's law constant (calculated)	<4 × 10 ⁻⁹ Pa.m ³ mol ⁻¹
Hydrolysis (DT50, 25 °C)	>30 days (pH 5, 7, 9; 40 °C)
Aqueous photolysis (DT50)	Stable to aqueous photolysis

Active Constituent Standards

The [Agricultural and Veterinary Chemicals Code \(Agricultural Active Constituents\) Standards 2022](#) (Agricultural Active Constituents Standards 2022) entry for paraquat dichloride (APVMA, 2022) is consistent with the specification for paraquat dichloride provided in the [Food and Agriculture Organization of The United Nations \(FAO\) Specifications for Plant Protection Products](#) (FAO, 2021). The minimum purity for paraquat dichloride on a dry weight basis is 920 g/kg, with maximum levels for 2 toxicologically significant impurities of total terpyridines at 0.001 g/kg (1.0 ppm) maximum and 4,4'-bipyridyl: 1.0 g/kg (1000 ppm) maximum. Paraquat dichloride technical concentrate (manufacturing concentrate) shall contain a lower limit of 500 g/L paraquat dichloride, which corresponds nominally to 442 g/kg paraquat dichloride (320 g/kg paraquat ion). When determined, the average measured content shall not differ from that declared by more than ± 25 g/L, which corresponds to ± 5% on a g/kg basis. Other important notes included in the paraquat dichloride standard include:

Note 1:

The product must not be allowed to come into direct contact with metal. If metal is used, containers must be lined with suitable polymeric material, or the internal surfaces treated to prevent corrosion of the container and/or deterioration of the contents.

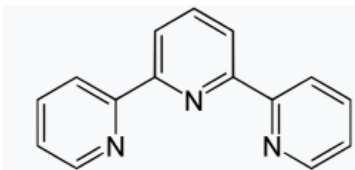
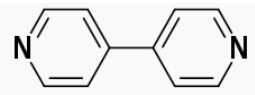
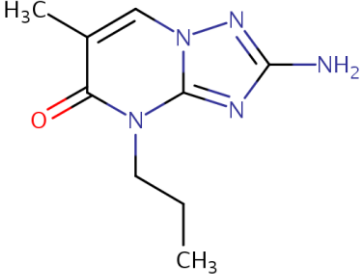
Note 2:

An effective emetic, having the following characteristics, must be incorporated into the Technical Concentrate (TK).

- It must be rapidly absorbed (more rapidly than paraquat) and be quick acting. Emesis must occur in about half an hour in at least 50% of cases.
- It must be an effective (strong) stimulant of the emetic centre of the brain, to produce effective emesis. The emetic effect should have a limited 'action period', of about 2 to 3 hours, to allow effective treatment of poisoning.
- It must act centrally on the emetic centre in the brain.
- It must not be a gastric irritant because, as paraquat is itself an irritant, this could potentiate the toxicity of paraquat.
- It must be toxicologically acceptable. It must have a short half-life in the body (to comply with the need for a limited action period).
- It must be compatible with, and stable in, the paraquat formulation and not affect the herbicidal efficacy or occupational use of the product.

To date, the only compound found to meet these requirements is 2-amino-4,5-dihydro-6-methyl-4-propyl-s-triazole-(1,5a)pyrimidin-5-one (PP796). PP796 must be present in the TK at not less than 0.8 g/L.

Figure 1: Related impurities and other compounds specified in the paraquat dichloride active standard

		
Terpyridines (2,2';6',2''-terpyridine)	4,4'-Bipyridine, CAS number 553-26-4	2-amino-4,5-dihydro-6-methyl-4-propyl-s-triazole-(1,5a)pyrimidin-5-one (PP796), CAS number 27277-00-5

Statutory considerations under the safety criteria – active constituents

Under section 5A of the Agvet Code, when determining whether an active constituent satisfies the safety criteria, the APVMA must (amongst other matters) have regard to:

- The method by which the active constituent is or is proposed to be manufactured
- The extent to which the active constituent will contain impurities
- Whether an analysis of the active constituent has been carried out and the results of any such analysis
- Any other relevant matters.

The manufacturing processes of each source of paraquat dichloride were assessed at the time of approval along with batch analyses of the chemical composition, including the levels of impurities.

Paraquat dichloride is generally manufactured using 4,4'-bipyridyl as a starting material or intermediate in the process. As 4,4'-bipyridyl is of toxicological significance, a maximum limit has been specified for this compound in paraquat dichloride technical concentrate in both the Agricultural and Veterinary Chemicals Code (Agricultural Active Constituents) Standards 2022 (Agricultural Active Constituents Standard 2022) and the FAO specification. Terpyridines, which are also of toxicological significance, can be formed as a byproduct during the manufacture of 4,4'-bipyridyl and can therefore be present in paraquat dichloride technical concentrates. Again, a maximum limit has been specified for this compound in paraquat dichloride technical concentrate in both the APVMA standard and the FAO specification.

Based on the information considered at the time of approval, including the manufacturing process, other impurities of toxicological significance are not expected to be present in approved sources of paraquat dichloride technical concentrate.

The APVMA standard for paraquat dichloride technical concentrate was revised in 2013 to align with the FAO specification, this included revising the limits for 4,4'-bipyridyl and terpyridines and the additional requirement to include an emetic due to the high acute toxicity of paraquat dichloride. Sources of paraquat dichloride technical concentrate approved following promulgation of the revised APVMA standard have been assessed against, and determined to comply with, that standard. Sources of paraquat dichloride technical concentrate approved prior to revision of the standard are required to meet the standard, but in general, have not provided data to demonstrate that they comply with the revised standard.

Based on the information provided and the assessment conducted at the time of approval, in respect of the chemistry-related matters in the section 5A safety criteria, it is considered that APVMA remains satisfied in respect of the manufacturing method for approved paraquat dichloride active constituents.

The APVMA is satisfied that sources of paraquat dichloride technical concentrate approved after the 2013 revision of the active constituent standard satisfy the safety criteria in regard to the analyses the extent to which they contain impurities. The APVMA is not satisfied sources of paraquat dichloride technical concentrate approved prior to the revision of the standard satisfy the safety criteria, as the APVMA does not hold data to demonstrate that those active constituents meet the current standard. To demonstrate that these approvals satisfy the safety criteria, holders should provide recent Declarations of Composition and batch analyses demonstrating compliance with the revised APVMA standard (and the FAO specification) for paraquat dichloride.

Table 4: Current paraquat active constituent approvals

Approval number	Formulation	Holder
44249	Manufacturing concentrate	Syngenta Australia Pty Ltd
44387	Manufacturing concentrate	Nufarm Australia Limited
47747	Manufacturing concentrate	UPL Australia Pty Ltd
48272	Manufacturing concentrate	Syngenta Australia Pty Ltd
51041	Manufacturing concentrate	Ronic International Pty Ltd
51678	Manufacturing concentrate	Unisun Chemicals Pty Ltd
54043	Manufacturing concentrate	Halley International Enterprise (Australia) Pty Ltd
54131	Manufacturing concentrate	Capital Commodities (Vic) Pty Ltd
55327	Manufacturing concentrate	ADAMA Australia Pty Ltd
55682	Manufacturing concentrate	Imtrade Australia Pty Ltd
55966	Manufacturing concentrate	Syngenta Australia Pty Ltd
56809	Manufacturing concentrate	Conquest Crop Protection Pty Ltd
58230	Manufacturing concentrate	Sinon Australia Pty Ltd
59171	Manufacturing concentrate	Agrogill Chemicals Pty Ltd
64565	Manufacturing concentrate	FMC Australasia Pty Ltd
64765	Manufacturing concentrate	Sharda Worldwide Exports Pvt Ltd
69493	Manufacturing concentrate	Grow Choice Pty Ltd
87171	Manufacturing concentrate	Agrogill Chemicals Pty Ltd
89426	Manufacturing concentrate	Hebei Shanli Chemical Company Limited
91420	Technical concentrate	Jiangsu Noon Crop Science CO., LTD

Formulated products

There are currently 123 registered agricultural chemical products containing paraquat as an active constituent. Of these, 39 also contain diquat as a secondary active constituent while 2 contain amitrole in addition to paraquat. The products are listed in Table 4, grouped by product format (formulation type, paraquat content, and other actives). Due to the need for consideration of paraquat and diquat together in products containing both actives, these products have been designated as group 2 in this reconsideration (paraquat) and in the concurrent diquat reconsideration.

Table 5: Currently registered agricultural products containing paraquat

Registration number	Product name	Holder	Active constituents	Product group
Soluble concentrate products containing paraquat as paraquat dichloride				
46531	Gramoxone 250 Herbicide	Syngenta Australia Pty Ltd	Paraquat 250 g/L	1a
48760	Uniquat 250 Herbicide	UPL Australia Pty Ltd	Paraquat 250 g/L	1a
51958	Accensi Paraquat 250 Herbicide	Accensi Pty Ltd	Paraquat 250 g/L	1a
52141	Kendon Sprayquat 250 Herbicide	Kendon Chemicals & Mnfng Co Pty Ltd	Paraquat 250 g/L	1a
53381	Imtrade Paraquat 250 Herbicide	Imtrade Australia Pty Ltd	Paraquat 250 g/L	1a
53919	Nufarm Shirquat Herbicide	Nufarm Australia Limited	Paraquat 250 g/L	1a
54520	Halley Paraquat 250 Herbicide	Halley International Enterprise (Australia) Pty Ltd	Paraquat 250 g/L	1a
54522	Spraytop 250 SL Herbicide	ADAMA Australia Pty Limited	Paraquat 250 g/L	1a
56102	Kenso Agcare Para-Ken 250 Herbicide	Kenso Corporation (M) Sdn. Bhd.	Paraquat 250 g/L	1a
57817	Conquest Explode 250 Herbicide	Conquest Crop Protection Pty Ltd	Paraquat 250 g/L	1a
58841	Genfarm Paraquat 250 Herbicide	Nutrien Ag Solutions Limited	Paraquat 250 g/L	1a
58992	Sinmosa 250 Herbicide	Sinon Australia Pty Limited	Paraquat 250 g/L	1a
59419	Inferno Herbicide	Sipcam Pacific Australia Pty Ltd	Paraquat 250 g/L	1a
61254	Biotis Paraquat 250 Herbicide	Biotis Life Science Pty Ltd	Paraquat 250 g/L	1a
61869	Titan Paraquat 250 Herbicide	Titan Ag Pty Ltd	Paraquat 250 g/L	1a
62096	Choice Paraquat 250 Herbicide	Grow Choice Pty Limited	Paraquat 250 g/L	1a
63090	Ozcrop Paraquat 250 Herbicide	Oz Crop Pty Ltd	Paraquat 250 g/L	1a

64281	Farmalinx Parquat 250 Herbicide	Farmalinx Pty Ltd	Paraquat 250 g/L	1a
64588	Smart Paraquat 250 Herbicide	Crop Smart Pty Ltd	Paraquat 250 g/L	1a
64651	Rc Paraquat 250 Herbicide	Ruralchem Pty Ltd	Paraquat 250 g/L	1a
64706	Fosterra Paraquat 250 Herbicide	Fosterra Pty Ltd	Paraquat 250 g/L	1a
64731	Agro-Essence Paraquat 250SL	Agro-Alliance (Australia) Pty Ltd	Paraquat 250 g/L	1a
65148	Trio Paraquat 250 Herbicide	CTS Chemicals Pty Ltd	Paraquat 250 g/L	1a
65524	Proterra Paraquat 250 Herbicide	Proterra Pty Ltd	Paraquat 250 g/L	1a
65537	Sanonda Herbicide Paraquat 250sl	Sanonda (Australia) Pty Ltd	Paraquat 250 g/L	1a
65694	Rainbow Paraquat 250 SI Herbicide	Shandong Rainbow International Co Ltd	Paraquat 250 g/L	1a
65713	Pacific Paraquat 250 Herbicide	Pacific Agriscience Pty Ltd	Paraquat 250 g/L	1a
66103	Apparent Paraquat 250 Herbicide	Titan Ag Pty Ltd	Paraquat 250 g/L	1a
66249	AW Putout 250 Herbicide	Agri West Pty Limited	Paraquat 250 g/L	1a
66309	Huilong Paraquat 250 Herbicide	Huilong Agrochemicals Australia Pty Ltd	Paraquat 250 g/L	1a
66531	ACP Paraquat 250 Herbicide	Australis Crop Protection Pty Ltd	Paraquat 250 g/L	1a
66548	Echem Paraquat 250 Herbicide	Echem (Aust) Pty Limited	Paraquat 250 g/L	1a
67163	Easyfarm Paraquat 250 SL Herbicide	Easyfarm Pty Ltd	Paraquat 250 g/L	1a
67307	AC Piston 250 Herbicide	Axichem Pty Ltd	Paraquat 250 g/L	1a
67437	Agroquat 250 Herbicide	Agrogill Chemicals Pty Ltd	Paraquat 250 g/L	1a

12 Paraquat Review Technical Report

67888	Spalding Paraquat 250 Herbicide	DGL Environmental Pty Ltd	Paraquat 250 g/L	1a
67977	Ezycrop Paraquat 250 SL Herbicide	Ezycrop Pty Ltd	Paraquat 250 g/L	1a
68196	Novaguard Paraquat 250 SL Herbicide	Novaguard Pty Ltd	Paraquat 250 g/L	1a
68477	Agmate Paraquat 250 SL Herbicide	Agcare Pty Ltd	Paraquat 250 g/L	1a
69274	Sabakem Paraquat 250SL Herbicide	Sabakem Pty Ltd	Paraquat 250 g/L	1a
69712	Paradox 250 Herbicide	Sinon Australia Pty Limited	Paraquat 250 g/L	1a
81797	Relyon Paraquat 250 Herbicide	Nutrien Ag Solutions Limited	Paraquat 250 g/L	1a
82754	Agritrading Paraquat 250 Herbicide	Agritrading Pty Limited	Paraquat 250 g/L	1a
83115	Kelpie Par-Q 250 Herbicide	Sinochem International Australia Pty Ltd	Paraquat 250 g/L	1a
83170	Barmac Paraquat 250 Herbicide	Amgrow Pty Ltd	Paraquat 250 g/L	1a
84794	Agmerch Paraquat 250 SL Herbicide	Agmerch Pty Ltd	Paraquat 250 g/L	1a
85420	Hemani Paraquat 250 SL Herbicide	Hemani Australia Pty Ltd	Paraquat 250 g/L	1a
87370	Kelpie P-Quat 250 SL Herbicide	Sinochem International Australia Pty Ltd	Paraquat 250 g/L	1a
88941	Genfarm Paraquat 250 SL Herbicide	Nutrien Ag Solutions Limited	Paraquat 250 g/L	1a
89076	F.S.A. Paraquat 250 Herbicide	Four Seasons Agribusiness Pty Ltd	Paraquat 250 g/L	1a
89808	Genfarm Para 250 SL Herbicide	Nutrien Ag Solutions Limited	Paraquat 250 g/L	1a
90155	Cropsure Parashot 250 Herbicide	Cropsure Pty Ltd	Paraquat 250 g/L	1a
91098	Sanonda Paraquat 250 Herbicide	Sanonda (Australia) Pty Ltd	Paraquat 250 g/L	1a

91833	JN PARAQUAT 250 HERBICIDE	JIANGSU NOON CROP SCIENCE CO., LTD	Paraquat 250 g/L	1a
91989	Red Dog Paraquat 250 Herbicide	OZ CROP PTY LTD	Paraquat 250 g/L	1a
92586	Weed Force Dagger 250 Knockdown Herbicide	WEED FORCE PTY LTD	Paraquat 250 g/L	1a
92841	Submarino Paraquat 250 SL Herbicide	SUBMARINO PTY LTD	Paraquat 250 g/L	1a
93958	Swan Paraquat 250 Herbicide	SWAN CHEMICAL HOLDINGS PTY LTD	Paraquat 250 g/L	1a
69502	Cruze 300 Herbicide	DGL Environmental Pty Ltd	Paraquat 300 g/L	1b
70143	Farmalinx Powerquat 300 SL Herbicide	Farmalinx Pty Ltd	Paraquat 300 g/L	1b
83185	Accensi Paraquat 300 Herbicide	Accensi Pty Ltd	Paraquat 300 g/L	1b
85110	Kelpie P-Quat 300 SL Herbicide	Sinochem International Australia Pty Ltd	Paraquat 300 g/L	1b
85169	Conquest Explode 300 Plus Herbicide	Conquest Crop Protection Pty Ltd	Paraquat 300 g/L	1b
87191	4Farmers Paraquat 300 Herbicide	4 Farmers Australia Pty Ltd	Paraquat 300 g/L	1b
89981	Smart Paraquat 300 Herbicide	Crop Smart Pty Ltd	Paraquat 300 g/L	1b
90742	Agro-Essence Paraquat 300 Herbicide	Agro-Alliance (Australia) Pty Ltd	Paraquat 300 g/L	1b
87665	Spraytop 330 Herbicide	ADAMA Australia Pty Limited	Paraquat 330 g/L	1c
64430	Kenso Agcare Para-Ken 334 Herbicide	Kenso Corporation (M) Sdn. Bhd.	Paraquat 334 g/L	1d
83010	Paraquick Force 350 Herbicide	Nutrien Ag Solutions Limited	Paraquat 350 g/L	1e
68577	Gramoxone 360 Pro Herbicide	Syngenta Australia Pty Ltd	Paraquat 360 g/L	1f

83835	Rainquat Full Herbicide	Shandong Rainbow International Co Ltd	Paraquat 360 g/L	1f
86364	Genfarm Paraquat 360 Herbicide	Nutrien Ag Solutions Limited	Paraquat 360 g/L	1f
86801	Ozcrop Paraquat 360 SL Herbicide	Oz Crop Pty Ltd	Paraquat 360 g/L	1f
87228	Relyon Paraquat 360 Herbicide	Nutrien Ag Solutions Limited	Paraquat 360 g/L	1f
87259	Conquest Explode 360 Herbicide	Conquest Crop Protection Pty Ltd	Paraquat 360 g/L	1f
87271	ACP Paraquat 360 Herbicide	Australis Crop Protection Pty Ltd	Paraquat 360 g/L	1f
87424	Titan Paraquat 360 Herbicide	Titan Ag Pty Ltd	Paraquat 360 g/L	1f
89872	Relyon Paraquat 360 Herbicide	Nutrien Ag Solutions Limited	Paraquat 360 g/L	1f
91705	CropSure Parashot Plus 360 Herbicide	Cropsure Pty Ltd	Paraquat 360 g/L	1f
93182	Sabakem Paraquat 360SL Herbicide	SABAKEM PTY LTD	Paraquat 360 g/L	1f
93444	eChem Paraquat 360 Herbicide	ECHEM (AUST) PTY LIMITED	Paraquat 360 g/L	1f
94216	F.S.A. Paraquat 360 Herbicide	FOUR SEASONS AGRIBUSINESS PTY LTD	Paraquat 360 g/L	1f
Soluble concentrate (SL) formulation containing paraquat as paraquat dichloride and diquat as diquat dibromide				
46516	Spray.Seed 250 Herbicide	Syngenta Australia Pty Ltd	Diquat 115g/L paraquat 135g/L	2
58336	Halley Premier 250 Herbicide	Halley International Enterprise (Australia) Pty Ltd	Diquat 115g/L paraquat 135g/L	2
58412	Imtrade Spraykill 250 Herbicide	Imtrade Australia Pty Ltd	Diquat 115g/L paraquat 135g/L	2
58470	Conquest Scorcher 250 Herbicide	Conquest Crop Protection Pty Ltd	Diquat 115g/L paraquat 135g/L	2
58733	4Farmers Brown Out 250 Herbicide	4 Farmers Australia Pty Ltd	Diquat 115g/L paraquat 135g/L	2
59098	Spray-Plant 250 Herbicide	Sipcam Pacific Australia Pty Ltd	Diquat 115g/L paraquat 135g/L	2

59333	Kenso Agcare Speedy 250 Herbicide	Kenso Corporation (M) Sdn. Bhd.	Diquat 115g/L paraquat 135g/L	2
59878	Genfarm Di-Par 250 Herbicide	Nutrien Ag Solutions Limited	Diquat 115g/L paraquat 135g/L	2
60287	Combik 250 Herbicide	Sinon Australia Pty Limited	Diquat 115g/L paraquat 135g/L	2
61460	Alarm Herbicide	Sipcam Pacific Australia Pty Ltd	Diquat 115g/L paraquat 135g/L	2
61860	Titan Eos Herbicide	Titan Ag Pty Ltd	Diquat 115g/L paraquat 135g/L	2
62495	Sanonda Paraquat/Diquat Herbicide	Sanonda (Australia) Pty Ltd	Diquat 115g/L paraquat 135g/L	2
62631	Accensi Paraquat/Diquat 250 Herbicide	Accensi Pty Ltd	Diquat 115g/L paraquat 135g/L	2
63274	Uni-Spray 250 Herbicide	UPL Australia Pty Ltd	Diquat 115g/L paraquat 135g/L	2
63565	Ozcrop Blowout Herbicide	Oz Crop Pty Ltd	Diquat 115g/L paraquat 135g/L	2
64325	Farmalinx Paradat Herbicide	Farmalinx Pty Ltd	Diquat 115g/L paraquat 135g/L	2
64704	Fosterra Paraquat / Diquat Herbicide	Fosterra Pty Ltd	Diquat 115g/L paraquat 135g/L	2
64802	Kwicknock 250 Herbicide	Grow Choice Pty Limited	Diquat 115g/L paraquat 135g/L	2
65295	Rainbow Diqu-Para 250 Herbicide	Shandong Rainbow International Co Ltd	Diquat 115g/L paraquat 135g/L	2
65708	Pacific Diquat/Paraquat 250 Herbicide	Pacific Agriscience Pty Ltd	Diquat 115g/L paraquat 135g/L	2
66197	Unispray 250 Herbicide	UPL Australia Pty Ltd	Diquat 115g/L paraquat 135g/L	2
66327	AW Dismantle Herbicide	Agri West Pty Limited	Diquat 115g/L paraquat 135g/L	2
66788	Agro-Essence Paraquat+Diquat 250 Herbicide	Agro-Alliance (Australia) Pty Ltd	Diquat 115g/L paraquat 135g/L	2

67399	Easyfarm Paraquat-Diquat 250 Herbicide	Easyfarm Pty Ltd	Diquat 115g/L paraquat 135g/L	2
67627	Apparent Weedy Seedy 250 Herbicide	Titan Ag Pty Ltd	Diquat 115g/L paraquat 135g/L	2
67707	Smart Combination 250 Herbicide	Crop Smart Pty Ltd	Diquat 115g/L paraquat 135g/L	2
67891	Spalding Exocet 250 Herbicide	DGL Environmental Pty Ltd	Diquat 115g/L paraquat 135g/L	2
68075	Ezycrop Paraquat-Diquat 250 Herbicide	Ezycrop Pty Ltd	Diquat 115g/L paraquat 135g/L	2
68202	Novaguard Paraquat-Diquat 250 Herbicide	Novaguard Pty Ltd	Diquat 115g/L paraquat 135g/L	2
68280	Agro Burner 250 Herbicide	Agrogill Chemicals Pty Ltd	Diquat 115g/L paraquat 135g/L	2
68479	Agmate Paraquat & Diquat 250 SL Herbicide	Agcare Pty Ltd	Diquat 115g/L paraquat 135g/L	2
81790	Relyon Di-Par 250 SC Herbicide	Nutrien Ag Solutions Limited	Diquat 115g/L paraquat 135g/L	2
83169	Barmac Paraquat/Diquat 250 Herbicide	Amgrow Pty Ltd	Diquat 115g/L paraquat 135g/L	2
83923	Accensi Paraquat / Diquat Prime 250 Herbicide	Accensi Pty Ltd	Diquat 115g/L paraquat 135g/L	2
85112	Raystar Paraquat Diquat SL Herbicide	Raystar Cropprotection Pty Ltd	Diquat 115g/L paraquat 135g/L	2
89832	Genfarm Di-Par 250 SC Herbicide	Nutrien Ag Solutions Limited	Diquat 115g/L paraquat 135g/L	2
89918	Trio Paraquat Diquat 250 SL Herbicide	CTS Chemicals Pty Ltd	Diquat 115g/L paraquat 135g/L	2
90172	Cropsure Squadron 250 Herbicide	Cropsure Pty Ltd	Diquat 115g/L paraquat 135g/L	2
91135	Agmerch Paraquat 135 & Diquat 115 Herbicide	Agmerch Pty Ltd	Diquat 115g/L paraquat 135g/L	2

Soluble concentrate products containing paraquat and amitrole				
67344	Imtrade Para-Trooper Herbicide	Imtrade Australia Pty Ltd	250 g/L paraquat, 10 g/L amitrole	3a
89484	Imtrade Guerrilla Herbicide	Imtrade Australia Pty Ltd	300 g/L paraquat, 12 g/L amitrole	3b

Statutory considerations under the safety criteria – formulated products

Under section 5A of the Agvet Code, when determining whether a chemical product satisfies the safety criteria, the APVMA must (among other matters) have regard to:

- how the product is formulated
- the composition and form of the constituents of the product
- any relevant particulars entered into the register for the product.

The APVMA may have regard to:

- the stability of the product
- specifications for containers for the product.

The APVMA has previously assessed the formulation details, constituent specifications, formulation type, manufacturing process (how the product is formulated), stability and containers of each proposed product prior to registration. In the case of paraquat products, this included the requirement under the *Therapeutic Goods (Poisons Standard—February 2024) Instrument 2024* (Poisons Standard) and preceding instruments for products containing paraquat to contain a blue or green dye and sufficient stenching agent to give the product an offensive smell. Based on the information provided and assessed at the time of registration, the APVMA remains satisfied with respect to the chemistry related aspects of the safety criteria for products containing paraquat dichloride as the active constituent in relation to how the product is formulated, the composition and form of the constituents of the products and product stability. Additional excipients and manufacturing impurities from the active constituent up to the levels declared in the declarations of composition are considered acceptable and do not present any additional toxicological concern.

The APVMA was satisfied at the time of registration that containers for products, met the relevant safety criteria. However, if it is determined that products containing paraquat dichloride must be mixed and loaded using closed systems, confirmation from holders will be required to verify any variation to packaging and pack sizes.

All currently registered paraquat products are soluble concentrates. The formulation type for currently registered products should be recorded as soluble concentrate (SL) and the register corrected if required.

Recommendations

The recommendations of the chemistry assessment of paraquat are that the APVMA:

- be satisfied that the paraquat dichloride active constituents (manufacturing concentrates) with the approval numbers 69493, 87171, 89426 and 91420 continue to meet the safety criteria from a Chemistry and Manufacture perspective
- not be satisfied that the active constituents with the approval numbers 44249, 55966 meet the safety criteria as the Declaration of Composition provided for those active constituents do not list all required impurities and components for paraquat dichloride technical concentrates listed in the Agricultural Active Constituent Standards 2022 or FAO Specification for paraquat dichloride
- not be satisfied that the remaining active constituent approvals listed in Table 4 meet the safety criteria as the holders have not demonstrated that the active constituents conform to the Agricultural Active Constituents Standard 2022 or FAO Specification for paraquat dichloride
- could be satisfied that all paraquat dichloride active constituent approvals listed in Table 4 meet the safety criteria if the holders of those approvals provide an updated Declaration of Composition, or an updated Declaration of Composition and the results of 5 batch analyses, as needed, conforming to the Agricultural Active Constituents Standard 2022 and FAO Specification for paraquat dichloride to the APVMA
- be satisfied that continued registration of agricultural chemical products containing paraquat dichloride, listed in Table 5, would meet the safety criteria under section 5A of the Agvet Code from a Chemistry and Manufacture perspective. Minor corrections should be made to the recorded formulation types of some products, to ensure consistent use of terminology.

Toxicology

A large toxicology database is available for paraquat and was considered to be of sufficient breadth and quality for human health risk assessment purposes. The following toxicology section is a summary of the conclusions of the mammalian toxicology and metabolism / toxicokinetics of paraquat assessments completed by the APVMA and published by in 2016 as the [Paraquat toxicology report](https://apvma.gov.au/node/12666) available at <https://apvma.gov.au/node/12666>. An examination of the published literature since that date has not changed the overall conclusions and no additional data relevant to the assessment of the toxicology of paraquat has been submitted to the APVMA since the publication of that report.

Evaluation of toxicology

Biochemical aspects

Paraquat is poorly absorbed following oral dosing in the rat, with only 10 to 18% of an oral dose absorbed. Following absorption, paraquat is widely distributed, with highest initial concentrations in the kidneys and lungs, however, is not extensively metabolised. In rats, more than half of the administered dose is excreted in the faeces (60 – 70%), with smaller amounts (10 – 20%) in the urine. While almost half of the administered dose was excreted within 48 hours of dosing, measurable amounts were detected for up to 21 days after dosing. In rats, the dose, frequency of dosing or sex of study animals did not result in major differences in absorption, distribution or excretion. The active uptake system indicates a potential for accumulation in the rat or rabbit lung.

In vitro studies conducted on the manufacturing concentrate revealed that absorption across rabbit skin was approximately 1% over 10 h, and 2.5% over 55 h for human skin. In addition, human skin was found to be at least 40 times less permeable than animal skin tested in vitro (including rat, mouse, rabbit and guinea-pig). A single in vivo study conducted in male volunteers determined that approximately 0.3% of an applied dose was absorbed over 120 h.

Percutaneous absorption of paraquat in rats ranged from 0.003-16.54% of the applied dose and was approximately proportional to the amount applied. Human skin or isolated epidermis showed lower levels of absorption (0.0001-1.43%) and was also proportional to the amount of paraquat applied. In most studies, absorption rates were higher after 10-12 hours of administration, possibly due to tissue degradation. Although the composition of these formulations was largely unknown, a number of studies indicated that the presence of diquat had no effect on percutaneous paraquat absorption.

Major toxicological mode(s) of action and key events

The mechanism of mammalian toxicity of paraquat is via the generation of highly reactive free radicals and consequent peroxidation of membrane lipids, sulfhydryl groups, proteins and DNA, leading to membrane damage and cell death.

Acute toxicity

The acute oral toxicity of paraquat is moderate in rodents (LD50 from 100 – 249 mg/kg bw) (Kimbrough & Gaines, 1970; Duerden, 1994b), and high in guinea pigs, rabbits, dogs and monkeys (LD50=22, 40-50 and 50 mg/kg bw,

respectively) (Murray & Gibson, 1972; Farnworth et al, 1993). A range of clinical signs have been observed in laboratory animals following acute oral exposures including hypoactivity, dehydration, hypothermia, irregular breathing, reduced faecal output, piloerection, staining around the mouth and upward curvature of the spine.

In rats, the acute dermal toxicity of paraquat is low (LD50 > 1448 mg/kg bw) (Duerden, 1994c) and the acute inhalational toxicity extremely high (LC50 = 0.5 mg/m³, whole body exposure, 4-h) ((Hathaway, 1966). The most concentrated aqueous solution of paraquat (33% paraquat cation, w/w) was a severe eye irritant in rabbits (Bugg & Duerden, 1994). A 28.6% (w/w) paraquat solution was a moderate to severe skin irritant in rabbits when tested undiluted or up to 1:25 (v/v) dilution, but a slight irritant from dilutions of 1:50 (Bullock, 1983). Paraquat was not a skin sensitiser in guinea pigs. (Thompson et al, 1985).

Acute toxicity in humans

In humans, following oral exposure, vomiting, abdominal pain, nausea, diarrhoea, ulceration of the oral and/or pharyngeal mucosa and gastrointestinal tract, irritability, dyspnoea, and tachycardia have been observed. In humans, there have been relatively few cases of fatality due to dermal paraquat exposure, although it appears that toxicologically-significant absorption can occur via damaged skin or sensitive skin areas such as the scrotum. Five fatalities were reported in Papua New Guinea as a result of occupational accidents or off-label use (to treat head lice or scabies). Exposure in these cases was via several routes including the skin of the scrotum, back, thighs, scalp, head, face or nose, although in at least one case, oral ingestion was strongly indicated due to ulceration in the mouth and throat. Similar case reports have involved exposure of the scrotum resulting in pulmonary fibrosis, renal and respiratory failure, with eventual recovery of the patients. Other human poisoning cases reported systemic toxicity and death following absorption through scratches and cutaneous lesions (including skin blisters) on the arms and legs.

Most occupational studies have shown that clinical signs or death due to repeated dermal exposure to paraquat are rare. In an occupational setting, the major manifestation of dermal paraquat toxicity appears to be localised skin reactions, rashes, burns and dermatitis at the exposure site/s.

Repeat dose toxicity

In numerous repeat-dose studies, the toxicological effects of paraquat were dose-related and appeared to be independent of sex, dosing route or duration. Dogs were the most sensitive test species followed by rodents and rabbits. Pulmonary toxicity was the predominant feature of repeated paraquat exposure, while renal damage can also occur. Gastrointestinal effects, including irritation, mucosal erosion or ulceration were observed in some rat and rabbit studies following oral dosing. At high enough oral doses (~20 mg/kg bw/d in rodents, ~1 mg/kg bw/d in dogs) decreased body weight gain, clinical signs (ataxia, laboured or rapid breathing, general malaise, lethargy, piloerection, weight loss) and mortalities eventuated.

Pulmonary toxicity

Localised tissue damage was apparent following inhalational or dermal exposure. Short-term inhalational studies conducted in rats revealed damage to the airways and throat, manifesting as metaplasia and/or hyperplasia of the epiglottis and arytenoid projections, and ulceration/necrosis and acute inflammatory cell infiltration in the larynx. Lung damage including loss of cilia and clara cells and the presence of mucous, debris or inflammatory cell infiltrates were also detected.

The types of gross and histopathological lung abnormalities observed in laboratory animals included alveolitis, alveolar wall thickening, congestion, collapse, fibrosis, haemorrhage, macrophage or lymphocyte infiltration, necrosis, oedema, the presence of inflammatory or congestive lesions of various size (a few mm to involvement of most of the lung) and colour (dark red, brown grey or black), and increased lung weight.

Renal toxicity

Paraquat-induced renal toxicity was observed, including by the occurrence of congestion, tubular degeneration, hydronephrosis and the urinary shedding of renal cells. Renal function was adversely affected, as shown by the elevation in plasma urea and creatinine, and urinary glucose, protein and albumin. Several studies also showed elevations in haematocrit (Hct) and erythrocyte counts (RBC) which were probably the result of decreased plasma volume due to dehydration.

Ocular toxicity

Ocular abnormalities, including retinal engorgement, were detected in dogs at doses from 0.175 – 3 mg/kg bw/day, but were not seen at lower doses (up to 1.25 mg/kg bw/day). In rats, opacity and cataracts were observed at and above 3.75 mg/kg bw/day, and lenticular degeneration at and above 1.25 mg/kg bw/day. These studies suggest that relatively high oral doses of paraquat can lead to ocular abnormalities in rats and dogs, however the mechanism of their formation has not been further elucidated.

Genetic toxicology

There was limited activity in mutagenicity studies. While there were occasional findings of clastogenicity, the weight of evidence indicates that paraquat is non-mutagenic.

Carcinogenicity

Long-term feeding studies in mice and rats revealed no evidence that paraquat was carcinogenic.

Reproduction studies

There was no evidence that paraquat caused reproductive toxicity in rats following dietary administration at up to 14.5 mg/kg bw/day, doses which produced systemic toxicity in parental animals. Signs of toxicity included lung lesions, decreased food consumption and body weight. Offspring showed decreased body weight in addition to hydrourethrosis or perivascular inflammatory cell infiltration in the lungs.

Dermal treatment of male rats at doses up to 30 mg/kg bw/day showed weak cytotoxic effects on epididymal sperm and late spermatids. No dose-response was observed, and the significance of this effect are questionable in the absence of demonstrated effects on male fertility in reproduction studies.

Developmental studies

Studies in mice, rats and rabbits did not show evidence that paraquat had potential to adversely affect development. Maternotoxic doses produced minor effects such as delayed or incomplete ossifications, reduced foetal weights and viability, and, in one rabbit study, post-implantation losses. No observed adverse effect levels

were 1 mg/kg bw/day for maternal toxicity and foetal effects in rats and rabbits, while in mice the foetal NOAEL was slightly higher.

In humans, following deliberate ingestion paraquat crossed the placenta, and was found in higher levels in foetal tissue than in maternal plasma. At maternally fatal doses, all foetuses died, while in 2 surviving women the pregnancy proceeded normally with no evidence of teratogenicity.

Special studies

Neurotoxicity

The APVMA completed an assessment of the potential for neurotoxicity mediated by paraquat and published these findings in detail in 2016 in the report [Paraquat toxicology report – supplement II neurotoxicology](#). The following summarises the key findings of that report.

The standard toxicological database contains a range of acute, short-term repeat-dose, subchronic and chronic laboratory studies which do not report any evidence of neurotoxicity in rodents, rabbits, or dogs, including any clinical signs (consistent with a proposed neurotoxicant) or neuropathy under the standard suite of pathology tests.

Paraquat is structurally similar to the known dopaminergic neurotoxicant 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP). For this reason, it has been investigated as a possible etiological agent in Parkinson's disease. Numerous published and unpublished studies have been assessed, including highly specialised techniques to examine effects, if any, on brain dopaminergic neurons (those neurones that degenerate in Parkinson's disease). Some studies demonstrated that repeat-dose intraperitoneal and/or subcutaneous administration of paraquat (typically 10 mg/kg bw or higher per dose, weekly for 3, 4 or 24 weeks) to mice or rats, causes the selective apoptotic loss of nigrostriatal dopaminergic neurons.

However, more recent, well-conducted studies failed to reproduce these findings in mice by either oral or intraperitoneal administration. No effects were found on the substantia nigra (SN), including the number of tyrosine hydroxylase (TH+) cells or neurotransmitter levels, casting doubt on the reliability of earlier studies. In particular, some of the original studies reporting a positive association have since been withdrawn due to fraudulent reporting of results.

With regard to a link between paraquat exposure and Parkinson's disease, in vitro and in vivo studies in animals, although supporting a mechanism of toxicity involving intracellular oxidative stress, do not support a mechanism of neurotoxicity consistent with MPTP and the known mode of action associated with Parkinsonism. Neurotoxicity findings in intraperitoneal and subcutaneous studies are not supported by findings in oral studies. Although limited evidence of neurotoxicity was reported from an oral study in neonatal rats, where paraquat was shown to cross the blood brain barrier, pathological damage to neurons was not seen in any oral studies.

Taking into consideration the available database of animal studies, including all studies carried out to OECD guidelines, the overwhelming weight-of-evidence, is that paraquat does not induce neurotoxicity via the oral, dermal or intranasal exposure routes; routes that are of relevance to human exposure to this pesticide.

Human studies

Occupational exposure

Localised skin reactions and damage resulting from unintentional exposure have been reported in overseas workers, typically associated with poor work practices, including faulty equipment and/or the lack of suitable protective equipment.

Epidemiology studies have investigated a possible link between paraquat and an increased risk of developing Parkinson's disease. Contemporary studies do not indicate a robust association between adverse health effects and exposure to pesticides. A retrospective worker cohort study did not indicate any evidence of an increased risk of Parkinson's disease in paraquat production facilities, with moderate to high levels of exposure to paraquat. It is concluded that the available epidemiology data is insufficient to conclude any association between paraquat exposure and neurotoxicity (including Parkinson's disease) in the occupational environment.

Poisoning incidents

Deliberate ingestion of commercial paraquat products has resulted in a large number of human poisonings in many parts of the world. Limited data is available in Australia on paraquat poisonings, as these are generally classified under more generic categories (such as herbicide or weed killer). There are currently no effective antidotes or treatment regimes, and treatment is supportive, including gastric lavage, haemodialysis or haemoperfusion. A reliable indicator of the likelihood of survival following poisoning appears to be the dose, as well as how quickly treatment is initiated after exposure.

Health-based guidance values

The points of departure established in the Human Health Risk Assessment (APVMA 2016 (a)) are detailed in Table 6.

Table 6: Points of Departure for Human Health Risk Assessment

Study type		Key effect	Point of departure	Reference
Repeat dose exposure				
Short term oral exposure	28 day oral (dietary) repeat dose; mouse)	Histopathological lung abnormalities (alveolar wall thickening, congestion and oedema	NOEL not established LOEL 15 mg/kg bw/day	Sotheran <i>et al</i> (1979)

Study type		Key effect	Point of departure	Reference
	28 day oral (dietary) repeat dose; rat)	Decrease body weight gain, decreased food consumption, histopathological lung abnormalities (alveolar wall thickening, congestion and oedema	NOEL – not established LOEL – 15 mg/kg bw/day	Hodge <i>et al</i> (1980)
Intermediate term oral exposure	13 week dietary repeat dose, mouse	Macroscopic and histopathological lung abnormalities,	NOEL – 11.5 mg/kg bw/day (males)	Maita & Saito (1980)
	13 week dietary repeat dose, rat (adult)	Lung abnormalities (alveolar epithelial hypertrophy in males) and splenic abnormalities (in females	NOEL – 6.6 mg/kg bw/day (males)	Maita <i>et al</i> (1980)
	13 week dietary repeat dose, dog	Macroscopic lung lesions and histopathological signs of alveolitis	NOEL – 0.5 mg/kg bw/day	Sheppard (1981(b))
	1 year dietary repeat dose, dog	Pulmonary lesions associated with chronic pneumonitis	NOEL – 0.45 mg/kg bw/day	Kalinowski <i>et al</i> 1983(a, b)
Long term oral exposure	2 year oral (dietary repeat dose; rat (adult)	Ocular lesions	NOEL – not established LOEL – 1.25 mg/kg bw/day	Woolsgrove, 1983; Ashby & Finn, 1983; Ishmael & Godley, 1983; Brown & Whitney, 1984; Woolsgrove & Ashby, 1985; Life Sci Res Inst, 1984; Ishmael, 1987
Reproduction and development				
Reproduction	Three-generation reproduction study; rat	Parents: increase in incidence and severity of focal alveolar histiocytosis Offspring: perivascular inflammatory cell infiltration	Parental: NOAEL 1.25 mg/kg bw/day Offspring: NOAEL 7.5 mg/kg bw/day	Lindsay <i>et al</i> (1982 (a,b))

Study type		Key effect	Point of departure	Reference
Development				
Maternal toxicity	Developmental toxicity study; rat, rabbit	Mortality, reduced body weight gain	NOEL – 1 mg/kg bw/day	Hodge <i>et al</i> , 1978
Foetal development	Developmental toxicity study; rabbit	Delayed ossification with increased incidence of developmental variations	NOEL – 1 mg/kg bw/day	Tinston 1991(a,b,c)

Based on the evaluation of the available toxicological database the current APVMA acceptable daily intake (ADI; shown in Table 7) and acute reference dose (ARfD; shown in Table 8) will be retained, however changes have been made to the text used to define the ARfD in the Human Health Risk Assessment (APVMA 2016 (a)), these are included in Table 8.

Table 7: Acceptable daily intake for paraquat

Chemical	ADI mg/kg bw/day	NOEL	Date	Study	Comments
Paraquat	0.004	0.45	27 June 2003	1-year dietary dog study; a NOAEL of 0.45 mg/kg bw/d was based on pulmonary lesions at the next higher dose.	Acceptable margin of exposure \geq 100.

Table 8: Acute reference dose for paraquat

Chemical	ARfD mg/kg bw/day	NOEL	Date	Study	Comments
Paraquat	0.004	0.45	27 June 2003	One-year chronic feeding dog study; a NOAEL of 0.45 mg/kg bw/d was based on the likelihood that the observed pulmonary lesions would also occur after an acute exposure at the next higher dose.	

Poisons scheduling

Paraquat is currently included in Schedule 7 of the Standard for the Uniform Scheduling of Medicines and Poisons (SUSMP). In recognition of the significant toxicity of paraquat, in addition to the signal heading “DANGEROUS POISON”, aqueous solutions of paraquat must also bear the cautionary statements:

CAN KILL IF SWALLOWED
DO NOT PUT IN DRINK BOTTLES
KEEP LOCKED UP

These statements must be printed on separate lines immediately below the cautionary statement “KEEP OUT OF REACH OF CHILDREN”. The SUSMP also requires that liquid preparations of paraquat must be coloured blue or green and must contain sufficient stenching agent to produce an offensive smell.

No changes to the current poisons scheduling are required.

Recommendations

The toxicological component of the Review Technical Report considered the hazards identified in acute, short-term, chronic, reproduction and developmental toxicity studies, genotoxicity, carcinogenicity and neurotoxicity studies of paraquat.

The paraquat toxicology component of the Review Technical Report concluded that:

- the acceptable daily intake (ADI) for paraquat should remain at 0.004 mg per kilogram body weight per day based on a no observed adverse effect level of 0.45 mg/kg bw/day in a one-year dog dietary study, based on pulmonary lesions at the next higher dose. The ADI incorporates a 100-fold uncertainty factor to account for inter- and intra-species variation in sensitivity
- the acute reference dose (ARfD) for paraquat should remain at 0.004 mg of paraquat per kg body weight based on a no observed adverse effect level of 0.45 mg per kilogram body weight in a dog dietary study, considering that pulmonary lesions would also occur after an acute exposure at the next higher dose. The ARfD incorporates a 100-fold uncertainty factor to account for inter- and intra-species variation in sensitivity
- that the scheduling for paraquat in the Standard for the Uniform Scheduling of Medicines and Poisons remain unchanged.

Provided conditions of registration and label instructions are followed, the active constituents and registration of products containing paraquat:

- would not be an undue health hazard to the safety of people exposed to it during its handling or people using anything containing its residues
- would not be likely to have an effect that is harmful to human beings

Worker health and safety

Worker exposure assessment

This exposure assessment and risk characterisations includes professional workers who mix, load and apply paraquat and combination products and professional workers who re-enter treated areas.

For exposure during mixing, loading and application, the current assessment has utilised the US EPA Office of Pesticide Programs Occupational Handler Exposure Unit Surrogate Exposure Reference Table (US EPA, 2021(a)). For exposure associated with re-entry into pesticide treated area, the current assessment has utilised the US EPA Occupational Pesticide Post-application Exposure Data and calculator (US EPA, 2021(b)).

The following assumptions have been used in the exposure modelling (see Table 9). Application by aircraft has not been assessed, as this use is not supported on currently approved labels.

Table 9: Assumptions used in modelling exposure for professional use of paraquat

Parameter	Value
Point of departure for risk assessment	0.045 mg/kg bw/day (based on NOAEL of 0.45 mg/kg bw/day and a 10% oral availability)
Acceptable margin of exposure (MOE)	100*
Body weight (adult)	80 kg
Body weight (child)	1 to 2 y: 11 kg 2 to 3 y: 15 kg
Dermal absorption factor	0.3%
Inhalation absorption factor	100%
Groundboom field application (most crops)	60 to 600 ha/day
Groundboom field application (cotton)	600 ha/day
Groundboom field application (broadacre uses)	600 ha/day
Backpack application (mixer, loader, applicator)	150 L dilute product/day
Manually pressurised hand wand application	150 L dilute product/day
Mechanically pressurised hand wand application	150 L dilute product/day

* As a NOAEL from an animal study was used to estimate risks, an acceptable MOE ≥ 100 was considered acceptable. This value is based on a 10-fold uncertainty factor (UF) for intra-species and 10-fold UF for inter-species differences.

The exposure assessments and risk characterisations for professional use of paraquat also rely upon a further series of reasonable assumptions, notably that professional users:

- are trained in accurate mixing, loading and application methods
- are trained in, and are competent and experienced users of, personal protective equipment and relevant application techniques and equipment
- have a high level of compliance with label directions, including label-specified application rates and the use of personal protective equipment specified on product labels
- wear long-sleeved shirt, long pants, shoes and socks or an equivalent single layer of clothing when using paraquat, in addition to any personal protective equipment specified on product labels.

Ground-based application

The outcomes for the exposure risk assessments for the professional use of paraquat in agricultural situations using ground-based application equipment are set out in Table 10 and Table 11. Modelling for ground-based application assumed that all steps in the use of paraquat products are performed by a single operator (i.e. a single operator mixes, loads and applies the pesticide) and that there was only one type of use or activity performed per operator per day. Modelling for re-entry activities (8-hour days) assessed worker exposure via dermal exposure, as inhalation exposure under these circumstances were regarded as negligible. It is noted that the calculated re-entry intervals are not required when crops are treated at the bare soil or pre-emergent stage. The application rates supported by the environmental risk assessment are significantly lower than the maximum label rates considered in the assessment for the exposure to workers. Based on the maximum acceptable quantities which it would be acceptable to be used by a worker per day, noted in Table 10 and Table 11 below, the area that could be treated exceeds the area assumed in the modelling. Therefore, restrictions on the maximum quantity of active constituent that may be handled per day are not considered necessary.

Table 10: Risk assessment outcomes for liquid paraquat products

Activity	Scale of use assessed	Minimum acceptable Personal Protective Equipment (PPE) ²	Use acceptable (Yes/No/Restricted)
Ground boom application mix, load, and apply (a single operator mixes, loads and applies)	Small scale agriculture (up to 6 ha/day)	Open cab Single layer Gloves PF10 respirator Face shield or goggles when mixing and loading	Yes
	Broad scale agriculture (up to 600 ha/day)	Enclosed cab application Enclosed mixing and loading (single layer of clothing, gloves, PF10 respirator, face shield or goggles when connecting, disconnecting or cleaning components of the mixing and loading system)	Yes Maximum acceptable handling rate of 337 kg of paraquat per operator per day

² Note that although mixer/loader exposure is acceptable with open mixing/loading with the specified PPE for certain uses, closed mixing/loading is proposed for all uses to minimise the likelihood of decanting into unacceptable containers which may lead to consequential accidental exposure.

Activity	Scale of use assessed	Minimum acceptable Personal Protective Equipment (PPE) 2	Use acceptable (Yes/No/Restricted)
Backpack sprayer (a single operator mixes, loads and applies)	150 L/day	Single layer Gloves PF10 respirator Face shield or goggles when mixing and loading	No Maximum acceptable handling rate of 0.2 kg of paraquat per operator per day
Manually pressurised hand wand application (a single operator mixes, loads and applies)	150 L/day	Single layer Gloves PF10 respirator Face shield or goggles when mixing and loading	Yes Maximum acceptable handling rate of ≤ 4.5 kg of paraquat per operator per day
Mechanically pressurised hand wand application (a single operator mixes, loads and applies)	150 L/day	Single layer Gloves PF10 respirator Face shield or goggles when mixing and loading	Yes Maximum acceptable handling rate of ≤ 2.3 kg paraquat per operator per day

Table 11: Risk assessment outcomes for liquid paraquat plus diquat products

Activity	Scale of Use	Minimum acceptable Personal Protective Equipment (PPE) 3	Use Acceptable (Yes/No/Restricted)
Ground boom application mix, load and apply (a single operator mixes, loads and applies)	Small scale agriculture (up to 6 ha/day)	Open cab Single layer Gloves PF10 respirator Face shield or goggles when mixing or loading	Yes
	Broad scale agriculture (up to 600 ha/day)	Enclosed cab application Enclosed mixing and loading (single layer of clothing, gloves, PF10 respirator, face shield or goggles when connecting, disconnecting or cleaning components of the mixing and loading system)	Yes Maximum acceptable handling rate of 337 kg of paraquat per operator per day
Backpack sprayer (a single operator mixes, loads and applies)	150 L/day	Single layer Gloves PF10 respirator Face shield or goggles when mixing and loading	No* Maximum acceptable handling rate of 0.2 kg of paraquat per operator per day

³ Note that although mixer/loader exposure is acceptable with open mixing/loading with the specified PPE for certain uses, closed mixing/loading is proposed across all uses to minimise the likelihood of decanting into unacceptable containers which may lead to consequential accidental exposure.

Activity	Scale of Use	Minimum acceptable Personal Protective Equipment (PPE) 3	Use Acceptable (Yes/No/Restricted)
Manually pressurised hand wand application (a single operator mixes, loads and applies)	150 L/day	Single layer Gloves PF10 respirator Face shield or goggles when mixing and loading	Yes Maximum acceptable handling rate of ≤ 4.5 kg of paraquat per operator per day
Mechanically pressurised hand wand application (a single operator mixes, loads and applies)	150 L/day	Single layer Gloves PF10 respirator Face shield or goggles when mixing and loading	Yes Maximum acceptable handling rate of ≤ 1.5 kg diquat per operator per day

*operator exposure for backpack use of combined paraquat and diquat products was not re-calculated as exposure to paraquat alone was not acceptable in any scenario

Re-entry to treated areas

Based on the acute hazards associated with exposure to paraquat and diquat, treated areas should not be entered until the spray has dried, except in a closed cab.

At the maximum application rates on currently approved paraquat and diquat labels, entry into treated areas without gloves requires a 24 day re-entry period for paraquat products and a 17 day re-entry period for paraquat + diquat products. Respective entry periods wearing gloves are 2 days and 0 days respectively. However, the re-entry periods can be refined considering the significantly lower application rates that are supported by the environment risk assessment (below). The re-entry exposure resulting from uses of paraquat formulations at up to 231 g paraquat/ha or uses of combined paraquat/diquat formulations at up to 175 g paraquat + diquat/ha the requires re-entry periods as follows:

- Paraquat: Re-entry for scouting and irrigation: once spray has dried (day 0), and for ploughing, tilling, levelling, planting and mechanical harvesting: day 3
- Combined paraquat/diquat: once spray has dried for all activities

Recommended label changes

The following changes to labels for products containing paraquat, or paraquat and diquat, are recommended to be applied as relevant to the use patterns that remain supported by all risk assessment outcomes.

Signal headings

All concentrations and formulations of paraquat are classified as a Schedule 7 poison. Additional labelling statements are required for paraquat, and the signal heading must read:

DANGEROUS POISON
KEEP OUT OF REACH OF CHILDREN
CAN KILL IF SWALLOWED

DO NOT PUT IN DRINK BOTTLES
KEEP LOCKED UP

The Poisons Standard also stipulates that paraquat products must be coloured blue or green and contain sufficient stenching agent to produce an offensive smell.

Restraints:

General Restraints

DO NOT remove contents except for immediate use.

DO NOT apply by spraying equipment carried on the back of the user.

DO NOT continue to use if eye irritation or bleeding from the nose occurs.

DO NOT use open mixing/loading equipment. Closed mixing and loading MUST be used.

Restraints for specific uses

For broadacre boom spray applications:

DO NOT apply using open cab equipment. Enclosed cab application MUST be used.

For small scale agriculture (up to 6 ha per day)

DO NOT apply using open cab equipment unless using a PF10 respirator

For hand spray applications

DO NOT use hand wand sprays by spraying out of the window of a vehicle.

First aid statements (all products)

If poisoning occurs, get to a doctor or hospital quickly. If sprayed on skin, wash thoroughly. If sprayed in mouth, rinse mouth with water. If in eyes, hold eyes open, flood with water for at least 15 minutes and see a doctor.

Safety Directions (all products)

Very dangerous, particularly the concentrate. DO NOT swallow. The product, particularly the concentrate, can kill if swallowed, absorbed through the eyes, or absorbed by skin contact. The liquid can cause burns particularly to the eyes. Will irritate the nose, throat, and skin. When handling, DO NOT touch or rub eyes, nose or mouth with hand. Avoid contact with eyes and skin, open wounds, and clothing. Protect eyes while using. If clothing becomes contaminated with product or with wet spray remove clothing immediately. DO NOT inhale spray mist. DO NOT allow children to play with containers or any equipment that is used. When connecting, disconnecting and cleaning equipment wear cotton overalls buttoned to the neck and wrist (or equivalent clothing) and a washable hat, impervious footwear, elbow-length chemical resistant gloves and a full face respirator with canister specified for paraquat/diquat OR half face-piece respirator with canister specified for paraquat/diquat and face shield or

goggles. When applying by low (manual pressurised) or high (mechanically pressurised) hand wand wear cotton overalls, over normal clothing, buttoned to the neck and wrist and a washable hat, impervious footwear and a full face piece respirator with a canister specified for paraquat/diquat. After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water. After each days use wash gloves, face shield or goggles, respirator (and if rubber wash with detergent and warm water), clothing and footwear

Re-entry statements for paraquat products

DO NOT allow entry to treated areas until the spray has dried except in an enclosed cab. DO NOT allow entry to the treated area for scouting and irrigation until the spray has dried (day 0), and for ploughing, tilling, levelling, planting, and mechanical harvesting for 2 days.

Re-entry statements for paraquat and diquat combination products

DO NOT allow entry to treated areas until the spray has dried.

Residues and Trade

This residues assessment is completed as part of the paraquat reconsideration to determine if the current registered uses of paraquat are supported by residues data and continue to meet the statutory safety and trade criteria.

Metabolism

Metabolism data for plants, laboratory and food animals were considered.

Studies in plants (lettuce, carrot, potato, soybean and sugar cane) demonstrated that the dominant residue in plant material was parent paraquat (Slade, 1965; Calderbank and Slade, 1966; Slade and Bell, 1966; Slade, 1966(a,b); WHO, 1984). Pre-emergent use of paraquat at 14.3 – 14.7 kg ac/ha (greater than 20 times the maximum Australian label rate) produced residues in root and leafy vegetables less than the LOQ of analytical methods (Grout, 1994(a)). When paraquat was applied as a desiccant to potato and soy beans at 8.2 – 8.8 kg ac/ha, the predominant component in potato tuber, soy beans and soy foliage was paraquat (Grout, 1994(b); Grout, 1996). On foliage, a photodegradation product, N-methyl isonicotinic acid (MINA), also known as 4-Carboxy-1-methyl pyridinium ion (CMP) in older literature, is seen at low concentrations (0.3% TRR). Use as a desiccant on potatoes at 8.7-8.8 or 1.1 kg ac/ha (10 and 1.6 times maximum label rate) produced paraquat residues in tubers of 0.08 and 0.06 mg/kg (Slade, 1966(a,b)).

Animal metabolism studies in rat, pig, sheep, lactating cow, lactating goat and the laying hen found that only small amounts of paraquat are absorbed from the gastrointestinal tract (GIT) and that there is minimal metabolism of the absorbed paraquat (Lythgoe and Howard, 1995(a, b, c); Hendley et al, 1976(a,b); MacPherson, 1995; Oliver and Hemingway, 1974(a,b)). Some studies failed to show the presence of any metabolites after oral administration of paraquat (Calderbank and McKenna, 1966, Stevens and Walley, 1965, 1966; Stevens et al, 1965; Daniel, 1971), while others have shown a small degree of metabolism (Hemmingway et al, 1972; Leahey et al, 1976, Spinks et al, 1976). Paraquat is excreted rapidly and largely unchanged, the large majority in the faeces (50.3% in goats) and a small amount in the urine (2.4% in goats) (Hendley et al, 1976). Residual radioactivity was primarily found in the liver (0.56 mg eq/kg in goat) and kidneys (0.74 mg eq/kg in goat)(Hendley et al, 1976(a)). Little paraquat was seen in muscle, fat, milk and eggs and even in studies conducted at exaggerated rates, residues in these tissues were less than 0.05 mg/kg (Slade, 1973; Leahey, 1975).

Analytical methods and storage stability

Analytical methods

Paraquat has been registered for many years and many analytical methods have been used for measuring residues of paraquat in plant and animal samples. Because paraquat is subject to limited metabolism in plants and animals, all the submitted methods are for determining paraquat only. These methods involve acid extraction of paraquat (not for liquid samples), filtration and clean-up by cation-exchange chromatography from which paraquat was eluted with saturated ammonium chloride. Some methods further involve conversion of paraquat to its coloured free radical form using 0.2% (w/v) sodium dithionite in 0.3 M NaOH and spectrophotometric measurement. Other methods determine paraquat in the “cleaned up” sample solution by reverse phase ion pair HPLC with UV detection at 258 nm.

Method RAM 272/02 for plant samples (Anderson and Boseley, 1995, 1997) and Method RAM 004/07 for animal samples (Anderson, 1994; Coombe, 1994; Anderson, 1997) were found to be suitable for the quantification of paraquat in plant and animal commodities. These methods were fully validated, include confirmatory techniques and recoveries were generally within acceptable limits (70-110%). The Limits of Quantification (LOQs) of these methods ranged from 0.01 to 0.05 mg/kg for plant commodities, except for straw for which the LOQ was up to 0.1 mg/kg and for oil cake, for which the LOQ was 0.5 mg/kg. For animal commodities the LOQs ranged from 0.005 – 0.01 mg/kg.

Stability of pesticide residues in stored analytical samples

Data were presented for stability of paraquat residues in carrot, cabbage, tomato, potato, banana, prune, wheat, corn, corn fodder, corn forage, corn silage, birdsfoot trefoil (forage and hay), coffee beans, milk, hen muscle and eggs that demonstrated that paraquat was stable when stored frozen at –15°C to –18°C (Earl et al, 1989(a); Roper, 1989a; Anderson, 1995; Coombe, 1995; .

Data on tomato, potato, prune and corn were 12 month studies (Roper, 1989(b,c,d,e,f,g,h), however the Joint FAO/WHO Meeting on Pesticide Residues (JMPR, 2004) evaluated 24 month storage data on the same commodities and found that the residues were stable with frozen storage for 24 months. Residues in cabbages and carrots were stable for 45 months. Residues in bananas and coffee beans were stable for 12 months, while residues in wheat were stable for 24 months. Studies with birdsfoot trefoil forage and hay were conducted over 25 weeks and demonstrated stability of incurred residues.

Stability studies demonstrated that paraquat residues were stable in chicken meat for 28 months, eggs for 29 months and milk for 13 months (Earl and Boseley, 1988(a, b); Anderson et al, 1991(a,b); Coombe, 1995).

Residue studies submitted for evaluation had stored samples under appropriate temperatures and time periods.

Residue definition

Due to little metabolism of paraquat in plants and animals, paraquat cation can be considered as the most appropriate residue definition for enforcement and risk assessment. This is consistent with the residue definition established overseas (see also the [Trade](#) section).

Residues in foods

The paraquat product labels have broad crop groupings for use patterns such as row crops, vegetables, market gardens and orchards. Paraquat, by virtue of its broad use pattern has lent itself to very general commodity groupings in the MRL standard such as fruits and vegetables.

The current best practice is to approve label claims and establish MRLs based on the APVMA crop group guidance⁴ and Codex Alimentarius (Codex) commodity groups. Therefore, it is appropriate that the current MRLs for fruits and vegetables and use patterns on labels reflect the appropriate crop groups and be reconsidered separately as part of this review.

The current practice is to support label claims and establish MRLs for commodity groups aligned with the Codex Commodity groups established by the FAO/WHO Codex Committee on Pesticide Residues (CCPR) and current [APVMA crop group guidelines](#). Therefore, the current MRLs for fruits and vegetables and the expression of these crops on labels are being considered as part of this residues review.

Plant commodities

The use of paraquat can be broadly ascribed to 4 general categories:

- Pre-emergent or pre-sowing application
- Post-emergent directed application
- Post-emergent over the top spraying
- Pre-harvest desiccant application

These generalised use patterns have different residue potentials. The first 2, under most circumstances are expected to produce negligible residues in food commodities at commercial maturity. Post-emergent spraying of the crop may produce residues, but they would generally be expected to be lower than those seen with pre-harvest desiccant uses that have very short withholding periods (WHPs).

Pre-emergent and pre-sowing use

Label rates for pre-emergent, pre-sowing or pre-planting application of paraquat range from 0.4 to 0.6 kg ac/ha, with exception of the pre-emergent use in rice which involves a rate of 0.2 kg ac/ha. The general crop groupings that have these uses on the label include: cereals; pulses; oilseeds; pasture; row crops; vegetables; market gardens and nurseries. Specific crops included on labels are: potato; rice and sugar cane.

Metabolism studies and residues trials, some at exaggerated application rates (up to 14.7 kg ac/ha or 20× the maximum label rate), have demonstrated non detectable residues in a large variety of crops and crop groups treated with pre-emergent or pre-sowing applications of paraquat (Grout, 1994) which indicates that residues in crops where paraquat has been applied as a pre-emergent or pre-sowing treatment would be expected to be less than the LOQ.

Post-emergent directed use

Directed applications of paraquat to weeds between rows of plants in orchards and vineyards, hops or produce in market gardens are unlikely to result in significant pesticide contact with produce being grown for human consumption. Metabolism studies and residue trials at rates in excess of Australian label rates demonstrated that

⁴ APVMA [crop group guidance](#), available on APVMA website.

residues will be non-detectable in a large variety of fruits and vegetables after directed inter-row spraying of paraquat. In orchard trials where residues have been detected, the method of application has been deliberate application to lower branches close to harvest, picking fallen fruit off recently sprayed ground or directly spraying fruit on the ground.

Use rates for post-harvest directed spraying in orchards (including walnuts) and vineyards are up to 0.8 kg ac/ha, for market gardens are up to 0.6 kg ac/ha and for hops are 0.4 kg ac/ha. The WHPs for these uses on current labels are 'Not Required when used as directed'.

Post-emergent over the top spraying

Post emergence uses of direct spraying of crops are approved for sugar cane and pasture. In pasture residue trials have shown high residues at application rates up to 0.6 kg ac/ha.

Australian labels have pre-harvest desiccation uses for potatoes and cotton and uses on pulses (chickpeas, faba beans, field peas, lentils, lupins and vetch) for reduction of seed set of annual ryegrass. Pre-harvest application for desiccation or reduction of seed set can be expected to produce significant residues in crops. Overseas, pre-harvest desiccation uses are also seen on some cereals, oilseeds, pulses and some other vegetables, but these uses are not on Australian paraquat product labels.

Fruit crops

The current MRL for fruit crops, listed as 'Fruits {except Olives}' is *0.05 mg/kg and includes all fruits on the labels from orchards (including bananas and vineyards) to market gardens and row crops and tropical fruits (avocado, custard apple, litchi and mango). In this assessment, separate MRLs for each of the codex groupings of fruits are proposed.

Pome fruit

The maximum Australian label rate is up to 0.8 kg ac/ha. Overseas residue data consisting of numerous trials from Canada, Germany and the United Kingdom (UK) on apples and pears treated at rates from 0.51 to 4.5 kg ac/ha found no paraquat residues above the LOQ of 0.01 mg/kg on fruit harvested from the trees with Post Harvest Intervals (PHIs) from 0 – 131 days (Calderbank and Yuan, 1963; Calderbank and McKenna, 1964; Anon., 1971(a); Kennedy and French, 1981). Residues in apple pomace, which is an animal feed, were not addressed in the available trials however as residues were not observed in apple fruit, residues are not expected in processed apple commodities including pomace.

The available paraquat residues data supports continued use in pome fruit orchards. The recommended entry into the MRL Standard for pome fruit is:

FP 0009 Pome Fruits

*0.01 mg/kg

As the use is directed to weeds and not the trees, a harvest withholding period statement of 'Not Required when used as directed' is supported for pome fruit.

Citrus fruit

The maximum Australian label rate is up to 0.8 kg ac/ha. Overseas residue data consisting of numerous trials from the United States of America (USA) and Italy on oranges, grapefruit, lemons and limes treated at rates from 0.8 to 2.44 kg ac/ha found no paraquat residues above the LOQ (0.01 – 0.05 mg/kg) on fruit harvested from the trees at PHIs from 0 – 177 days (Anon., n.d.(a); Dick et al, 1995; Reeve, 1970). Residues were also not detected in juice, peel or pulp, which is an animal feed commodity.

The available paraquat residues data supports continued use in in citrus orchards. The recommended entry into the MRL Standard for citrus fruit is as follows noting that the majority of trials addressed the LOQ of 0.01 mg/kg:

FC 0001 Citrus Fruits	*0.01 mg/kg
-----------------------	-------------

As the use is directed to weeds and not the trees, a harvest withholding period statement of 'Not Required when used as directed' is supported for citrus fruit.

Stone fruit

The maximum Australian label rate is up to 0.8 kg ac/ha. Overseas residue data consisting of numerous trials from Canada, Germany and the UK on apricots, plums, peaches and cherries treated at rates which ranged from 1.0 to 4.5 kg ac/ha found no paraquat residues above the LOQ (0.01 mg/kg) on fruit harvested from the trees at PHIs from 9 – 87 days. Residues were not detected in dried prunes (Calderbank and McKenna, 1964, Anon., 1971(a); Anon., n.d.(b); Roper, 1989(i)).

The available paraquat residues data supports continued use in in stone fruit orchards. The recommended entry into the MRL Standard for stone fruit is:

FS 0012 Stone Fruits	*0.01 mg/kg
----------------------	-------------

As the use is directed to weeds and not the trees, a harvest withholding period statement of 'Not Required when used as directed' is supported for stone fruit.

Berries and other small fruits

The maximum Australian label rate for vineyards is up to 0.8 kg ac/ha. Overseas residue data consisting of numerous trials from Canada, Japan, Switzerland and the USA on vineyards treated once or twice at rates which ranged from 0.3 to 4.4 kg ac/ha found no paraquat residues above the LOQ (0.01 mg/kg) on fruit harvested from the grape vines at PHIs from 0 - 196 days. No residues were detected in sun dried grapes or juice from grapes treated at 5.6 kg ac/ha (Edwards, 1974; Earl and Anderson, 1992; Anon., 1971(a)).

The maximum Australian label rate is up to 0.6 kg ac/ha for row crops and market gardens which may include berries and other small fruit, except for grapes (covered by the vineyard use). Overseas residue data which consisted of numerous trials from Canada, Ireland and the USA on blueberries, blackberries, blackcurrants, redcurrants, loganberries, cranberries, gooseberries, raspberries and strawberries treated once or twice at rates which ranged from 0.42 to 4.5 ac/ha found no paraquat residues above the LOQ (0.01 mg/kg) in fruit at PHIs from 1 – 210 days (Calderbank and McKenna, 1964; Anon. n.d.(b); Anon., 1967).

The available paraquat residues data supports continued use in grapes (vineyards) and other members of the berries and other small fruit crop group. The recommended entry into the MRL Standard for berries and small fruits, including grapes is:

FB 0018 Berries and other small fruits *0.01 mg/kg

As the use is targeting inter-row weeds and not the crop, a harvest withholding period statement of 'Not Required when used as directed' is supported for berries and other small fruit.

Tropical fruits – inedible peel

The maximum Australian label rate for use in orchards which may include all crops within the tropical fruit with inedible peel crop group except for pineapple is up to 0.8 kg ac/ha. For use in row crop, which may include pineapple, the maximum label rate is 0.6 kg ac/ha. The Australian labels also have a specific use pattern for avocados, custard apples, litchis and mangoes at 32.4 g ac/100 L (or 0.324 kg ac/ha with an assumed spray volume of 1000 L/ha).

Overseas residue data on bananas from Honduras and pineapples from Hawaii which involved one to 3 applications at rates between 0.55 and 4.5 kg ac/ha found no paraquat residues above the LOQ (0.01 mg/kg) in fruit at PHIs from 0 – 501 days (Anon., 1973; Anon., 1965 (a,b)).

No data was submitted for tropical fruit with inedible peel, except for banana and pineapple. In light of the extensive data presented for pineapple, bananas and other fruit trees, the weight of evidence demonstrates that directed spraying of weeds around tropical fruit with inedible peel trees with paraquat is unlikely to result in quantifiable residues in the fruit.

The available paraquat residues data supports continued use in tropical fruit with inedible peel which was covered by the label claim for orchards, the use in pineapples which was covered by the label claim for row crops and the specific use for avocados, custard apples, litchis and mangoes (2 application, 14 days apart at 32.4 g ac/100L). The recommended entry into the MRL Standard for tropical fruits – inedible peel is:

FI 0030 Assorted tropical and subtropical fruits – inedible peel *0.01 mg/kg

As application is to the ground cover underneath the tree or to inter row weeds and not the crop, a withholding period of "Not required when used as directed" is appropriate.

Tropical fruits – edible peel

The maximum Australian label rate is up to 0.8 kg ac/ha for olives and other tropical fruit with edible peel (orchard crops). Overseas residue data from Italy, Spain and the USA on olives which involved one to 4 applications at rates between 0.36 and 5.6 kg ac/ha found no paraquat residues above the LOQ (0.01, 0.05 or 0.1 mg/kg) on fruit harvested from the trees at PHIs from 0 – 21 days. No residues of paraquat were detected in olive oil (Anon., 1987; Roper, 1989(j); Anderson and Earl, 1993; Dick et al, 1995(b); Anon., 1973; Massey, 1987(a); Kennedy, 1987).

A North American processing study in figs at rates of 1.1 to 5.5 kg ac/ha found no paraquat residues above the LOQ in figs (0.01 mg/kg for fresh figs, 0.05 mg/kg for dried figs) at PHIs of 13-14 days (Roper, 1989(k)).

Residue trials on olives, figs and a variety of fruit trees has shown that residues would not be found in fruit harvested from trees in orchards that have been treated with directed applications of paraquat. On this basis a MRL for the whole group, tropical fruits edible peel, can be established at the LOQ of *0.05 mg/kg noting that while a LOQ's in the available olive and fig trials ranged from 0.01 to 0.1 mg/kg, and 0.05 mg/kg was the most common LOQ.

The recommended entry into the MRL Standard for tropical fruits – edible peel is:

FT 0026 Assorted tropical and subtropical fruits – edible peel *0.05 mg/kg

The available paraquat residues data supports continued use in tropical fruit with edible peel. The current MRL for olives at 1 mg/kg can be deleted. Residues in table olives will be covered by this recommended MRL however olives for oil production (SO 0305) will be covered by the oilseed MRL at the same level recommended below.

As application is to the ground cover underneath the tree, a withholding period of “Not required when used as directed” is appropriate.

Tree nuts

The maximum Australian label rate for orchards (including tree nuts) and for the specific use on walnuts is up to 0.8 kg ac/ha. Overseas residue data from Canada, Italy and the USA on almonds, pecans, macadamias, pistachios, walnuts and hazelnuts which involved one to 8 applications at rates between 0.54 to 4.55 kg ac/ha found no paraquat residues above the LOQ (0.01 mg/kg) on nuts harvested from the trees (PHI 1 – 73 days) (Anon., n.d.(b); Anon., 1965(c); Anon., 1966; Anon., 1971(b); Anon., 1977, Anon., 1987).

Residues were detected in some nuts that were picked of the ground that had been sprayed a day before or sprayed directly whilst on the ground and from nuts that were picked of branches that were directly sprayed 3 days before picking. While almonds may be harvested from the ground, it would not be considered good agricultural practice to treat weeds 0 - 3 days before harvest. Residues were generally <0.01 mg/kg in nuts sampled at longer PHIs 4 – 73 days (all <LOQ (0.01 to 0.05 mg/kg)). It is noted that residues > ½ the current MRL (0.05 mg/kg) have not been detected in almonds by the National Residues Survey for the last 8 years.

The available paraquat residues data supports continued use in tree nuts. The recommended entry into the MRL Standard for tree nuts is:

TN 0085 Tree nuts *0.01 mg/kg

As application is to the ground cover underneath the tree, a withholding period of “Not required when used as directed” is appropriate for tree nuts.

Vegetable crops

The current MRL for vegetables [except potato and pulses] is *0.05 mg/kg. The general vegetable MRL will be broken down to separate MRLs for the various codex classifications of vegetables.

Application rates for 'Row crops, vegetables, market gardens, nurseries', which is considered to cover all vegetables (except pulses), are '0.4 to 0.432 kg ac/ha or 50 g ac/100 L' for pre-emergent spraying and up to 0.6 kg ac/ha for post-emergence directed inter-row spraying. As a worst case, the maximum rate is considered to be 0.5 kg ac/ha (50 g ac/100 L for an assumed spray volume of 1000 L/ha) for pre-emergence spraying. Potatoes also have a pre-harvest desiccant application rate up to 0.7 kg ac/ha. Pulses (chickpeas, faba beans, field peas, lentils, lupins and vetch) in general have a post-emergence use rate of 0.2 kg ac/ha.

Bulb vegetables

The maximum Australian label rate for vegetables is up to 0.6 kg ac/ha. Overseas residue data from Canada, Germany and the UK on bulb onions and spring onions involved one to 4 applications at 0.66 to 2.24 kg ac/ha. Trials which best approximated Australian use rates, namely: 0.75; 0.66 + 0.96; 0.75 + 1, had residues at or less than the LOQ of 0.01 or 0.02 mg/kg (depending on the trial) (Anon. n.d.(h); Calderbank and Yuan, 1963; Reeve, 1970; Edwards, 1974; Swaine, 1983(a); Kennedy, 1984(a); Anon., 1985; Massey; 1987(b)). These trials demonstrated that residues should be <LOQ (0.01 or 0.02 mg/kg) in bulb vegetables following application at the label rate for vegetables (0.6 kg ac/ha) at PHI's ranging from 0 – 143 days and therefore a LOQ MRL recommended.

The available paraquat residues data supports continued use in bulb vegetables. The recommended entry into the MRL Standard for bulb vegetables is as follows noting that the majority of trials addressed the LOQ of 0.01 mg/kg:

VA 0035 Bulb vegetables	*0.01 mg/kg
-------------------------	-------------

As the use is pre-emergent or targets inter-row weeds and not the crop, a harvest withholding period statement of 'Not Required when used as directed' is supported for bulb vegetables.

Root and tuber vegetables

The maximum Australian label rate for pre-emergence and directed spray uses in vegetables is up to 0.6 kg ac/ha. Potatoes have an additional label use to the rest of the group, namely a pre-harvest weed control application rate up to 0.7 kg ac/ha.

Relevant to the pre-harvest use in potatoes, residues data from the UK, Canada and the USA involved pre-harvest treatment at rates ranging from 0.2 to 6.27 kg ac/ha. Residues in potato tubers were <LOQ (0.01 mg/kg) to 0.2 mg/kg at PHI's of 14 to 41 days (Anon., n.d.(i), Calderbank and McKenna, 1964; Reeve, 1970; Anon., 1970 (a); Anon., 1971(a); Anon., 1974; Kennedy, 1984(a); Anon. 1985; Roper, 1989(m); Earl and Anderson 1991). Scaled to application rate the high residue (HR) for potatoes is 0.13 mg/kg (at a 14 day PHI).

Although residue data on pre-harvest use of paraquat approximating Australian label rates on potatoes was submitted, the trials only addressed PHIs of 14 days or more whereas some Australian labels indicate that applications should be made 3 to 7 days before digging. It therefore was not possible to support the pre-harvest use on potatoes with instructions for applications to be made 3-7 days before digging, due to a lack of relevant residues data.

There is sufficient data relevant to an application timing of 14 days before digging (10 results for application at 1.12 kg ac/ha, 14 day PHI), however, the scaled HR (0.13 mg/kg) would give an unacceptable acute dietary exposure

for children (111% of ArfD). Application to potatoes 14 days (or less) before digging therefore cannot be supported due to acute consumer safety concerns.

For the alternative pre-harvest potato Good Agricultural Practice (GAP) on some labels which allows application to potatoes at 4-5 weeks before digging, the current MRL of 0.2 mg/kg would remain appropriate based on available data that addressed a 27-31 day PHI. Based on the HR of 0.09 mg/kg at a 27–31 day PHI, the acute dietary exposure is estimated to be acceptable for potatoes (77% of the ArfD for children and 32% of ArfD for general population). This use on potatoes 4-5 weeks before digging remains appropriate in conjunction with a harvest withholding period of “Not required when used as directed”. The current MRL at 0.2 mg/kg for potatoes remains appropriate.

Labels that currently have the ‘3 to 7 days before digging and after tops have died down’ instruction must be changed to state that application must occur ‘4-5 weeks before digging’.

Relevant to the pre-emergence and directed spray uses on potatoes and other root and tuber vegetables, overseas residue data from the UK, Canada, the USA, Germany, South Africa, Japan and France on potatoes, beetroot, carrots, parsnip, swedes, turnip and black salsify addressed rates ranging from 0.28 to 2.24 kg ac/ha. Pre-emergent and post-emergent directed applications of paraquat to potatoes, beetroot, carrot, parsnip, turnip and black salsify resulted in residues in the roots and tubers at <LOQ (0.01 – 0.05 mg/kg) when scaled to the Australian rate (0.6 kg ac/ha) (Calderbank and McKenna, 1964; Edwards, 1974; Anon., n.d.(i) Kennedy, 1984(b); Earl and Anderson 1991; Anon., 1974; Reeve, 1970; Anon., 1970 (a); Anon., 1971(a); Anon. 1985; Roper, 1989(m, n)).

The available paraquat residues data for root and tuber vegetables supports continued use as a pre-emergence and directed spray in all root and tuber vegetables and as a pre-harvest application to potatoes 4–5 weeks before digging. The recommended entries into the MRL Standard for root and tuber vegetables is as follows noting that the majority of trials addressed the LOQ of 0.01 mg/kg:

VR 0589 Potato	0.2 mg/kg
VR 0075 Root and tuber vegetables {except Potatoes}	*0.01 mg/kg

For the pre-emergence and directed spray use in root and tuber vegetables, a harvest withholding period statement of ‘Not Required when used as directed’ is supported as the use is pre-emergent or targets inter-row weeds and not the crop. The ‘Not Required when used as directed’ withholding period statement is also considered appropriate for the pre-harvest spray given that the pre-harvest application should be made 4–5 weeks before digging.

Leafy vegetables

The maximum Australian label rate for vegetables is up to 0.6 kg ac/ha. Overseas residue data from Germany, the UK and the USA on lettuce treated at rates ranging from 0.5 to 0.97 kg ac/ha found no paraquat residues above the LOQ (0.01 or 0.02 mg/kg). Trials on lettuce, turnip tops and kale at rates in excess of 1 kg ac/ha did detect residues at time of harvest but these generally were less than 0.01 mg/kg when scaled for the proposed rate or were from samples collected at very short PHI's (Anon., n.d; Kennedy, 1984(a); Roper, 1989(o); Swaine, 1983(b); Massey, 1987(c,d)).

Although data was available only for lettuce for Australian GAP, use in the leafy vegetable crop group can be supported based upon the pattern of non-detects in a large variety of vegetable produce with directed inter row application of paraquat. The recommended entry into the MRL Standard for leafy vegetables is:

VA 0035 Leafy vegetables *0.02 mg/kg

As the use is pre-emergent or targets inter-row weeds and not the crop, a harvest withholding period statement of 'Not Required when used as directed' is supported for leafy vegetables.

Brassica vegetables

The maximum Australian label rate for vegetables is up to 0.6 kg ac/ha. Overseas residue data from Japan, Canada and the Netherlands on cabbage, broccoli and cauliflower treated at rates ranging from 0.96 to 2.24 kg ac/ha all found no paraquat residues above the LOQ (0.01 or 0.03 mg/kg) with exception of a cabbage trial conducted at 2.24 mg/kg which found a residue of 0.09 mg/kg which would be below the LOQ of 0.03 mg/kg when corrected to the Australian rate (0.6 kg ac/ha)(Edwards, 1974; Anon., n.d.(b)).

The available paraquat residues data supports continued use in brassica vegetables. The recommended entry into the MRL Standard for brassica vegetables is:

VB 0040 Brassica vegetables *0.03 mg/kg

As the use is pre-emergent or targets inter-row weeds and not the crop, a harvest withholding period statement of 'Not Required when used as directed' is supported for brassica vegetables.

Stalk and stem vegetables

The maximum Australian label rate for vegetables is up to 0.6 kg ac/ha. Overseas residue data from Canada on asparagus and celery treated at rates of 1.12 or 2.24 kg ac/ha found residues to be less than the LOQ of 0.05 mg/kg in most trials (Calderbank and McKenna, 1964; Anon., n.d.(b)). When scaled for the Australian rate (0.6 kg ac/ha) the high residue of 0.07 mg/kg is below the LOQ.

The available paraquat residues data supports continued use in stalk and stem vegetables. The recommended entry into the MRL Standard for stalk and stem vegetables is:

VS 0078 Stalk and stem vegetables *0.05 mg/kg

As the use is pre-emergent or targets inter-row weeds and not the crop, a harvest withholding period statement of 'Not Required when used as directed' is supported for stalk and stem vegetables.

Fruiting vegetables, cucurbits

The maximum Australian label rate for vegetables is up to 0.6 kg ac/ha. Overseas residue data from the USA on cucumber, summer squash (zucchini), and melons (including watermelon) treated one to 4 times at rates ranging from 0.56 to 1.12 kg ac/ha found no paraquat residues above the LOQ (0.01 to 0.03 mg/kg)(Roper, 1989(p), Reeve, 1970).

The available paraquat residues data supports continued use in cucurbits. The recommended entry into the MRL Standard for fruiting vegetables, cucurbits is:

VC 0045 Fruiting vegetables, cucurbits *0.03 mg/kg

As the use is pre-emergent or targets inter-row weeds and not the crop, a harvest withholding period statement of 'Not Required when used as directed' is supported for cucurbit vegetables.

Fruiting vegetables, other than cucurbits

The maximum Australian label rate for vegetables is up to 0.6 kg ac/ha. Overseas residue data from Canada and the USA at 0.11 to 0.22 kg ac/ha in one tomato trial or rates ranging from 1.12 to 11.2 kg ac/ha on tomatoes and peppers treated found no paraquat residues above the LOQ (0.005 mg/kg or 0.01 mg/kg) (Calderbank and McKenna, 1964; Edwards, 1974; Roper 1989(q,r).

The available paraquat residues data support continued use in fruiting vegetables. The recommended entry into the MRL Standard for fruiting vegetables, other than cucurbits is:

VO 0050 Fruiting vegetables, other than cucurbits *0.01 mg/kg

As the use is pre-emergent or targets inter-row weeds and not the crop, a harvest withholding period statement of 'Not Required when used as directed' is supported for fruiting vegetables.

Legume vegetables

The maximum Australian label rate for vegetables is up to 0.6 kg ac/ha. Overseas residue data from Canada, Guatemala and the UK on a variety of beans and peas treated at post-emergence application rate from 0.14 to 2.24 kg ac/ha found no paraquat residues above the LOQ (0.01 to 0.05 mg/kg) (Calderbank and McKenna, 1964; Edwards, 1974; Anon., n.d.(b); Kennedy, 1984; Anon. 1985; Anon. n.d.(b)).

The available paraquat residues data support continued use in legume vegetables. The recommended entry into the MRL Standard for legume vegetables is:

VP 0060 Legume vegetables *0.05 mg/kg

As the use is pre-emergent or targets inter-row weeds and not the crop, a harvest withholding period statement of 'Not Required when used as directed' is supported for legume vegetables.

Pulses

Paraquat has registered uses in pulses (under the vegetables label claim or cultivation aid label claim on paraquat and diquat combination products) as a pre-emergence herbicide (0.4-0.6 kg ac/ha) or spray topping treatment to reduce seed set of ryegrass weeds (0.2 kg ac/ha) in chickpeas, faba beans, field peas and lupins with a WHP of 7 or 14 days.

Australian trials which addressed the spray topping use were submitted on field peas, chickpeas and lupins at 0.2 and 0.4 kg ac/ha. Trials on soybeans which addressed a pre-harvest desiccant treatment (which is not on Australian labels for soybeans) or a pre-emergent application at 1.12 kg ac/ha (Roper, 1989(s). The current MRL for pulses is 1 mg/kg for the whole group.

Soybean trials with pre-emergence applications at 1.12 kg ac/ha did not detect any residues above the LOQ (0.05 mg/kg in the majority of trials)(Roper, 1989(t,u); Anon., 1972(a); Anon., 1978; Hayward and Robbins, 1981; Kennedy and Robbins, 1982; Hayward and Robbins, 1981; Kennedy et al,1983; Earl and Muir, 1988; Roper, 1993; Roper and Elvira, 1996(a)). This data supports an MRL of *0.05 mg/kg for pulse crops which only have an approved pre-emergent use vegetables label claim or cultivation aid label claim on paraquat and diquat combination products.

Australian trials with chickpeas, field peas and lupins at 0.2 and 0.4 kg ac/ha found residues in seed were up to 0.41 mg/kg at the label rate and up to 0.54 mg/kg at double the maximum application rate following a 14 day PHI. Residues at 14-15 day PHI (or later if higher) following one application at 0.2 kg ac/ha were 0.05, 0.1, 0.31 and 0.41 mg/kg (Roy, 1973; Marcus, 1993 (a,b,c) Brown, 1994 (a,b,c)). The OECD MRL calculator estimates an MRL of 0.9 mg/kg based on this dataset (STMR 0.21 mg/kg). This data supports an MRL a 1 mg/kg for chickpeas, faba beans, field peas, lentils and lupins which have an approved spray topping use noting that data for chickpeas and field peas are relevant to other dried peas (i.e. lentils) while data for lupins are relevant to other dried beans (i.e. faba beans). The MRL for other pulses that only have a pre-emergent use will be *0.05 mg/kg for 'Pulses {except Broad bean (dry); Chick-pea (dry); Field pea (dry); Lentil (dry); Lupin (dry)}.

The available paraquat residues data support continued use in pulses. This data supports a 14 day withholding period for the spray toping use at 0.2 kg ac/ha for chickpeas, faba beans, field peas, lentils and lupins. For labels with a 7 day withholding period for this use pattern, the withholding period should be changed to 14 days as there was insufficient residues data addressing a 7 day withholding period. For other pulses the supported withholding period is "Not required when used as directed" as the use would be pre-emergent or directed to inter row weeds.

The recommended entries into the MRL Standard for pulses are as follows noting that the most common LOQ in the available pulse trials was 0.05 mg/kg:

VD 0070 Pulses {except Broad bean (dry); Chick-pea (dry); Field pea (dry); Lentil (dry); Lupin (dry)}	*0.05 mg/kg
VD 0523 Broad bean (dry) [faba bean (dry)]	1 mg/kg
VD 0524 Chick-pea (dry)	1 mg/kg
VD 0561 Field pea (dry)	1 mg/kg
VD 0533 Lentil (dry)	1 mg/kg
VD 0545 Lupin (dry)	1 mg/kg

Cereals

In Australia the maximum rate for cereals is 0.6 kg ac/ha as pre-sowing cultivation aid application. Rice has a separate entry on some Australian labels with a pre-sowing maximum rate of 0.4 kg ac/ha and a pre-emergent maximum rate at 0.2 kg ac/ha. Australian trials on rice, wheat and barley were submitted along with overseas trials from a range of countries on sorghum, rice, corn, wheat, barley, oats and buckwheat. The current MRL for cereals (except maize and rice) is *0.05 mg/kg with MRLs for maize being 0.1 mg/kg, rice being 10 mg/kg and polished rice being 0.5 mg/kg.

Sorghum trials with pre-emergence treatment at 1.12 kg ac/ha combined with post-emergence application at 0.56 kg ac/ha did not detect paraquat residues above the LOQ (0.025 mg/kg) in grain (Anon., n.d.(d); Anon., 1970 (b,c)); Ward, 1979; Roper, 1989 (w)).

No paraquat residues above the LOQ (0.05 mg/kg) were detected in rice grain in trials that involved rates ranging from 0.13 to 1 kg ac/ha (Anderson et al, 1995; Reeve, 1970) Anon., 1972 (b,c); Kennedy, 1984(c)). The current MRL of 10 mg/kg for rice is based upon a pre-harvest use on rice which is not on current labels.

Pre-emergence and pre-sowing use patterns at rates ranging from 0.28 to 1.12 kg ac/ha did not detect residues above the LOQ (0.01 to 0.05 mg/kg) in maize/corn (Calderbank and McKenna, 1964; Anon., n.d.(a) Anderson and Lant, 1994; Reeve, 1970; Kennedy, 1984(d); Roper, 1989 (x)).

Pre-emergence trials on wheat, barley and oats did not detect residues above the LOQ (0.01 to 0.05 mg/kg) in grain after application at 1.12 – 5.6 kg ac/ha (up to 9× the proposed rate) (Calderbank and McKenna, 1964; Roper, 1989(y); Reeve, 1970; Reeve, 1972; Brown, 1994(d,e)).

The available paraquat residues data support continued use in cereals. As the use pattern for all cereals is a pre-emergent/pre-sowing use pattern no paraquat residues above the LOQ in seed is expected or was found in residue trials. Therefore, a single entry can be established for the whole group at *0.05 mg/kg whilst deleting the existing MRLs for rice, polished rice and maize.

The recommended entry into the MRL Standard for cereals is as follows noting that the most common LOQ in the available cereal trials was 0.05 mg/kg:

GC 0080 Cereal grains

*0.05 mg/kg

A harvest withholding period statement of 'NOT required when used as directed' is appropriate for cereals as the use is pre-sowing or post sowing / pre-crop emergence.

Oilseeds

Current Australian use patterns differ amongst the oilseeds. All oilseeds have a pre-emergent use as a cultivation aid at up to 0.6 kg ac/ha. Cotton has an additional pre-harvest desiccant application at 0.216 kg ac/ha with a WHP of 7 days. Peanuts have an additional post-emergent application (up to 7–8 leaf stage) at 0.25 kg ac/ha.

Cotton

An Australian study found that the spray topping use at 0.4 kg ac/ha (1.9x the label rate) resulted in residues <0.1 mg/kg (n=2) in cotton seed after the current 7 day WHP (Roper and Elvira, 1996(b)). Additional relevant pre-harvest desiccation application cotton trials presented in the 2004 JMPR indicate that at Australian GAP, finite residues could be expected in cotton seed (Roper, 1994; Roper, 1990; Brown and Marcus, 1996). At a WHP of 7 days after pre-harvest applications at 0.14 to 0.28 kg ac/ha, residues in cotton seed would be expected to be less than 0.2 mg/kg.

The available paraquat residues data support continued use in cotton. The current and recommended entry into the MRL Standard for cotton is:

SO 0691 Cotton seed	0.2 mg/kg
---------------------	-----------

The current entry for cotton seed oil of 0.05 mg/kg in the MRL Standard can be deleted (see Section 2.4.7).

A 7 day withholding period is supported for the desiccation use pattern on cotton.

Peanuts

Two Australian residue trials for peanuts were submitted for review. No paraquat residues above the LOQ (0.01 mg/kg) were seen in peanut kernels or nuts in shell at post-emergent application rates up to 0.6 kg ac/ha (Williams, 1989 (a,b)). The maximum label rate for post-emergent application is 0.25 kg ac/ha.

The available paraquat residues data support continued use in peanuts. The current Australian MRL of *0.01 mg/kg in peanuts is not considered necessary as the recommended MRL for 'Oilseeds {except Cotton seed}' below at *0.05 mg/kg will cover this use on peanuts.

SO 0088 Oilseed {except Cotton seed}	*0.01 mg/kg
--------------------------------------	-------------

A current harvest withholding period statement of 'NOT required when used as directed' is appropriate as the use is only permitted up to the 7–8 leaf stage.

Oilseeds other than cotton and peanuts

The current product labels only have a pre-emergent use pattern for oilseeds. Only a US trial on sunflowers provided data on pre-emergent application of paraquat. Even though the application rates were 2.5 to 12 times the maximum Australian label rate no paraquat residues above the LOQ were detected in seed (LOQ 0.05 mg/kg) (Roper, 1989 (v); Wilde, 1978; Ward, 1979; Cowdy, 1976; Roper, 1995; Anon., n.d.(c); Marcus, 1996).

The available paraquat residues data support continued pre-emergent use in oilseeds. A LOQ MRL at *0.05 mg/kg is recommended for 'Oilseeds {except Cotton seed}'. A harvest withholding period statement of 'NOT required when used as directed' is appropriate as the use is pre-sowing.

Sugar cane

Australian label rates for sugar cane are: 0.432 kg ac/ha for pre-sowing applications; and 0.4 kg ac/ha for post-emergent treatments which include over the top spraying of cane at the 3 to 4 leaf stage and directed inter-row spraying after cane has reached the $\frac{3}{4}$ leaf stage. The current Australian MRL for cane is *0.05 mg/kg.

Available data for sugarcane consists of Argentinian trials involving a pre-harvest treatment 7 days before harvest (Anon., n.d.(b)). Suitable trial data reflective of the Australian pre-emergent, post emergent or inter-row treatments have not been submitted for sugar cane. Data on the post-emergent application, particularly the over-the-top spraying are required to support this specific use pattern.

Metabolism data indicate that pre-emergent or post-emergent directed spraying is unlikely to result in detectable residues in sugar cane (California Chemical Company, 1965). A plethora of pre-emergent data for fruits, vegetables, cereals and oilseeds supports the conclusion that residues above the LOQ should not occur in sugar cane at harvest following the pre-emergent or directed (inter-row) treatment and these uses therefore can be supported from a residue's perspective.

However, Australian labels currently includes over the top spraying at 3-4 leaf stage. Post emergent applications can result in direct contact with plants and can potentially result in quantifiable residues but there is no relevant data to quantify the level of residue that could be expected following the current post emergent use. The continued post-emergent use on sugar cane is not supported from a Residues and Trade perspective due to a lack of residues data relevant to that use pattern.

In the absence of residue data relevant to the post-emergent use on sugar cane, it is recommended that the use of paraquat on sugar cane be restricted to pre-emergent or directed post emergent applications and a harvest withholding period statement of 'Not Required when used as directed' is supported for those use patterns. The current MRL for sugar cane of *0.05 mg/kg can remain to support the pre-planting use on sugar cane. The post-emergent application to sugar cane is not supported due to a lack of residues data but is considered suitable for a phase out period.

Hops

The maximum Australian label rate is up to 0.4 kg ac/ha for hops. The current MRL for hops is 0.2 mg/kg. Overseas trial data from Canada, Germany and the USA on hops treated at 1 to 2.8 kg ac/ha found no paraquat residues above the LOQ (0.01, 0.05 or 0.1 mg/kg) mg/kg in dried and fresh hops. No residues were detected in processed hops treated at 2.8 kg ac/ha. In Australian data for hops, paraquat residues were <0.05 mg/kg (n = 2) at 12 – 14 days after 2-3 applications at 432 g ac/ha by inter row boom spray (Anon., n.d.(b); Roper, 1989(l); Anon., 1979).

The available paraquat residues data support continued use in hops. The recommended entry into the MRL Standard for hops is as follows noting that the LOQ in the majority of hops trials was 0.05 mg/kg:

DH 1100 Hops, dry

*0.05 mg/kg

As the use is targeting inter-row weeds and not the crop, a harvest withholding period statement of 'Not required when used as directed' is supported for hops.

Herbs and spices

No residues data for herbs and spices have been provided.

Herbs and spices are also grown in market gardens and hence have a potential label use pattern; namely that of a pre-planting/pre-emergent application up to 0.5 kg ac/ha and post-emergent directed spray at up to 0.6 kg ac/ha. Data for pre-emergent use in a plethora of fruit, vegetable, cereal and oilseed crops, including leafy vegetables which are physiologically similar to herbs, show that no detectable residues would be expected under these pre-emergent use patterns and hence MRL at the LOQ of *0.05 mg/kg can be considered for herbs and spices.

As the use is pre-emergent or targets inter-row weeds and not the crop, a harvest withholding period statement of 'Not required when used as directed' is supported for herbs and spices.

The recommended entry into the MRL Standard for herbs and spices are:

HH 0092 Herbs	*0.05 mg/kg
HS 0093 Spices	*0.05 mg/kg

Processed commodities

Processing data demonstrated that residues of paraquat in major food processed items (flour, peeled potatoes, malt, sugar, oil, juice and beer) can be reduced by processing.

Data from processing studies demonstrated that paraquat does not concentrate in oil produced from cereal grains, oilseeds or olives. Application at label rates to cereals, olives and oilseeds is unlikely to produce detectable residues in oil (Anon., 1973; Kennedy, 1985; Roper, 1989(j, aa, ab, ac); Anderson and Earl, 1993; Dick et al, 1995; Calderbank and McKenna, 1964; Roper and Elvira, 1996).

Potatoes exposed to pre-harvest desiccant applications of paraquat demonstrated decreases in residues by ~70% after peeling (Roper, 1989 (z); Alary et al, 1974).

Juice from pineapples exposed to exaggerated rates of paraquat (11 kg ac/ha) decreased by 25% from the raw fruit. Under normal label rates no residues would be expected in fruit juices (Roper, 1989(af)).

Residues in refined sugar would not be expected under GAP. Residues in malt derived from treated barley would be expected to decrease by 20 to 70% (Roper, 1989(ad, ae)).

Processing studies did show that paraquat would concentrate in the outer covering of cereal grains and oilseeds by 2 to 5 times. However, residues in flour would decrease by 70 to 90% (Roper, 1989(aa)).

Vegetable oil

Vegetable oils can be derived from a variety of sources: cottonseed; peanuts; other oilseeds; olives and pulses. Except for cotton seed which has a proposed MRL of 0.2 mg/kg, the remaining commodities have proposed MRLs at the LOQ (generally 0.05 mg/kg). Processing studies described above have indicated that even with residues of

0.2 mg/kg in the primary commodity, no residues above the LOQ were detected in oil. Therefore, an MRL can be established at the LOQ (0.05 mg/kg).

The recommended entry into the MRL Standard for edible vegetable oil is:

OR 0172 Vegetable oils, edible *0.05 mg/kg

Residues in animal feed commodities

The current MRL for animal feed commodities is 500 mg/kg for primary feed commodities.

The critical use will be for pastures where the grazing WHP is 1 day (except for horses which is 7 days) and application rates are up to 0.6 kg ac/ha.

Animal feeds derived from grasses

In pre-emergence grass pasture trials from the US indicate that at Australian rates up to 0.6 kg ac/ha, no detectable residues in grass forage or hay would be expected. No residues are expected in cereal grain forage or fodder as the use pattern is solely a pre-emergent/pre-sowing one (Calderbank and McKenna, 1964; Roper, EM (1989(an,ao)). The hay-freezing use on some labels would be expected to be covered by the assessment for pastures grasses below.

Residues in forage in pasture grasses treated at 0.55 kg ac/ha (0.9x) ranged from 100 to 140 mg/kg dry weight (DW) at 1 day after application. Residues in grass hay ranged from 120 to 220 mg/kg dry matter (DM) at 1 day after application (Calderbank and Yuan, 1963; Calderbank and McKenna, 1964: Anon., n.d.(a); Reeve, 1970; Fletcher, 1972, Roper, 1989(ag, ah)).

No changes are required to the current MRL of 500 mg/kg for paraquat on Primary feed commodities to cover the cereal / grass pasture uses.

Legume animal feeds

Legume animal feeds include fodder from pulses, from legume vegetables and fodder from pasture legumes such as lucerne, vetch clover. The current Australian use pattern for pulses (including vetch) is 0.2 kg ac/ha with a 7 or 14 day WHP for livestock while the legume vegetable use is pre-emergent. The use pattern for pastures and lucerne is 0.6 kg ac/ha with a 1 day grazing WHP. Therefore, the highest residues for legume animal feeds are likely to come from pasture legumes.

The maximum residue in fodder or straw of pulses was 12 mg/kg following the Australian GAP (Roper, 1989(ak, al, am)).

Residues in lucerne fodder and forage at GAP ranged from 40 to 170 mg/kg DM (Anon., n.d.(b); Reeve, 1970; Anon., n.d.(e); Roper, 1989(aj); Coombe, 1990). Residues in clover fodder and forage ranged from 50 to 180 mg/kg (Roper, 1989(am)). Residues in birdsfoot trefoil fodder and forage ranged from 100 to 250 mg/kg (Roper, 1989(ao)).

No changes are required to the current MRL of 500 mg/kg for paraquat on primary feed commodities to cover the uses on legume animal feeds.

Cotton trash

No suitable data on cotton trash at the Australian label rates was presented, however processing data indicates that paraquat will concentrate in cotton trash by 3 to 190 times. Without cotton trash data relevant to the Australian use pattern, an appropriate MRL cannot be established for cotton trash.

In the absence of relevant data for cotton trash or fodder, the restraint of 'DO NOT feed cotton fodder, stubble or trash to livestock' is recommended for cotton uses.

Almond hulls

Residues in almond hulls (from almonds collected from the tree) at 1 day after application at 1.1 kg ac/ha (1.4×) were <0.01 (3), 0.02 (2), 0.06 and 0.12 mg/kg (Anon., (1966)). The OECD MRL calculator recommends an MRL of 0.2 mg/kg, the STMR is 0.02 mg/kg. An MRL of 0.2 mg/kg is recommended for paraquat on almond hulls in conjunction with a withholding period of "Not required when used as directed".

Other animal feeds

Residues in minor animal feed commodities form no more than 20% of the diet livestock and will not influence animal MRLs due to the higher residues of paraquat in pastures, hay and fodder. Such animal feeds include citrus pulp, grape pomace, apple pomace and tomato pomace and the primary crops may be treated with pre-emergent or directed applications and should not result in residues in the raw commodity or animal feed. MRLs in Table 4 of the MRL standard are not considered necessary as residues above the LOQ are not expected.

Animal transfer studies and required animal commodity MRLs

Metabolism and animal residue studies indicate that paraquat is not fat-soluble. The WHP of 7 days for horses appear to be based upon toxic/irritant effects on oral mucous membranes of horses after consuming herbage freshly treated with paraquat rather than residue related reasons (Walley et al, 1966; Calderbank et al, 1968). This horse withholding period will not be reconsidered as part of this residues assessment.

Poultry

Metabolism studies indicate that there is little metabolism of paraquat in the hen (97–98% of radioactivity is the parent compound) and that elimination is entirely by the faecal route (at least 99% of radioactivity at 30 and 60 ppm). Radioactive labelling also indicated that egg residues were mainly the parent compound with most being found in the yolk and very little in the albumen. At 6 ppm in the diet, whole egg residues showed a plateau around 0.01 mg/kg, but at 30 ppm in the diet, no plateau effect occurred after 10 days with residues reaching 0.05/0.06 mg/kg. Highest tissue levels were 0.113 and 0.072 mg/kg in the kidney and liver respectively (Fletcher, 1974; Leary, 1974).

Two animal transfer studies in hens produced similar residue levels as seen in the metabolism studies. Plateaux in whole egg residues were seen at 0.01, 0.02 and 0.05 mg/kg with dietary feeding of 6, 13 and 30/36 ppm respectively. The whole egg residues did not accumulate and declined further when an untreated diet was fed. Tissue residues were less than 0.01 mg/kg when fed diets containing 1.8, 3.6, 6, or 7.2 ppm paraquat. At a feeding rate of 13 ppm, tissue levels were less than 0.01 mg/kg with the exception of the kidney where residues of 0.05 and 0.06 mg/kg were found. At 30 ppm in the diet kidney residues were up to 0.14 mg/kg, liver residues were up to 0.1 mg/kg and muscle residues up to 0.05 mg/kg but all decreased to less than 0.05 mg/kg after a 7 day withdrawal period (Anon., 1976; Earl and Boseley, 1988(c)).

A typical poultry ration would contain up to 70% cereal grains, 10% animal protein and 20% vegetable protein. Pulses can be up to 25% of the ration but usually at the expense of some grain or vegetable protein. The only feed components of poultry diet that would have residues above the LOQ are cotton seed (0.2 mg/kg) and pulses (1 mg/kg). The 2004 JMPR reported residues of 0.02 mg/kg in cotton meal when residues in fuzzy seed were 0.18 mg/kg. A diet based on pulses as a worst case containing maximum residues of 1 mg/kg would only produce a diet containing 1 ppm of paraquat. More refined dietary burden calculations for poultry broilers and layers are presented in Table 12 and Table 13 below using the OECD Feed Calculator and the relevant High Residue (HR) or Supervised Trials Median Residue (STMR).

Table 12: Calculation of poultry broiler dietary burden of paraquat

Poultry Broiler – for MRLs							
Commodity	Codex Commodity Code ⁵	Residue (mg/kg)	Basis	Dry matter (%)	Residue dry weight (mg/kg)	Diet content (%)	Residue Contribution (ppm)
Alfalfa forage	AL	170	HR	100	170.0		
Potato culls	VR	0.09	HR	20	0.45		
Bean seed	VD	0.21	STMR	88	0.24	70	0.17
Lupin seed	VD	0.21	STMR	88	0.24		
Pea seed	VD	0.21	STMR	90	0.23		
Sorghum, grain	GC	0.05	STMR	86	0.06	30	0.02
Corn, field grain	GC	0.05	STMR	88	0.06		
Cotton meal	SM	0.02	STMR	89	0.0		
Total						100	0.18

⁵ <https://www.apvma.gov.au/crop-groups>

Table 13: Calculation of poultry layer dietary burden of paraquat

Poultry broiler – for MRLs							
Commodity	Codex Commodity Code	Residue (mg/kg)	Basis	Dry matter (%)	Residue dry weight (mg/kg)	Diet content (%)	Residue Contribution (ppm)
Trefoil forage	AL	250	HR	100	250.0		
Grass hay	AF/AS	220	HR	100	220.0		
Potato culls	VR	0.09	HR	20	0.45		
Bean seed	VD	0.21	STMR	88	0.24	70	0.17
Lupin seed	VD	0.21	STMR	88	0.24		
Pea seed	VD	0.21	STMR	90	0.23		
Sorghum, grain	GC	0.05	STMR	86	0.06	30	0.02
Corn, field grain	GC	0.05	STMR	88	0.06		
Cotton meal	SM	0.02	STMR	89	0.0		
Total						100	0.18

Current MRLs for poultry are *0.05 for meat and offal and *0.01 for eggs. Data from the animal transfer studies in poultry indicate that a dietary intake of 7.2 ppm or less would not produce residues in excess of the current MRLs for meat, offal or eggs. Therefore, the estimated dietary burdens for commodities that would be relevant to poultry feed of 0.18 ppm should not result in residues for poultry meat, offal or eggs exceeding current LOQ MRLs.

It is concluded that the following poultry commodity MRLs which are currently in the MRL standard remain appropriate:

PE 0112 Eggs	*0.01 mg/kg
PO 0111 Poultry, edible offal	*0.05 mg/kg
PM 0110 Poultry meat	*0.05 mg/kg

Pigs

The pig residue transfer study indicated that diets containing 150 ppm paraquat ion produced residues in offal at 0.4 mg/kg or less and residues in meat had a plateau at 0.1 mg/kg but dissipated to 0.04 and 0.02 mg/kg on continued dosing out to 30-36 days. There was no accumulation in pig tissues. A diet containing 50 ppm paraquat ion had offal residues less than 0.09 mg/kg and muscle residues of 0.02 mg/kg. Metabolism studies with single

doses of paraquat at 50 ppm produced offal residues up to 0.5 mg/kg and meat residues up to 0.06 mg/kg. Feeding at 8 ppm found no detectable residues in tissues (Hemingway et al, 1975).

Typical Australian pig feed can contain up to 85% grain and up to 15% protein meals (mainly meat meal and soybean meal). Pig diets are therefore unlikely to contain any significant residues of paraquat.

Ruminants

Dietary burdens calculations for beef and dairy cattle using the OECD Feed Calculator are presented in Table 14 and Table 15 below.

Table 14: Calculation of beef cattle dietary burden of paraquat

Beef cattle – for MRLs							
Commodity	Codex Commodity Code	Residue (mg/kg)	Basis	Dry matter (%)	Residue dry weight (mg/kg)	Diet content (%)	Residue Contribution (ppm)
Trefoil forage	AL	250	HR	100	250.0	100	250
Grass hay	AF/AS	220	HR	100	220.0		
Clover forage	AL	180	HR	100	180.0		
Alfalfa forage	AL	170	HR	100	170.0		
Potato culls	VR	0.09	HR	20	0.5		
Sorghum grain	GC	0.05	STMR	86	0.1		
Barley grain	GC	0.05	STMR	88	0.1		
Total						100	250.0

Table 15: Calculation of dairy cattle dietary burden of paraquat

Dairy cattle – for MRLs							
Commodity	Codex Commodity Code	Residue (mg/kg)	Basis	Dry matter (%)	Residue dry weight (mg/kg)	Diet content (%)	Residue Contribution (ppm)
Trefoil forage	AL	170	HR	100	250.0	40	100
Grass hay	AF/AS	220	HR	100	220.0	60	132
Potato culls	VR	0.09	HR	20	0.45		

Sorghum grain	GC	0.05	STMR	86	0.06		
Total						100	232

Metabolism studies in the cow, goat, sheep and pig indicated that paraquat was not readily metabolised but was rapidly eliminated, mainly in the faeces with a very small amount in the urine (Toral and Kay, 1964; Sarfety, 1963). Highest tissue residues were generally seen in the kidney then liver then muscle. There was very little in the fat. Single oral dosing at 8 mg/kg to cows found 0.005 ppm in the milk with paraquat, monoquat and the monopyridone of paraquat all present at 0.01 ppm or less. Dosing over 3 consecutive days found a maximum of 0.01 mg/kg in the milk, but chemical analysis did not detect any parent paraquat (limit of determination 0.005 mg/kg). Goats dosed over 7 days demonstrated increasing milk residues to a maximum of 0.009 mg/kg (Hendley et al, 1976(a)).

Five feeding trials with cattle were submitted. Three were trials where cattle grazed treated pasture and hence were exposed to decreasing residue intakes over time though initial residues were high (up to 1000 ppm). The pasture applications were at rates double the maximum label rate for pastures.

Feeding studies concentrations up to 100 ppm for 30 days and at feed concentrations up to 170 ppm for 95 days found milk residues to be 0.001 mg/kg or less, offal residues were 0.3 mg/kg or less and muscle residues were less than 0.03 mg/kg. Pasture trials did not detect paraquat in milk or muscle. Residues in offal were mainly seen in the kidney with the highest residue being 0.16 mg/kg. Residues up to 72 mg/kg were seen in the digestive tract but this was due to the presence of treated fodder (Sarfety, 1963; Edwards et al, 1974; Walley et al, 1966; Calderbank et al, 1966; Calderbank et al, 1968; Litchfield, 1969; Edwards, 1977; Anon., 1985).

Residue studies with pasture grasses and legumes have indicated that the maximum residue limit should be set at 500 mg/kg DM. The HR was 250 mg/kg (dw) in legume animal feeds (trefoil fodder and forage). This MRL will be set on a use pattern based on pasture spraying with subsequent grazing. Under this setting, the pasture residues would decrease with time as indicated in the pasture trials.

Current MRLs for meat (mammalian) are *0.05, for edible offal (mammalian) are 0.5 and for milks are *0.01 mg/kg. Data from the animal transfer studies indicate that a dietary intake of 460 to 1030 ppm as an initial pasture residue would not exceed current MRLs for milks. Meat and offal residues would not exceed the current MRLs under such a feeding regime. Data from the other animal transfer studies indicated that cattle can be fed diets containing up to 170 ppm paraquat ion on a daily basis without exceeding current MRLs. The submitted studies have indicated the depletion of residues once access to paraquat has ceased with no residues were observed in tissues after a depuration period of 12-13 days.

It is concluded that the following mammalian commodity MRLs which are currently in the MRL standard remain appropriate:

MO 0105 Edible offal (mammalian)	0.5 mg/kg
MM 0095 Meat (mammalian)	*0.05 mg/kg
ML 0106 Milks	*0.05 mg/kg

As residues in tissues will meet current MRLs without the requirement for a slaughter (clean feed) interval, the 3 day slaughter interval can be removed from the grazing WHP statement. A one day grazing withholding period remains appropriate for livestock other than horses.

In relation to the slaughter (clean feed) interval, it is noted that residues in kidney plateaued at higher levels than in tissue. The HR in kidney after feeding at 170 ppm was 0.24 mg/kg. The estimated residue in kidney from feeding at the dietary burden for beef cattle of 250 ppm is 0.35 mg/kg. Residues in kidney were <0.04 mg/kg after 12 days on clean feed, the first sampling point after initial feeding at 170 ppm. The estimated half-life in kidney is therefore ≤4.64 days. It would take ≤13 days for the estimated kidney residue of 0.35 mg/kg to decline to the Codex mammalian offal MRL of 0.05 mg/kg.

To prevent an undue risk to international trade, it is considered appropriate to conduct a contemporary assessment of an Export Slaughter Interval (ESI) noting MRLs for animal commodities are not established in the EU and Korea, and that the Codex Edible offal (mammalian) MRL is 0.05 mg/kg (see Section 4). The available data suggests that after 13 days on clean feed, paraquat residues in kidney should be below 0.05 mg/kg, which is the Codex MRL. A 13 day ESI is recommended to prevent an undue risk to international trade of mammalian offal.

The following label statements are appropriate:

LIVESTOCK DESTINED FOR EXPORT MARKETS

The grazing withholding period only applies to stock slaughtered for the domestic market. Some export markets apply different standards. To meet these standards, ensure that in addition to complying with the grazing withholding period, the export slaughter interval is observed before stock are sold or slaughtered.

EXPORT SLAUGHTER INTERVAL (ESI) 13 DAYS

Livestock that has grazed on or been fed treated crops should be placed on clean feed for 13 days prior to slaughter

Crop rotation

Studies undertaken with radiolabelled paraquat applied to soil at 1.3x (1.05 kg ac/ha) and 20x (14.3 – 14.7 kg ac/ha) maximum label rates in which wheat, lettuce and carrot were subsequently planted indicated that detectable residues would not present in the plant commodities of following crops (Vickers et al, 1990; Wilkinson, 1980). Consideration of MRL coverage for following or plant back intervals is not required from a residues perspective.

Spray drift

Paraquat labels indicate application should be by ground application only. Droplet sizes are often not specified, some labels indicate droplets in the medium diameter range should be used.

The Regulatory Acceptable Level (RAL) and the buffer zones for livestock areas for the protection of international trade are assessed and set by the Residues and Trade section of the APVMA.

It is noted that the risk through spray drift is only for offal and that appropriate offal MRLs are established in Japan, Taiwan and the USA. However, offal MRLs are not established in the EU or Korea and the Codex Edible offal (mammalian) MRL is at 0.05 mg/kg. In an available dairy cattle transfer study, feeding at 25 ppm gave a high residue of 0.13 mg/kg in kidney. The feeding level for residues in kidney to be at the Codex Edible offal (mammalian) MRL of 0.05 mg/kg is 9.62 ppm.

Dietary risk assessment

The following health standards have been established in the APVMA ADI and ARfD lists, as of 18 December 2023 and by the JMPR (2003).

Table 16: Health Standards established for paraquat

Compound	Dietary standard, mg/kg bw		No Observable Adverse Effect Level (NOAEL), mg/kg bw (study)	Uncertainty factor	Reference/date set
Paraquat (as cation)	ADI	0.004	0.45 (1-year dog)	100	APVMA 27 June 2003
	ARfD	0.004	0.45 (1-year dog)	100	APVMA 27 June 2003
Paraquat (ion)	ADI	0.005	0.45 (1-year dog)	100	JMPR (2003)
	ARfD	0.006	0.55 (13-week dog)	100	JMPR (2003)

Chronic dietary exposure assessment

The chronic dietary exposure to paraquat is estimated by the National Estimated Daily Intake (NEDI) calculation encompassing all registered/temporary uses of the chemical and the mean daily dietary consumption data derived primarily from the 2011-12 National Nutritional and Physical Activity Survey. The NEDI calculation is made in accordance with WHO Guidelines (WHO, 2008) and is a conservative estimate of dietary exposure to chemical residues in food. The NEDI for paraquat is equivalent to <20% of the Australian ADI.

It is concluded that the chronic dietary exposure of paraquat is acceptable.

Acute dietary exposure assessment

The acute dietary exposure is estimated by the National Estimated Short Term Intake (NESTI) calculation. The NESTI calculations are made in accordance with the deterministic method used by the JMPR with 97.5th percentile food consumption data derived primarily from the 2011–12 National Nutritional and Physical Activity Survey. NESTI calculations are conservative estimates of short-term exposure (24 hour period) to chemical residues in food.

The highest acute dietary intake was estimated at <80% of the Australian ARfD for the uses supported by this evaluation. It is concluded that the acute dietary exposure is acceptable.

It is noted that if residues in potatoes were at the current MRL of 0.2 mg/kg the acute dietary exposure for children would be equivalent to 171% of the ARfD. It is also noted that if an application timing of 14 days before digging was considered for potatoes then the scaled HR of 0.13 mg/kg would give an unacceptable acute dietary exposure for children (111% of the ARfD). The estimated acute exposure associated with the scaled HR of 0.09 mg/kg for the supported use (application 4-5 weeks before digging) is however acceptable (77% of the ARfD for children and 32% of ARfD for general population).

Trade

Table 17: Overseas MRLs established for major export commodities (December 2023)

Commodity	Australia	Codex ⁶	EU ⁷	Japan ⁸	Korea ⁹	Taiwan ¹⁰	USA ¹¹
Residue definition	Paraquat cation	Paraquat cation	Paraquat	Paraquat	-	-	Calculated as the cation
Cereal grains	*0.05 (proposed) Current: 0.1 (maize) 10 (rice) 0.5 (rice, polished) *0.05 (other cereals)	0.03 (maize) 0.05 (maize flour) 0.05 (rice) 0.03 (sorghum)	*0.02 (barley, maize, oat, rye, wheat) 0.05 (rice)	0.1 (brown rice) 0.05 (wheat) 0.05 (barley) 0.05 (rye) 0.1 (corn)	0.05 (rice) 0.03 (corn)	0.03 (corn) 0.2 (rice) 0.03 (sorghum)	0.05 (barley) 0.1 (corn, field, grain) 0.05 (rice, grain) 1.1 (wheat grain)
Cotton seed	0.2 (current)	2	*0.02	0.2	2.0	-	3.5
Oilseed {except cotton seed}	*0.05 (current)	2 (sunflower seed)	*0.02	0.05 (rapeseeds)	-	-	2 (sunflower seed)

⁶ Food and Agriculture Organisation of the United Nations (FAO), 2023. [Codex Alimentarius, International Food Standards](#), FAO website, accessed December 2023.

⁷ European Commission (EC), [EU Pesticides Database](#), EC website, accessed December 2023.

⁸ Japanese Food Chemistry Research Foundation (JFCRPF), 2023. [Table of MRLs for Agricultural Chemicals](#), JFCRPF website, accessed December 2023.

⁹ Ministry of Food and Drug Safety Korea, 2023. [MRLs in Pesticides](#), accessed December 2023.

¹⁰ Laws & Regulations Database of the Republic of China (Taiwan), 2023. [Standards for Pesticide Residue Limits in Foods](#), accessed December 2023.

¹¹ Electronic Code of Federal Regulations (eCFR), 2023. [USA Electronic Code of Federal Regulations](#), eCFR website, accessed December 2023.

Commodity	Australia	Codex ⁶	EU ⁷	Japan ⁸	Korea ⁹	Taiwan ¹⁰	USA ¹¹
Pulses	1 (chickpeas, faba beans, field peas, lentils, lupins) *0.05 (others)(proposed) 1 (current for all pulses)	0.5 (pulses)	*0.02	0.05 (beans, dried) 0.05 (other legumes / pulses) 0.1 (soya bean)	0.2 (soya bean)	0.5 (soya bean)	0.3 (lentil, seed) 0.3 (pea and bean, dried and shelled except soybean, guar bean) 0.7 (soya bean)
Sugar cane	*0.05 (current)	-	*0.02	0.3	-	-	0.5
Berries and other small fruits (grapes)	*0.01 (proposed) Current: *0.05 (Fruits, except olives)	0.01	*0.02 (grapes)	0.05		0.01 (grape)	0.05 (grape)
Citrus fruit	*0.01 (proposed) Current: *0.05 (Fruits, except olives)	0.02	*0.02	0.05	-	-	0.05
Pome fruit	*0.01 (proposed) Current: *0.05 (Fruits, except olives)	0.01	*0.02	0.05	-	0.01	0.05
Stone fruit	*0.01 (proposed) Current: *0.05 (Fruits, except olives)	0.01	*0.02	0.05	-	0.01 (cherry, nectarine, peach, plum, prune))	0.05
Edible offal (mammalian)	0.5 (current)	0.05	-	0.3 (cattle liver) 0.5 (cattle kidney)	-	0.5 (kidney) 0.05 (edible offal except kidney)	0.5 (cattle kidney) 0.05 (cattle meat by-products, except kidney)
Meat [mammalian]	*0.05 (current)	0.005	-	0.05 (cattle muscle) 0.05 (cattle fat)	-	0.05	0.05 (cattle meat) 0.05 (cattle fat)
Milks	*0.01 (current)	0.005	-	0.01	-	0.01	0.01

Export of treated produce containing finite (measurable) residues of paraquat may pose a risk to Australian trade in situations where (i) no residue tolerance (import tolerance) is established in the importing country or (ii) where residues in Australian produce are likely to exceed a residue tolerance (import tolerance) established in the importing country.

The MRL changes proposed as part of this review are in general new MRLs at the LOQ for analytical methods (cereal grains, oilseed (except cotton), pulses (except chickpeas, faba beans, field peas, lentils and lupins)) and various fruit crops). The risk to trade in these commodities is low.

For cottonseed and specified pulses (chickpeas, faba beans, field peas, lentils and lupins) MRLs will remain in place at the same levels. The cotton MRL at 0.2 mg/kg is lower than that established by Codex and the USA and at the same level as those established in Japan and Korea. The chickpea, faba bean, field pea, lentil and lupin MRLs at 1 mg/kg are higher than tolerances established overseas, however the risk is unchanged to that which has currently been managed. The National Residues Survey (NRS) has not detected residues in field peas or lentils at $> \frac{1}{2}$ MRL in the last 3 years.

No changes have been recommended to the sugar cane MRL (at *0.05 mg/kg) with only the pre-planting use supported. The risk to trade in sugar is therefore reduced.

No changes have been proposed to the current animal commodity MRLs for paraquat. The meat and milk MRLs are at the LOQ, while the edible offal (mammalian) MRL is at the same level as those established for cattle kidney in Japan, Taiwan and the USA. However, MRLs for animal commodities are not established in the EU and Korea, and the Codex Edible offal (mammalian) MRL is 0.05 mg/kg. As finite residues may occur in mammalian offal as a result of the proposed use in pasture and hay, an Export Slaughter Interval (ESI) is recommended. The available data suggests that after 13 days on clean feed, paraquat residues should be below 0.05 mg/kg, which is the Codex MRL. A 13 day ESI is recommended to prevent an undue risk to international trade of mammalian offal.

Oaten hay is also a major export commodity, noting that an MRL of 500 mg/kg has been supported for paraquat on Primary feed commodities. An animal feed MRL of 5 mg/kg has been established for paraquat on grass in Japan. This risk to trade is unchanged.

For cotton seed, specified pulses (chickpeas, faba beans, field peas, lentils and lupins) and oaten hay, finite residues of paraquat are expected from the Australian uses. As the potential trade risk associated with paraquat residues expected in cottonseed, specified pulses (chickpeas, faba beans, field peas, lentils and lupins) and oaten hay have been managed by industry, and because international standards for paraquat have not significantly changed in recent years, it is currently considered that the trade risk associated with the uses of paraquat in cotton, pulses and oaten hay is not undue. However, as the Australian MRLs are higher than those set by Codex or major export destinations, it is recommended that:

The following Trade Advice statement should be added to the labels of products containing pre-harvest uses on cottonseed and specified pulses (chickpeas, faba beans, field peas, lentils and lupins) and the 'hay-freezing' use:

EXPORT OF TREATED PRODUCE: Growers should note that maximum residue limits (MRLs) or import tolerances may not exist in all markets for [edible produce name] treated with [chemical product name]. If you are growing [edible produce name] for export, please check with [company name, industry body, etc.] for the latest information on MRLs and import tolerances before using [chemical product name].

As the Australian MRLs for cotton seed and pulses are higher than some of those set by Codex and major export destinations, the APVMA should seek comments from members of the grain, fodder and cotton industries on their ability to manage the risk to international trade associated with paraquat during the Proposed Regulatory Decision consultation for paraquat before a final decision against the trade criteria is made for pre-harvest uses on cottonseed and specified pulses (chickpeas, faba beans, field peas, lentils and lupins) and the 'hay-freezing' use.

Conclusions from the residues and trade assessment

The Residues and Trade section recommends that the APVMA should be satisfied that the continued approval of the use patterns as currently described would not pose an undue hazard to the safety of people consuming anything containing its residues, according to the safety criteria as defined by Section 5A nor an undue risk to international trade as described by Section 5C of the Schedule to the Code Act, with the following exceptions:

Potato: No data were available to support the ongoing use of paraquat as a pre-harvest weed control application on potatoes 3-7 days before digging. There was sufficient residues data relevant to support an application timing of 14 days before digging, however, the scaled HR (0.13 mg/kg) would give an unacceptable acute dietary exposure for children (111% of ARfD). Application to potatoes 14 days (or less) before digging therefore cannot be supported due to acute consumer safety concerns. It is therefore recommended that labels that currently have the '3 to 7 days before digging and after tops have died down' instruction must be changed to state that application must occur '4-5 weeks before digging'.

Sugar cane: No residues data were available to support the ongoing use of paraquat as a post-emergent over the top application to sugar cane this use should be removed due to a lack of relevant residues data.

Expression of crop groups: The following crops were considered against the broad claims for orchards (including bananas) and vineyards and row crops, vegetables and market gardens:

- Orchards (including bananas) and vineyards:
 - Citrus, grapes, pome fruit, stone fruit, tree nuts, tropical fruit (edible peel), tropical fruit (inedible peel, except pineapple)
- Row crops, vegetables and market gardens:
 - Berries and other small fruit (except grapes) brassica vegetables, bulb vegetables, fruiting vegetables (cucurbits), fruiting vegetables (other than cucurbits), leafy vegetables, legume vegetables, pineapple, root and tuber vegetables; stalk and stem vegetables, herbs and spices

The directions for use tables on product labels should be amended to indicate the specified crops/crop groups as above for the orchards (including bananas) and vineyards, and row crops, vegetables and market gardens uses. The broad terms of 'orchards (including bananas) and vineyards' and 'row crops, vegetables and market gardens uses' should be removed from labels as they are not directly linked to contemporary APVMA crop group guidelines.

The following withholding periods and trade advice statements are supported by this evaluation:

- A 14-day harvest withholding period is recommended for the spray topping use on chickpeas, faba beans, field peas, lentils, lupins (some labels currently have 7 days, while others have 14 days)

- A 7 day harvest withholding period remains appropriate for the pre-harvest desiccation use on cotton
- In the absence of relevant data for cotton trash or fodder, the restraint of 'DO NOT feed cotton fodder, stubble or trash to livestock' is recommended for cotton uses.
- Recommended harvest withholding periods for all other uses are 'Not required when used as directed' for pre-emergent or pre-sowing applications (and for post emergent application in peanuts up to 7–8 leaf stage, potatoes no later than 25% emergence and potatoes at 4–5 weeks before digging) and for post-emergent directed applications

No changes to the intent of the current grazing withholding periods are required, however language changes are recommended based on the current Agricultural labelling code. The slaughter interval should be replaced with a 13 day ESI. The following label statements are recommended:

- LIVESTOCK: DO NOT GRAZE OR CUT FOR STOCK FOOD FOR 1 DAYS AFTER APPLICATION
- HORSES: DO NOT GRAZE OR CUT FOR STOCK FOOD FOR 7 DAYS AFTER APPLICATION
- LIVESTOCK DESTINED FOR EXPORT MARKETS

The grazing withholding period only applies to stock slaughtered for the domestic market. Some export markets apply different standards. To meet these standards, ensure that in addition to complying with the grazing withholding period, the export slaughter interval is observed before stock are sold or slaughtered.

- EXPORT SLAUGHTER INTERVAL (ESI) 13 DAYS

Livestock that has grazed on or been fed treated crops should be placed on clean feed for 13 days prior to slaughter

- The following Trade Advice statement should be added to the labels of products containing pre-harvest uses on cottonseed and specified pulses (chickpeas, faba beans, field peas, lentils and lupins) and the 'hay-freezing' use:

EXPORT OF TREATED PRODUCE: Growers should note that maximum residue limits (MRLs) or import tolerances may not exist in all markets for [edible produce name] treated with [chemical product name]. If you are growing [edible produce name] for export, please check with [company name, industry body, etc.] for the latest information on MRLs and import tolerances before using [chemical product name].

As the Australian MRLs for cotton seed, pulses and oaten hay are higher than some of those set by Codex and major export destinations, the APVMA will need to seek comments from members of the grain, fodder and cotton industries on their ability to manage the risk to international trade associated with paraquat during the Proposed Regulatory Decision consultation for paraquat before a final decision against the trade criteria is made for pre-harvest uses on cottonseed and specified pulses (chickpeas, faba beans, field peas, lentils and lupins) and the 'hay-freezing' use.

The following amendments should be made to the Agricultural and Veterinary Chemicals (MRL Standard for Residues of Chemical Products) Instrument 2023, should all the uses supported in this Residues and Trade assessment of paraquat be supported by the APVMA chemical review:

Table 18: Amendments to Table 1 of the MRL Standard

Code	Commodity	Current MRL	Recommended MRL
FT 0026	Assorted tropical and sub-tropical fruits – edible peel	-	*0.05
FI 0030	Assorted tropical and sub-tropical fruits – inedible peel	-	*0.01
FB 0018	Berries and other small fruits	-	*0.01
VB 0040	Brassica (cole or cabbage) vegetables, head cabbages Flowerhead brassicas	-	*0.03
VD 0523	Broad bean (dry), [faba bean (dry)]	-	1
VA 0035	Bulb vegetables	-	*0.01
GC 0080	Cereal grains [except maize; rice]	*0.05	Delete
GC 0080	Cereal grains	-	*0.05
VD 0524	Chick-pea (dry)	-	1
FC 0001	Citrus fruits	-	*0.01
SO 0691	Cotton seed	0.2	0.2
OR 0691	Cotton seed oil, edible	0.05	Delete
MO 0105	Edible offal (Mammalian)	0.5	0.5
PE 0112	Eggs	*0.01	*0.01
VD 0561	Field pea (dry)	-	1
VC 0045	Fruiting vegetables, cucurbits	-	*0.03
VO 0050	Fruiting vegetables, other than cucurbits	-	*0.01
	Fruits [except olives]	*0.05	Delete
HH 0092	Herbs	-	*0.05
DH 1100	Hops, dry	0.2	*0.05
VL 0053	Leafy vegetables	-	*0.02
VP 0060	Legume vegetables	-	*0.05
VD 0533	Lentil (dry)	-	1
VD 0545	Lupin (dry)	-	1
GC 0645	Maize	0.1	Delete

MM 0095	Meat [mammalian]	*0.05	*0.05
ML 0106	Milks	*0.01	*0.01
SO 0088	Oilseed [except cotton seed; peanut]	*0.05	Delete
SO 0088	Oilseed {except cotton seed}	-	*0.05
FT 0305	Olives	1	Delete
SO 0697	Peanut	*0.01	Delete
SO 0703	Peanut, whole	*0.01	Delete
FP 0009	Pome fruits	-	*0.01
VR 0589	Potato	0.2	0.2
PO 0111	Poultry, edible offal of	*0.05	*0.05
PM 0110	Poultry meat	*0.05	*0.05
VD 0070	Pulses	1	Delete
VD 0070	Pulses {except broad bean (dry); Chick-pea (dry); Field pea (dry); lentil (dry); lupin (dry)}	-	*0.05
GC 0649	Rice	10	Delete
CM 1205	Rice, polished	0.5	Delete
VR 0075	Root and tuber vegetables {except Potato}	-	*0.01
HS 0093	Spices	-	*0.05
VS 0078	Stalk and stem vegetables	-	*0.05
FS 0012	Stone fruits	-	*0.01
GS 0659	Sugar cane	*0.05	*0.05
TN 0085	Tree nuts	*0.05	*0.01
	Vegetables [except potato; pulses]	*0.05	Delete
OR 0172	Vegetable oils, edible	-	*0.05

Table 19: Amendments to Table 4 of the MRL Standard

Code	Animal feed commodity	Current MRL	Recommended MRL
	Primary feed commodities	500	500
	Almond hulls	-	0.2

Consideration of proposed APVMA chemical review outcomes for paraquat

The APMVA's risk assessments for human and environmental exposure to paraquat based on currently approved uses indicate that many of those uses will not continue to be supported. The uses that are supported are presented in Table 20 and Table 21 below. These uses are within the application rate range indicated on currently approved labels.

Table 20: Paraquat uses supported by human health, environment, and residues and trade risk assessments

Crop Use or Situation	Weeds controlled / Use	Application Method	Assessment outcome
Aid to cultivation; crop, pasture or fallow establishment	Wild oats at 2–5 leaf stage (autumn/winter) low rate	Boomspray	Supported (up to 231 g ac/ha per season)
Bananas	Annual grasses and broadleaf weeds	Spot spray	Supported (up to 175 g ac/ha per season)
Peanuts (up to 7–8 leaf stage)	Annual ground cherry (2–3 leaf), apple-of-Peru (2–4 leaf), milkweed (2–3 leaf)	Boomspray	Supported (up to 231 g ac/ha per season)
	Bellvine (2–3 leaf), common morning glory (2 leaf)		
	Datura spp. (2–4 leaf)		
	Stagger weed (2–3 leaf), blue heliotrope (2–3 leaf), wandering jew (2–3 leaf), anoda weed (2–4 leaf)		
Rice	Post-sowing, pre-crop emergence annual grass and broadleaf weed control	Boomspray	Supported up to 231 g ac/ha per season
Spray topping to reduce seed set (field peas, lupins, lentils, chickpeas, faba beans)	Annual ryegrass	Boomspray	Supported up 149 g ac/ha per season

Table 21: Paraquat and diquat combination uses that are supported by human health, environment and residues and trade risk assessments

Crop	Weeds Controlled / Use	Application Method	Assessment outcome (risk area)
<p>Aid to cultivation (Southern Australia - full disturbance)</p> <p><u>Winter</u></p> <p>Canola, chickpeas, wheat, barley, oats, rye, triticale, field beans, field peas, lentils, linseed (Linola), lupins, vetch</p> <p><u>Spring/summer</u></p> <p>Fodder rape, pigeon peas, safflower, sorghum, soybeans, sunflower</p> <p><u>Pasture</u></p> <p>Clover grass, lucerne, medics</p>	<p>Seedling grasses: annual ryegrass (<i>Lolium rigidum</i>), barley grass (<i>Hordeum</i> spp.), brome grass (<i>Bromus</i> spp.), volunteer cereals, wild oats (<i>Avena</i> spp.) (2–3 leaf)</p> <p>Vulpia (Silver Grass, Sand Fescue) (<i>Vulpia</i> spp.) (2–3 leaf)</p>	Boomspray	Supported up to 175 g/ha of combined active constituents per season (700 mL of product/ha)

Aid to cultivation; crop, pasture or fallow establishment (supported use: 231 g ac/ha)

Crops included on product labels are: canola, chick peas, cereals (wheat, barley, oats, rye, triticale, sorghum, maize, millet), cotton, field beans, field peas, lentils, linseed, lupins, fodder rape, mungbeans, navy beans, peanuts, pigeon peas, safflower, soybeans, sunflower, pasture (clover, grass, lucerne, medic), vetch. Other products indicate the use for crop, pasture or fallow establishment.

The Cereal grain MRL recommended earlier at the LOQ of *0.05 mg/kg would remain appropriate for the supported use as a cultivation aid at a maximum rate lower than currently registered.

For Pulses other than those with a spray topping use (see below) the MRL recommended earlier at the LOQ of *0.05 mg/kg would remain appropriate for the supported use as a cultivation aid at a maximum rate lower than currently registered.

The LOQ MRL at *0.05 mg/kg recommended for Oilseeds {except Cotton seed} would remain appropriate for the supported use as a cultivation aid at a maximum rate lower than currently registered. As the pre-harvest desiccation use on Cotton is not supported by the environmental assessment the higher Cotton MRL is not required so the MRL at *0.05 mg/kg can be for all oilseeds for the cultivation aid use. This MRL will also cover the supported use on peanuts below.

The supported harvest withholding period for these uses is “Not required when used as directed”. The supported grazing withholding period is discussed below.

Bananas (supported use: 175 g ac/ha)

For general weed control in bananas application of paraquat at 25 g ac/100 L to a maximum spray volume of 700 L/ha (0.175 kg ac/ha) through a hand wand is supported.

Overseas residue data on bananas from Honduras involved one to three applications at rates between 1.4 and 2.8 kg ac/ha found no paraquat residues above the LOQ (0.01 mg/kg) in fruit at PHIs from 0 – 90 days.

An MRL of *0.01 mg/kg for FI 0327 Banana is supported to cover this banana use pattern which was supported by the environment assessment. A harvest withholding period of “Not required when used as directed” is supported as the spray is not directed at the crop.

Peanuts (supported use: 231 g ac/ha)

The supported use on peanuts from the environmental assessment was for application at up to the 7-8 leaf stage at 231 g ac/ha. The supported rate change is within 25% of the maximum registered rate. The previous recommendations with respect to peanuts remain appropriate and the use will be covered by the Oilseeds MRL recommended above at *0.05 mg/kg.

A harvest withholding period statement of ‘NOT required when used as directed’ is appropriate as the use is only permitted up to the 7-8 leaf stage. The supported grazing withholding period is discussed below.

Spray topping to reduce seed set (Field peas, Lupins, Lentils, Chickpeas, Faba Beans. Supported use: 149 g ac/ha)

The use pattern for spray topping to control seed set of annual rye grass in field peas, lupins, lentils, chickpeas and faba beans, supported by the environmental assessment, is at a reduced maximum rate of 149 g ac/ha compared to the maximum currently registered rate of 200 g ac/ha. The supported change in application rate is therefore approximately at the 25% limit which is considered equivalent from a residues perspective. Australian trials with chick peas, field peas and lupins at 0.2 and 0.4 kg ac/ha found residues in seed were up to 0.41 mg/kg at the label rate and up to 0.54 mg/kg at double the maximum application rate following a 14 day PHI. Residues at 14-15 day PHI (or later if higher) following one application at 0.2 kg ac/ha were 0.05, 0.1, 0.31 and 0.41 mg/kg. Given the limited dataset that relies on residues remaining within the MRL for the higher application rates, the previously recommended MRLs in relation to pulses will remain appropriate for the supported use at the lower rate:

The recommended entries into the MRL Standard for pulses are as follows noting that the most common LOQ in the available pulse trials was 0.05 mg/kg:

VD 0070 Pulses {except Broad bean (dry); Chick-pea (dry); Field pea (dry); Lentil (dry); Lupin (dry)}	*0.05 mg/kg
VD 0523 Broad bean (dry) [faba bean (dry)]	1 mg/kg

VD 0524 Chick-pea (dry)	1 mg/kg
VD 0561 Field pea (dry)	1 mg/kg
VD 0533 Lentil (dry)	1 mg/kg
VD 0545 Lupin (dry)	1 mg/kg

As before, the data supports a 14 day withholding period for the spray topping use at 149 g ac/ha for chickpeas, faba beans, field peas, lentils and lupins. For labels with a 7 day withholding period for this use pattern, the withholding period should be changed to 14 days as there was insufficient residues data addressing a 7 day withholding period. For other pulses the supported withholding period is “Not required when used as directed” as the use would be pre-emergent or directed to inter row weeds. The supported grazing withholding period is discussed below.

Rice

The use on rice supported by the environmental risk assessment was the maximum post-sowing, pre-crop emergence use on the current labels of 200 g ac/ha. A use on rice pre-crop emergence at 200 g ac/ha as registered should not require any changes to the earlier recommended Cereal grains MRL at the LOQ at *0.05 mg/kg.

A harvest withholding period statement of ‘NOT required when used as directed’ is appropriate for rice as the use is pre-sowing or post sowing / pre-crop emergence. The supported grazing withholding period is discussed below.

Required animal commodity MRLs

In pre-emergence grass pasture, trials from the US indicate that at current Australian rates up to 600 g ac/ha, no detectable residues in grass forage or hay would be expected. No finite residues are expected in cereal grain forage or fodder as the use pattern is solely a pre-emergent/pre-sowing one. A similar outcome is expected for oilseeds. The maximum residue in fodder or straw of pulses was 12 mg/kg following the Australian GAP. Residue data for peanut hay which can form 60% of the diet for beef and dairy cattle are not available. Highest residues in lucerne and clover forage and fodder after application at 600 g ac/ha were similar at 170 – 180 mg/kg (dry weight), although higher residues were observed in birdsfoot trefoil. Extrapolating the lucerne and clover data and scaling to the maximum application rate for peanuts of 231 g ac/ha the estimated HR in peanut forage and fodder is 69.3 mg/kg (dry weight).

Mammalian animal commodity MRLs for paraquat should also be considered to cover the potential for livestock grazing in treated banana plantations. As an application rate of 550 g ac/ha gave a residue of up to approximately 220 mg/kg (dry weight) in grass hay, the scaled HR in grass/weeds around banana plantations for the supported rate of 175 g ac/ha is 70 mg/kg (dry weight).

The paraquat Primary Feed Commodities MRL at 500 mg/kg can be reduced to 100 mg/kg should the only supported use in animal feeds apart from pre-emergent application, be for interrow plants in banana plantations, post emergent treatment of peanuts or for spray-topping selected pulse crops.

The worst-case animal feeding burden (assuming 100% of the diet of mammalian livestock was from banana plantations) is 70 ppm. In available animal transfer studies, feeding at 80 ppm gave a HR in kidney of 0.31 mg/kg, noting that residues in kidney plateaued at higher doses (so the MRLs would also be appropriate for higher dietary burdens). It is concluded that the following mammalian commodity MRLs which are currently in the MRL standard remain appropriate:

MO 0105 Edible offal (mammalian)	0.5 mg/kg
MM 0095 Meat (mammalian)	*0.05 mg/kg
ML 0106 Milks	*0.05 mg/kg

The following label statements are recommended:

LIVESTOCK: DO NOT GRAZE OR CUT FOR STOCK FOOD FOR 1 DAYS AFTER APPLICATION.

HORSES: DO NOT GRAZE OR CUT FOR STOCK FOOD FOR 7 DAYS AFTER APPLICATION.

LIVESTOCK DESTINED FOR EXPORT MARKETS

The grazing withholding period only applies to stock slaughtered for the domestic market. Some export markets apply different standards. To meet these standards, ensure that in addition to complying with the grazing withholding period, the export slaughter interval is observed before stock are sold or slaughtered.

EXPORT SLAUGHTER INTERVAL (ESI) 13 DAYS

Livestock that has grazed on or been fed treated crops should be placed on clean feed for 13 days prior to slaughter

The poultry commodity MRLs for paraquat at the LOQ can remain in place to indicate that residues should not occur in poultry commodities due to the supported uses. All other MRLs for paraquat can be deleted as no other uses are supported.

Trade

For specified pulses (chickpeas, faba beans, field peas, lentils and lupins) MRLs will remain in place at the same levels. The chickpeas, faba beans, field peas, lentils and lupins MRLs at 1 mg/kg are higher than tolerances established overseas, however the risk is unchanged to that which has currently been managed. The National Residue Survey has not detected residues in field peas or lentils at > ½ MRL in the last 3 years.

For pulses (other than those specified above), cereals, and oilseeds MRLs have been recommended at the analytical method LOQ as finite residues are not expected to occur. The risk to trade in these commodities should be low.

Bananas are not considered to be a major export commodity and finite residues are not expected to occur in fruit. Therefore, the trade risk associated with the banana use is not considered to be undue and is acceptable.

The recommended ESI will ensure there are no detectable residues in any animal commodities from livestock allowed to graze treated crops or in banana plantations.

Revised dietary exposure assessment

Chronic dietary exposure assessment

The chronic dietary exposure to paraquat is estimated by the National Estimated Daily Intake (NEDI) calculation encompassing all registered/temporary uses of the chemical and the mean daily dietary consumption data derived primarily from the 2011-12 National Nutritional and Physical Activity Survey. The NEDI calculation is made in accordance with WHO Guidelines and is a conservative estimate of dietary exposure to chemical residues in food. The NEDI for paraquat is equivalent to <15% of the Australian ADI, for the uses proposed to be supported by the APVMA chemical review. It is concluded that the chronic dietary exposure to paraquat is acceptable.

Acute dietary exposure assessment

The acute dietary exposure is estimated by the National Estimated Short Term Intake (NESTI) calculation. The NESTI calculations are made in accordance with the deterministic method used by the JMPR with 97.5th percentile food consumption data derived primarily from the 2011-12 National Nutritional and Physical Activity Survey. NESTI calculations are conservative estimates of short-term exposure (24 hour period) to chemical residues in food.

The highest acute dietary intake was estimated at <50% of the Australian ARfD for the uses proposed to be supported by the APVMA chemical review. It is concluded that the acute dietary exposure to paraquat is acceptable.

Revised MRL recommendations

The following amendments should be made to the Agricultural and Veterinary Chemicals (MRL Standard for Residues of Chemical Products) Instrument 2023, at the end of any phase out period, to reflect uses which are proposed to remain at the completion of the APVMA chemical review.

Table 22: Amendments to Table 1 of the MRL Standard

Code	Commodity	Current MRL	Recommended MRL
FI 0327	Banana	-	*0.01
VD 0523	Broad bean (dry) [faba bean (dry)]	-	1
GC 0080	Cereal grains [except maize; rice]	*0.05	Delete
GC 0080	Cereal grains	-	*0.05
VD 0524	Chick-pea (dry)	-	1

70 Paraquat Review Technical Report

SO 0691	Cotton seed	0.2	Delete
OR 0691	Cotton seed oil, edible	0.05	Delete
MO 0105	Edible offal (Mammalian)	0.5	0.5
PE 0112	Eggs	*0.01	*0.01
VD 0561	Field pea (dry)	-	1
	Fruits [except olives]	*0.05	Delete
DH 1100	Hops, dry	0.2	Delete
VD 0533	Lentil (dry)	-	1
VD 0545	Lupin (dry)	-	1
GC 0645	Maize	0.1	Delete
MM 0095	Meat [mammalian]	*0.05	*0.05
ML 0106	Milks	*0.01	*0.01
SO 0088	Oilseed [except cotton seed; peanut]	*0.05	Delete
SO 0088	Oilseed	-	*0.05
FT 0305	Olives	1	Delete
SO 0697	Peanut	*0.01	Delete
SO 0703	Peanut, whole	*0.01	Delete
VR 0589	Potato	0.2	Delete
PO 0111	Poultry, Edible offal of	*0.05	*0.05
PM 0110	Poultry meat	*0.05	*0.05
VD 0070	Pulses	1	Delete
VD 0070	Pulses {except Broad bean (dry); Chick-pea (dry); Field pea (dry); Lentil (dry); Lupin (dry)}	-	*0.05
GC 0649	Rice	10	Delete
CM 1205	Rice, polished	0.5	Delete
GS 0659	Sugar cane	*0.05	Delete
TN 0085	Tree nuts	*0.05	Delete
	Vegetables [except Potato; Pulses]	*0.05	Delete

Table 23: Amendments to Table 4 of the MRL Standard

Code	Animal feed commodity	Current MRL	Recommended MRL
	Primary feed commodities	500	100

Environmental safety

Assessment scenarios

Paraquat products are registered for general weed control in a broad range of situations at rates ranging from 200 g ac/ha for spray topping to 2250 g ac/ha in fallow. Most applications in crops are before planting or crop emergence (i.e. bare soil); however, applications can also occur at later crop stages and as directed sprays or inter-row.

There is one diquat/paraquat combination product that is registered as a pre-harvest desiccant in cotton at a paraquat rate of 216 g ac/ha. There are also diquat/paraquat combination products that are registered for general weed control at paraquat rates up to 432 g ac/ha in a broad range of situations, including crops, pasture, forestry, public service areas, and rights of way. Spot spray application is also approved in tropical fruit orchards up to 32.4 g ac/100L (each application is equivalent to 324 g ac/ha assuming a spray volume of 1000 L/ha). Assuming a maximum of 40% of an orchard is treated, environmental exposure across the entire orchard is equivalent to 130 g ac/ha.

There are also 4 amitrole/paraquat combination products that are registered for general weed control at paraquat rates up to 1250 g ac/ha in fallow (including aid to cultivation), 1125 g ac/ha in industrial vegetation management (firebreaks, sheds, roadways, paths), 600 g ac/ha in crops (orchards, vineyards, potatoes), and 300 g ac/ha in pasture (including spray topping and hay freezing).

The initial assessment addresses the risks of paraquat only; environmental risks of the diquat/paraquat are then assessed separately and the environmental risks of amitrole/paraquat combination products are then considered, noting that amitrole is not currently under reconsideration.

The environmental risk assessment scenarios considered in this assessment are summarised in the table below. Environmental risks were determined according to contemporary methodology outlined in the APVMA Risk Assessment Manual – Environment: <https://apvma.gov.au/node/46416>. All endpoints are expressed in terms of the paraquat cation as the active constituent.

Table 24: Paraquat – Environmental risk assessment scenarios

Category	Situation	Risk assessment scenario
General weed control	Fallow	1× 150–2250 g ac/ha
	Non-agricultural situations, around sheds, roadways, paths, firebreaks	1× 390–1140 g ac/ha
	Orchards, vineyards	1× 280–810 g ac/ha
	Bananas	1× 175–1120 g ac/ha
	Potatoes	1× 300–720 g ac/ha
	Pasture ¹²	1× 100–600 g ac/ha
	Lucerne, market gardens, row crops, vegetables	1× 300–1050 g ac/ha

¹² Includes spray topping to prevent ryegrass toxicity

Category	Situation	Risk assessment scenario
	Hops, sugarcane	1x 300–420 g ac/ha
	Rice	1x 200–420 g ac/ha
	Peanuts	1x 100–250 g ac/ha
	Spray topping in pulses	1x 100–200 g ac/ha
Combination products containing diquat	Cotton desiccation	1x 162–216 g ac/ha
	Spray topping in grasses	1x 108–203 g ac/ha
	Bananas, duboisia ¹³ , forests, public service areas, rights of way, market gardens, nurseries, potatoes, rice, vegetables	1x 324–432 g ac/ha
	Vineyards	1x 324–432 g ac/ha
	Forests, orchards, plantations	1x 216–432 g ac/ha
	Fallow (minimal disturbance)	2x 108–432 g ac/ha 7-day retreatment interval
	Fallow (full disturbance), lucerne	1x 81–432 g ac/ha
	Spot application in avocado, custard apples, lychees, mangos ¹⁴	2x 324–432 g ac/ha 14-day retreatment interval
	Sugarcane, pasture	1x 162–432 g ac/ha
Combination products containing amitrole	Fallow	1x 112–1250 g ac/ha
	Non-agricultural situations, around sheds, roadways, paths, firebreaks	1x 300–1125 g ac/ha
	Orchards, vineyards	1x 325–800 g ac/ha
	Potatoes	1x 525–700 g ac/ha
	Pasture, including hay freezing and spray topping	1x 75–400 g ac/ha

Fate and behaviour in the environment

Paraquat has low volatility and high solubility in water. Its octanol-water partition coefficient indicates low potential for bioaccumulation. In water paraquat readily dissociates into the paraquat cation.

Maximum residues of paraquat in insects ranged from 2.1 to 8.1 mg/kg one to 4 days after application at 1100 g ac/ha to melons and 1.4 to 12 mg/kg on day 2 after application at 1100 g ac/ha in an apple orchard. No residues were detected in seeds of wheat, corn or soybeans following application to soil at up to 114 kg ac/ha. The available residue data implies that paraquat will typically dissipate from arthropods more rapidly than assumed by default for animal food items (DT₅₀ 10 d). The most reliable arthropod DT₅₀ estimates are between 3.5 and 4.6 d. Other larger DT₅₀ estimates (DT₅₀ 7.6-14 d) have been calculated, however those model fits are considered less reliable and are based on fewer samples. For animal food items such as insects it is considered reasonably

¹³ Spot spray also possible in duboisia

¹⁴ Assuming a maximum of 40% of an orchard is treated, each application is equivalent to 130 g ac/ha across the entire orchard

conservative to set the DT₅₀ to 4.6 days (i.e. the most conservative of the most reliable values), given the uncertainties with the available data.

Paraquat's behaviour in soil has been well studied, see reviews in Sartori & Vidrio (2018) and Roberts et al, (2002) for a more expansive discussion of the available literature. In brief, under aerobic and anaerobic laboratory conditions in the dark, paraquat was very persistent and had no significant degradation with <0.1% mineralisation after 180 days in sandy loam soils. Under field conditions, long term continuous application resulted in increased soil concentrations over time. Paraquat was very persistent at sites in the UK, Malaysia and the United States (DT₅₀ 6.6-20 years), while much lower persistence has been reported at a site in Thailand (DT₅₀ 41 days). It is postulated that relatively high application rates (increasing bioavailability) in the Thailand study may have influenced the apparent increase in degradation rate. This is supported by the observed concentration dependant degradation rate of paraquat when in excess of SAC-WB values. It was also observed that the rate of loss was more rapid under field conditions where annual treatments were applied (21% remaining in soils) as opposed to single application high-rate treatments (48-58% remaining in soil).

The adsorption of paraquat to soil is very strong with concentration dependence and a positive linear relationship between clay content and K_d. Paraquat absorbed to clay minerals is biologically unavailable and highly stable, as it is not expected to undergo significant physical, chemical or biological degradation. Paraquat in pore water may be subject to degradation; primarily microbial, though photolysis may play a role in the upper soil layer.

Paraquat is stable to hydrolysis and aqueous photolysis. In water/sediment systems, paraquat partitions rapidly to particulate matter and sediment, where it is strongly sorbed, non-bioavailable, and very persistent. There is no apparent desorption of paraquat back into the water.

Based on a theoretical calculation of the potential for photo-oxidation of paraquat dichloride in the atmosphere, using a OH radical concentration of $1.5 \times 10^6 \text{ cm}^{-3}$ (12-hour day), a first order half-life of 0.25 days (6.0 hours) was estimated. However, paraquat concentrations in air following application would be negligible, given it is highly sorbed to soil and sediment, fully ionised in aqueous conditions, very soluble in water, and has low volatility.

Monitoring studies have been conducted investigating paraquat residues in soil after long-term treatment of various crops in Europe. The maximum concentration observed was 4.7 mg ac/kg dry soil after 10 years use in Italy. Due to uncertainty over the accuracy of the record keeping it is not possible to reliably compare the measured and predicted paraquat concentrations. However, the studies do imply that for many sites the observed paraquat was significantly below that predicted given the reported application rates. The soil samples for the water monitoring study in Thailand also indicated reduced rates of accumulation compared to predicted.

The key regulatory endpoints for the environmental exposure assessment are summarised in Table 25:

Paraquat – Key regulatory endpoints for exposure assessment. A full listing of endpoints is provided in Appendix B.

Table 25: Paraquat – Key regulatory endpoints for exposure assessment

Compartment	Value	Reference
Animal food items	Foliage: DT ₅₀ 10 d	Default
	Seeds:DT ₅₀ 10 d	
	Insects: DT ₅₀ 4.6 d	Bakker 2005a, 2005b

Compartment	Value	Reference
Soil	DT ₅₀ 1000 d Sand: K _d 480 mL/g Non-sands: K _d 9400 mL/g	Default for persistent substances Robbins et al, 1988
Water	DT ₅₀ 7.0 d	Long et al, 1996, Hamer & Ashwell 1997
Sediment	DT ₅₀ 1000 d K _p 50000 mL/g	Default for persistent substances Robbins et al, 1988
Air	DT ₅₀ 6.0 h	Hayes 2006

Effects on non-target species

Paraquat has high toxicity to mammals (lowest LD₅₀ 22 mg ac/kg bw, *Cavia porcellus*) and birds (lowest LD₅₀ 27 mg ac/kg bw, *Taeniopygia guttata*). Therefore, the following protection statement is required on paraquat product labels (followed by an appropriate risk management statement).

Toxic to birds and native mammals.

Following long-term dietary exposure, mammals exhibit 17–43% mortality at 7.5 mg ac/kg bw/d (NOAEL 3.8 mg ac/kg bw/d), which is considered the ecologically relevant endpoint from the study. An additional study is available where 24–37% mortality was observed at 14 mg ac/kg bw/d (NOAEL 7.2 mg ac/kg bw/d). Given the level of mortality observed at 7.5 mg ac/kg bw/d, the lower of the 2 NOAEL values is considered the relevant value for risk assessment.

For birds, reproductive toxicity has been tested in the mallard (*Anas platyrhynchos*), with an eighteen-week exposure period (10 weeks prior to full egg production and 8 weeks during full egg production). Biologically relevant reductions in eggs laid and numbers of viable/live embryos were observed at doses as low as 9.1 mg ac/kg bw/d (NOAEL 2.7 mg ac/kg bw/d).

Paraquat has moderate toxicity to fish (lowest LC₅₀ 4.7 mg ac/L, *Pimephales promelas*) and aquatic invertebrates (lowest LC₅₀ 0.23 mg ac/L, *Americamysis bahia*), and it has high toxicity to algae (lowest ErC₅₀ 0.00034 mg ac/L, *Navicula pelliculosa*) and aquatic plants (EC₅₀ 0.037 mg ac/L, *Lemna gibba*). Therefore, the following protection statement is required on paraquat product labels.

Very toxic to aquatic life. DO NOT contaminate wetlands or watercourses with this product or used containers.

Reduced growth of fish was observed at concentrations as low as 1.5 mg ac/L (NOEC 0.74 mg ac/L, *Pimephales promelas*), whilst reduced survival and reproduction was observed in aquatic invertebrates at concentrations as low as 0.076 mg ac/L (NOEC 0.038 mg ac/L, *Americamysis bahia*).

Paraquat has moderate toxicity to freshwater amphipods (LC₅₀ 39 mg ac/kg dry sediment, *Hyalella azteca*). It is noted that the clay content of the test sediment was relatively low (1%). Low toxicity was observed in midges (LC₅₀ >100 mg ac/kg dry sediment, *Chironomus dilutus*) and marine amphipods (LC₅₀ >100 mg ac/kg dry sediment, *Leptocheirus plumulosus*), noting the clay content in the test sediments ranged 20–25%. Following long-term exposure of midges, no significant adverse effects were observed at the highest tested concentrations in both

water-dosed (NOEC 0.38 mg ac/L, *Chironomus riparius*) or sediment-dosed (NOEC 68 mg ac/kg dry sediment, *C. riparius*) test systems with 14-20% clay content in the sediments.

Noting that primary producers, such as algae, are most sensitive to paraquat, an SSD analysis was performed on the toxicity data (EC₅₀ values) obtained in the absence of sediment. Paraquat dissipates quickly from the water column under natural conditions due to rapid adsorption to sediment and suspended particulates; therefore, the endpoints were adjusted to account for the expected dissipation under natural conditions (Table 26). After considering the exposure periods for each of the aquatic endpoints and a conservative water DT₅₀ of 7.0 days, an HC₅ of 0.41 µg ac/L was derived, which is approximately equal to the lowest EC₅₀ value. In addition, the lower limit HC₅ is more than 1/3 of the median HC₅. As such, 0.41 µg ac/L was set as the RAL for the protection of natural aquatic areas.

Paraquat has moderate toxicity to bees by contact exposure (lowest LD₅₀ 16 µg ac/bee, *Apis mellifera*) and moderate toxicity by oral exposure (lowest LD₅₀ 13 µg ac/bee, *Apis mellifera*). The RAL for spray drift assessment is 2667 g ac/ha based on the contact LD₅₀ 16 µg ac/bee and a conversion factor of LOC 0.4 / ExpE 2.4 * 1000 as per APVMA's Spray drift risk assessment manual (SDRAM): <https://apvma.gov.au/node/51826>.

In tier 1 (glass plate) laboratory tests on the toxicity of an SL formulation of paraquat to the indicator species of predatory arthropods (predatory mite *Typhlodromus pyri*) the LR₅₀ value is 1.9 g ac/ha. Exposure under tier 2 (natural substrate) conditions did not greatly influence toxicity to the predatory mite, LR₅₀ 8.2 g ac/ha (*Typhlodromus pyri*). Soil dwelling arthropods such as carabid beetles, spiders and rove beetles were unaffected at field relevant rates.

Paraquat has low toxicity to soil macro-organisms such as earthworms (LC₅₀ >1000 mg ac/kg dry soil, *Eisenia fetida*). It is noted that the available acute toxicity test was conducted in artificial soil containing 20% kaolinite clay, as such it may not represent a realistic worst-case exposure system (i.e. compared to soils with lower capacity to adsorb and deactivate paraquat). However, the test was conducted at a rate exceeding the soil's expected strong adsorption capacity (SAC-WB 230-260 mg ac/kg dry soil), as measured for an artificial soil with the same composition as in the acute toxicity test. Implying that it is reasonable to conclude there would have been paraquat in excess of the SAC-WB in the acute toxicity test. There are no laboratory studies investigating long-term effects of paraquat in soil dwelling macro-organisms or micro-organisms.

Effects on soil macro-organisms and micro-organisms have been investigated in long-term field studies. Adverse effects on earthworms and soil micro-arthropods were observed at soil concentrations equivalent to 110 and 400% of the soils SAC (120 mg ac/kg dry soil). No adverse effects on soil micro-organisms were observed at soil concentrations as high as 400% of a soils SAC (120 mg ac/kg dry soil).

Paraquat has low toxicity to non-target terrestrial plants following pre-emergent exposure to soil residues under laboratory conditions (lowest definitive ER₂₅ 712 g ac/ha, *Avena sativa*). However, because paraquat is a non-selective contact herbicide, post-emergent foliar exposure is of greatest concern. Under laboratory conditions, rough cocklebur was the most sensitive species following foliar exposure (ER₅₀ 25 g ac/ha, *Xanthium strumarium*). An SSD analysis was performed on the post-emergent ER₅₀ values for 12 non-target terrestrial plant species. An HR₅ of 30 g ac/ha was derived (Table 26), which is higher than the lowest ER₅₀ value. As such the lower limit HR₅ of 19 g ac/ha was selected as the RAL for the protection of vegetation areas.

In terms of endocrine disrupting properties, results in non-mammalian species are either equivocal or negative. No targeted studies were available to mechanistically understand the reproductive toxicity to non-mammalian species; therefore, it is not possible to assess whether any observed effects were endocrine-mediated. Therefore, no firm conclusion can be drawn regarding endocrine effects of paraquat.

The regulatory acceptable levels (RALs) for the environmental risk assessment are proposed in Table 28, below. The RAL values for the spray drift assessment are 0.41 µg ac/L for the protection of natural aquatic areas, 2667 g ac/ha for the protection of pollinator areas, and 19 g ac/ha for the protection of vegetation areas.

Table 26: Paraquat – Toxicity endpoints for primary producers used in SSD analysis

Species	Exposure days	Measured EC ₅₀	Adjusted EC ₅₀	Notes
<i>Navicula pelliculosa</i>	4	0.00034 mg ac/L	0.00041 mg ac/L	
<i>Anabaena flos-aquae</i>	5	0.0078 mg ac/L	0.0099 mg ac/L	
<i>Lemna minor</i>	7	0.015 mg ac/L	0.021 mg ac/L	
<i>Chlamydomonas reinhardtii</i>	3	0.025 mg ac/L	0.028 mg ac/L	(geomean of 3 studies)
<i>Raphidocelis subcapitata</i>	4	0.26 mg ac/L	0.31 mg ac/L	(geomean of 5 studies)
<i>Lemna gibba</i>	7/14*	0.034 mg ac/L	0.054 mg ac/L	(geomean of 2 studies)
<i>Chlorella vulgaris</i>	4	0.53 mg ac/L	0.64 mg ac/L	
<i>Skeletonema costatum</i>	4	5.9 mg ac/L	7.1 mg ac/L	
	HC ₅	0.00032 mg ac/L (95% CI 0.000084-0.0012)	0.00041 mg ac/L (95% CI 0.00012-0.0015)	(8 species)

Endpoints from Table B10 in Appendix B have been adjusted to account for rapid dissipation from the water column under natural conditions (adjusted EC₅₀ = measured EC₅₀ / (1 - EXP (exposure days * (-ln(2)/DT₅₀ 7.0 days))) * (exposure days * ln(2)/DT₅₀ 7.0 days)

*7d E_rC₅₀ 0.031 and 14d E_rC₅₀ 0.0037 mg ac/L

Table 27: Paraquat – Post-emergent toxicity endpoints for non-target terrestrial plants used in SSD analysis

Species	ER ₂₅	ER ₅₀	Notes
<i>Xanthium strumarium</i>	14 g ac/ha	25 g ac/ha	
<i>Lolium perenne</i>	23 g ac/ha	35 g ac/ha	
<i>Beta vulgaris</i>	20 g ac/ha	68 g ac/ha	
<i>Avena sativa</i>	47 g ac/ha	108 g ac/ha	
<i>Abutilon theophrasti</i>	50 g ac/ha	135 g ac/ha	
<i>Allium cepa</i>	23 g ac/ha	136 g ac/ha	
<i>Brassica napus</i>	41 g ac/ha	161 g ac/ha	(geomean of 2 studies)
<i>Lycopersicon esculentum</i>	47 g ac/ha	188 g ac/ha	
<i>Ipomoea hederacea</i>	111 g ac/ha	201 g ac/ha	
<i>Zea mays</i>	77 g ac/ha	207 g ac/ha	(geomean of 2 studies)
<i>Cucumis sativa</i>	99 g ac/ha	267 g ac/ha	
<i>Glycine max</i>	49 g ac/ha	476 g ac/ha	(geomean of 2 studies)
<i>Raphanus sativus</i>	182 g ac/ha	—	
	HR ₅	14 g ac/ha (95% CI 11-18)	30 g ac/ha (95% CI 19-49)

Table 28: Paraquat – Regulatory acceptable levels for non-target species

Group	Exposure	Endpoint	AF	RAL	Reference
Mammals	Acute	LD ₅₀ 61 mg ac/kg bw	10	6.1 mg ac/kg bw	Duerden 1994, Farnworth et al, 1993, Fletcher 1967, Heylings & Farnworth 1992, Kimbrough & Gaines 1970, Murray & Gibson 1974
	Chronic	NOAEL 3.8 mg ac/kg bw/d	1	3.8 mg ac/kg bw/d	Lindsay 1982a,1982b
Birds	Acute	LD ₅₀ 57 mg ac/kg bw	10	5.7 mg ac/kg bw	Fink et al, 1979, Hubbard et al, 2014, Johnson 1998
	Chronic	NOEL 2.7 mg ac/kg bw/d	1	2.7 mg ac/kg bw/d	Fink et al, 1982(a)
Aquatic species	Chronic	HC ₅ 0. 41 µg ac/L*	1	0. 41 µg ac/L	Baltazar et al, 2014, Cheloni & Slaveykova 2021, Grillo et al, 2015, Jamers & de Coen 2010, Mohammad et al, 2010, Scheerbaum 2007b, Smyth et al 1990(a), 1990b, Smyth et al, 1992(a), 1992(b), 1992(c), 1992(d), 1992(e), Tagun & Boxall 2018, Tanaka et al, 2011
Sediment dwellers	Acute	LC ₅₀ 39 mg ac/kg ds	10	3.9 mg ac/kg ds	Bradley 2015a
Adult bees	Acute contact	LD ₅₀ 16 µg ac/bee	2.5	6.4 µg ac/bee	Bull & Wilkinson 1987
	Acute oral	LD ₅₀ 13 µg ac/bee	2.5	5.2 µg ac/bee	Bull & Wilkinson 1987
Foliar arthropods	Contact	LR ₅₀ 8.2 g ac/ha	1	8.2 g ac/ha	Austin 1999a
Ground arthropods	Contact	ER ₅₀ >600 g ac/ha	1	600 g ac/ha	Petto 1993
Soil macro-organisms	Acute	LC ₅₀ 1000 mg ac/kg ds	10	100 mg ac/kg ds	Edwards & Coulson 1993
Terrestrial plants	Post-emergent	LLHR ₅ 19 g ac/ha	1	19 g ac/ha	Canning & White 1992, Martin 2014b

*Aquatic endpoints have been adjusted to account for rapid dissipation from the water column under natural conditions (adjusted endpoint = measured endpoint / (1 - EXP (exposure days * (-ln(2)/DT₅₀ 7.0 days))) * (exposure days * ln(2)/DT₅₀ 7.0 days)

Risks to non-target species

Terrestrial vertebrates

Direct dietary exposure is possible for uses of paraquat as a pre-harvest cotton desiccant, spray topping in pulses, or for general weed control in a wide range of situations. A full assessment for terrestrial vertebrates for the different use patterns is presented in Appendix C. Acceptable risks of paraquat could only be concluded for general weed control in bananas at a rates up to 231 g ac/ha, depending on the use situation (Table 29).

The following protection labelling is appropriate for the supported use.

Toxic to birds and native mammals. However, the use of this product as directed is not expected to have adverse effects on birds or native mammals.

The remaining uses are not supported unless application is restricted to one per season at the maximum supported rate(s) indicated in Table 29.

Paraquat is not expected to bioaccumulate in biota based on its low octanol-water partition coefficient. Therefore, a food chain assessment is not necessary.

Table 29: Paraquat – Summary of risk assessment outcomes for terrestrial vertebrates

Use pattern	Situation	Rate range (g ac/ha)	Wild mammal assessment	Bird assessment	Max. seasonal rate supported (paraquat)
General weed control	Non-agricultural situations, around sheds, roadways, paths, firebreaks	390–1140	Not supported	Not supported	45 g ac/ha
	Fallow	150–2250	Acceptable up to 432 g ac/ha	Acceptable up to 231 g ac/ha	231 g ac/ha
	Orchards, vineyards	280–810	Not supported	Not supported	45 g ac/ha
	Potatoes	300–720	Not supported	Not supported	231 g ac/ha
	Lucerne, market gardens, row crops, vegetables	300–1050	Not supported	Not supported	231 g ac/ha
	Pasture ¹⁵	100–600	Not supported	Not supported	45 g ac/ha
	Bananas	175–1120	Acceptable up to 432 g ac/ha	Acceptable up to 231 g ac/ha	231 g ac/ha
	Hops, sugarcane	300–420	Acceptable risk	Not supported	231 g ac/ha
	Rice	200–420	Acceptable risk	Acceptable up to 231 g ac/ha	231 g ac/ha
	Peanuts	100–250	Acceptable risk	Acceptable up to 231 g ac/ha	231 g ac/ha
	Spray topping in pulses	100–200	Acceptable up to 149 g ac/ha	Acceptable risk	149 g ac/ha

¹⁵ Includes spray topping to prevent ryegrass toxicity

Use pattern	Situation	Rate range (g ac/ha)	Wild mammal assessment	Bird assessment	Max. seasonal rate supported (paraquat)
Combination products containing diquat	Fallow (minimal disturbance)	108–432	Acceptable risk	Acceptable up to 231 g ac/ha	231 g ac/ha
	Fallow (full disturbance)	81–432	Acceptable risk	Acceptable up to 231 g ac/ha	231 g ac/ha
	Bananas, duboisia, market gardens, nurseries, potatoes, rice, vegetables	324–432	Acceptable risk	Not supported	231 g ac/ha
	Lucerne	216–324	Not supported	Not supported	45 g ac/ha
	Sugarcane	162–432	Acceptable risk	Acceptable up to 231 g ac/ha	231 g ac/ha
	Pasture	162–432	Not supported	Not supported	45 g ac/ha
	Public service areas, rights of way	324–432	Not supported	Not supported	45 g ac/ha
	Spray topping in grasses	108–203	Not supported	Not supported	45 g ac/ha
	Forests, orchards, plantations	216–432	Not supported	Not supported	45 g ac/ha
	Spot application in avocado, custard apples, lychees, mangos ¹⁶	324–432	Not supported	Not supported	112 g ac/ha
	Vineyards	324–432	Not supported	Not supported	45 g ac/ha
	Cotton desiccant	162–216	Acceptable up to 179 g ac/ha	Acceptable risk	179 g ac/ha
Combination products containing amitrole	Fallow	112–1250	Acceptable up to 432 g ac/ha	Acceptable up to 231 g ac/ha	231 g ac/ha
	Non-agricultural situations, around sheds, roadways, paths, firebreaks	300–1125	Not supported	Not supported	45 g ac/ha
	Orchards, vineyards	325–800	Not supported	Not supported	45 g ac/ha
	Potatoes	525–700	Not supported	Not supported	231 g ac/ha
	Pasture, including hay freezing and spray topping	75–400	Not supported	Not supported	45 g ac/ha

Aquatic species

As indicated in Table 28, the RAL for the spray drift assessment is 0.41 µg ac/L for the protection of natural aquatic areas. Risks of spray drift are addressed separately, as needed.

¹⁶ Assuming a maximum of 40% of an orchard is treated, each application is equivalent to 130 g ac/ha across the entire orchard; maximum supported rate in this instance is specific to spot application

A runoff assessment according to APVMA's method to refine estimates of pesticide runoff to waterways considered the lowest RAL values of 0.41 µg ac/L and 3.9 mg ac/kg dry sediment and assumed a runoff event occurs 3 days after the last application. The Tier 1 (screening) level of assessment is a worst-case scenario where slope is fixed at 8%, which is considered protective of 95% of agricultural activities in Australia. The rainfall value is set at 8 mm, which results in the maximum receiving water concentration using the standard water body of 1 ha and 15 cm initial depth when the worst-case Australian soil profile is used; the catchment is 10 ha. Further, for this worst-case scenario, a fallow/bare soil runoff profile is assessed.

A runoff assessment according to APVMA's method to refine estimates of pesticide runoff to waterways¹⁷ considered the lowest RAL values of 0.41 µg ac/L and 3.9 mg ac/kg dry sediment. Because the assessment assumes that a runoff event occurs 3 days after application, the following restraints are recommended for the supported uses.

DO NOT apply if heavy rains or storms are forecast within 3 days.

DO NOT irrigate to the point of field runoff for at least 3 days after application.

The Tier 1 (screening) level of assessment is a worst-case scenario where slope is fixed at 8%, which is considered protective of 95% of agricultural activities in Australia. The rainfall value is set at 8 mm, with results in the maximum receiving water concentration using the standard water body of 1 ha and 15 cm initial depth when the worst-case Australian soil profile is used; the catchment is 10 ha. Further, for this worst-case scenario, a fallow/bare soil runoff profile is assessed.

Acceptable risks could be concluded at the screening level for soils that contain >10% clay (Table 7). For sand soils containing ≤10% soil, the maximum supported annual peak soil concentration is 1.0 mg ac/kg dry soil¹⁸ at the screening level, which is equivalent to an annual rate of 175 g ac/ha over 20 years. As such, the only use supported by the terrestrial vertebrate assessment (bananas up to 231 g ac/ha) can only be supported up to 175 g ac/ha for all soil types.

¹⁷ See Appendix B, Attachments 1 and 2 of <https://apvma.gov.au/node/46416>

¹⁸ Back-calculated from 785 g ac/ha and soil depth of 5-cm (785/750)

Table 30: Soil exposure estimates for paraquat

Use pattern	Situation	Application rate and frequency	Foliar interception fraction	Peak annual soil concentration (mg/kg)	Steady state soil concentration (mg/kg)
General weed control	Fallow	1x 2250 g ac/ha	0	13	10
	Industrial vegetation management	1x 1140 g ac/ha	0	6.8	5.2
	Bananas, orchards, vineyards	1x 1120 g ac/ha	0	6.6	5.1
	Potatoes	1x 720 g ac/ha	0	4.3	3.3
	Lucerne, market gardens, row crops, vegetables	1x 600 g ac/ha	0	3.6	2.8
	Hops, rice sugarcane	1x 420 g ac/ha	0	2.5	1.9
	Peanuts	1x 250 g ac/ha	0	1.5	1.1
	Pasture	1x 600 g ac/ha	0.90	0.36	0.28
	Spray topping in pulses	1x 200 g ac/ha	0.85	0.18	0.14
Combination products containing paraquat	Fallow (minimal disturbance)	2x 432 g ac/ha 7d interval	0	5.1	4.0
	Bananas, duboisia, forests, industrial vegetation management, market gardens, nurseries, orchards, plantations, potatoes, rice, vegetables, vineyards	1x 432 g ac/ha	0	2.6	2.0
	Fallow (full disturbance), lucerne	1x 324 g ac/ha	0	1.9	1.5
	Sugarcane	1x 270 g ac/ha	0	1.6	1.2
	Spot application in avocado, custard apples, lychees, mangos ¹⁹	2x 324 g ac/ha 14d interval	0	1.5	1.2
	Cotton	1x 216 g ac/ha	0.75	0.32	0.25
	Pasture	1x 432 g ac/ha	0.90	0.26	0.20
Combination products containing amitrole	Fallow	1x 1250 g ac/ha	0	7.4	5.7
	Industrial vegetation management	1x 1125 g ac/ha	0	6.7	5.2
	Orchards, vineyards	1x 600 g ac/ha	0	3.6	2.8
	Potatoes	1x 525 g ac/ha	0	3.1	2.4
	Pasture	1x 300 g ac/ha	0.90	0.18	0.14

Risk assessment scenarios as described in section 2; foliar interception values are based on EFSA (2020) defaults for similar situations; soil exposure estimates based on indicated application rate and frequency applied annually for 20 years with indicated interception and soil DT₅₀ 1000 d

¹⁹ Assuming a maximum of 40% of an orchard is treated, each application is equivalent to 130 g ac/ha across the entire orchard

Table 31: Assessment of runoff risks to aquatic species

Parameter	Worst-case scenario		Max supported	
	Non-sands (clay >10%)	Sands (clay ≤10%)	Sands (clay ≤10%)	
Soil				
Exposure rate	(g/ha)	9750	9750	785
Soil DT ₅₀	(d)	1000	1000	1000
Kd	(L/kg)	9400	480	480
Rainfall – P	(mm)	8.00	8.00	8.00
Runoff – Q	(mm)	1.34	1.34	1.34
Cr _{soil surface}	(fraction)	0.00011	0.0021	0.0021
slope factor - F	(fraction)	0.26	0.26	0.26
Runoff	(% applied)	0.00023	0.0045	0.0045
Water				
PEC	(µg/L)	0.14	2.7	0.22
RAL	(µg/L)	0.41	0.41	0.41
Risk quotient	(fraction)	0.34	6.6	0.53
Sediment				
PEC	(mg/kg)	2.6	51	4.1
RAL	(mg/kg)	3.9	3.9	3.9
Risk quotient	(fraction)	0.66	13	1.0

Worst-case scenario based on 1× 2250 g ac/ha applied annually for 20 years with no interception and indicated soil DT₅₀
 Exposure rate is back-calculated from maximum predicted annual peak concentration in top 5-cm for worst-case scenario (13 mg ac/kg dry soil for general weed control in fallow from Table 30)

Soil DT₅₀ and Kf from Table 53

Rainfall P value is default for Tier 1

Runoff Q value = $((-0.000196 * (\text{rain}^3)) + (0.0232 * (\text{rain}^2))) + (-0.00520 * \text{rain})$; runoff curve for worst-case Australian soil profile

$Cr_{\text{soil surface}} = \text{EXP}(-3 * \ln(2) / DT_{50\text{soil}}) * (1 / (1 + Kf))$

Slope factor F = $(0.02153 * \text{slope} + 0.001423 * \text{slope}^2)$, where default screening level slope is 8%

Runoff (% applied) = $Q / P * F * Cr_{\text{soil surface}} * 0.5$

PEC (water) = $\text{application rate} * \% \text{runoff} / 100 * 10 / (1500 + 134) * 1000$

PEC (sediment) = $\text{PEC (water)} * (0.8 + (0.2 * Kp / 1000 * 2400)) / 1280$, where K_p 50000 (from Table 59)

RAL = regulatory acceptable level (from Table 28)

RQ = risk quotient = PEC/RAL, where acceptable RQ ≤1

Bees

For spray applications, risks to bees foraging in treated areas are assessed using a tiered approach. A screening level risk assessment assumes the worst-case scenario of a direct overspray of blooming plants that are frequented by bees in order to identify those substances and associated uses that do not pose a risk. Risks of exposure to foliar residues (contact exposure) were acceptable at the highest application rate of 2250 g ac/ha (Table 32). However, acceptable risks of oral exposure (via pollen and nectar) to foraging bees could only be concluded at rates up to 175 g ac/ha. To mitigate risks of oral exposure, the following protection statement is advised for all spray uses of paraquat products where rates exceed 175 g ac/ha.

Harmful to bees. DO NOT apply to flowering weeds or crops at rates exceeding [175 g ac/ha]. DO NOT allow spray drift to flowering weeds or crops in the vicinity of the treatment area. Before spraying, notify beekeepers to move hives to a safe location with an untreated source of nectar and pollen, if there is potential for managed hives to be affected by the spray or spray drift.

Table 32: Screening level assessment of risks to bees

Life stage	Exposure	Rate (g/ha)	Predicted total dose (µg/bee)	RAL (µg/bee)	RQ
Adults	Acute contact	2 250	5.4	6.4	0.84
		Acute oral	2 250	64	5.2
		1 500	43	5.2	8.3
		1 140	33	5.2	6.3
		1 125	32	5.2	6.2
		1 120	32	5.2	6.2
		810	23	5.2	4.5
		800	23	5.2	4.4
		720	21	5.2	4.0
		700	20	5.2	3.9
		600	17	5.2	3.3
		420	12	5.2	2.3
		400	11	5.2	2.2
		300	8.6	5.2	1.7
		250	7.2	5.2	1.4
	200	5.7	5.2	1.1	
	175	5.0	5.2	1.0	

Predicted total dose calculated using USEPA BeeREX tool for adult worker bee foraging for nectar and larval drone within the hive

RAL = regulatory acceptable level (from Table 28)

RQ = risk quotient = PEC / RAC, where acceptable RQ ≤1

Other arthropod species

Commercial use of predatory or parasitic arthropods in integrated pest management programs can occur in a wide range of agricultural industries. For broad-spectrum herbicides such as paraquat, exposure of natural populations of arthropod species that are beneficial to agricultural systems is also possible. The risk assessment assumes that arthropods are exposed to fresh-dried residues within the treatment area immediately after the last application. Risks to predatory and/or parasitic arthropods could not be concluded for any of the assessed scenarios (Table 33). Therefore, the following protection statement is advised for all registered uses of paraquat.

Toxic to beneficial arthropods. Not compatible with integrated pest management (IPM) programs utilising beneficial arthropods. Minimise spray drift to reduce harmful effects on beneficial arthropods in non-crop areas.

Table 33: Assessment of risks to other non-target arthropods

Scenario	Group	Exposure	Rate (g/ha)	RAL (g/ha)	RQ
Worst-case (1× 2250 g ac/ha)	Foliar arthropods	Contact	2250	8.2	274
	Ground arthropods	Contact	2250	600	3.8
Best-case (1× 175 g ac/ha)	Foliar arthropods	Contact	175	8.2	21
	Ground arthropods	Contact	175	600	0.29

RAL = regulatory acceptable level (from Table 28)

RQ = risk quotient = PEC / RAL, where acceptable RQ ≤1

Soil organisms

The risk assessment assumes soil organisms are exposed to accumulated residues in the top 5-cm after 20 years of use. Assuming annual use at the highest rate of 2250 g ac/ha with no foliar interception, the peak concentration was predicted to be 13 mg ac/kg dry soil (acute exposure scenario), while the steady state concentration was predicted to be 10 mg ac/kg dry soil (chronic exposure scenario). Risks due to acute exposure of soil organisms were determined to be acceptable under this worst-case scenario (Table 34).

The available field studies imply that, when paraquat has not exceeded a given soils strong absorption capacity, no adverse effects are expected for soil dwelling macro or micro-organisms, as any paraquat is essentially biologically unavailable. If the strong absorption capacity of a soil is exceeded, i.e. paraquat is present in solution in soil pore water, then adverse effects may occur amongst soil macro-organisms. Soil micro-organisms are not expected to be affected given their intrinsic reproductive capacity and involvement in the degradation of bioavailable paraquat. For most soils, the strong absorption capacity of the soil will be hundreds of times the annual application rate and it would take further inputs to reach or exceed the SAC-WB value, at which adverse effects have been observed. It has also been observed that under normal agricultural practice (multiple years of accumulated residues, at ≤2.25 kg ac/ha) the rate of degradation of paraquat is expected to be greater than for the single applications tested in the field studies, reducing the likelihood that adverse concentrations will be reached. Given the available evidence, long-term risks to soil organisms are concluded to be acceptable and no protection statements are therefore required.

Table 34: Screening level assessment of risks to soil organisms (worst-case scenario)

Group	Exposure	Annual rate (g/ha)	PEC (mg/kg dry soil)	RAL (mg/kg dry soil)	RQ
Macro-organisms	Acute	2 250	13	100	0.13

Worst-case scenario based on 1× 2250 g ac/ha applied annually for 20 years with no interception and soil DT₅₀ 1000 d

Acute PEC is based on maximum predicted annual peak concentration in top 5 cm

RAL = regulatory acceptable level (from Table 28)

RQ = risk quotient = PEC / RAL, where acceptable RQ ≤1

Non-target terrestrial plants

As indicated in Table 28, the RAL for the spray drift assessment is 19 g ac/ha for the protection of vegetation areas. Risks of spray drift are addressed separately, as needed.

Combination toxicity

Assessment scenarios

In a separate assessment, the risks of paraquat were determined to be acceptable at a maximum rate of 179 g ac/ha as a cotton desiccant and 231 g ac/ha in fallow and sugarcane situations. For the combination products containing 115 g/L diquat and 135 g/L paraquat, these correspond to rates of 1.3 L/ha and 1.7 L/ha, respectively. Risks of diquat were also determined to be acceptable at these rates. For the lower rates of the combination products in these situations (starting from 600 mL/ha in some fallow situations), risks of combination toxicity to non-target species have also been assessed.

Table 35: Diquat/paraquat combination products: environmental risk assessment scenarios

Crop / situation	Product rate range (L/ha)	Diquat rate range (g ac/ha)	Paraquat rate range (g ac/ha)	Total actives rate range (g acs/ha)
Desiccant to aid harvest in cotton	1.2 to 1.3	138 to 150	162 to 176	300 to 325
As an aid to cultivation in fallow (full disturbance)	0.6 to 1.7	69 to 196	81 to 230	150 to 425
As an aid to cultivation in fallow (minimum disturbance)	0.8 to 1.7	92 to 196	108 to 230	200 to 425
As an aid in establishing sugarcane or controlling weeds in a fallow prior to sugarcane	1.2 to 1.7	138 to 196	162 to 230	300 to 425
As an aid in post-harvest weed control in fallow (minimum disturbance)	1.6 to 1.7	184 to 196	216 to 230	400 to 425
Sugarcane plant and ratoon	1.6 to 1.7	184 to 196	216 to 230	400 to 425

Effects on non-target species

A representative combination product containing 115 g/L diquat and 136 g/L paraquat had moderate toxicity to rats (LD₅₀ 119 mg acs/kg bw, *Rattus norvegicus*). No data are available on the toxicity of a representative combination product containing 115 g/L diquat and 136 g/L paraquat to any other non-target species. Therefore, combination toxicity to non-target species was estimated assuming additive toxicity of the active constituents. All combination toxicity endpoints are expressed in terms of total active constituents (acs). Please refer to in Appendix B for all predicted combination toxicity values for non-target species. For further details on the estimation method, please refer to the [APVMA Risk Assessment Manual – Environment](#).

Based on available data, the diquat/paraquat combination products were predicted to have high toxicity to mammals (geomean LD₅₀ 76 mg acs/kg bw, 4 mammal species) and birds (geomean LD₅₀ 4.2 mg acs/kg bw, 2 bird species). Therefore, the following hazard statement is required on diquat/paraquat combination product labels (followed by an appropriate risk management statement).

Toxic to birds and native mammals.

In aquatic systems, diquat and paraquat dissipate quickly from the water column under natural conditions due to rapid adsorption to sediment and suspended particulates; therefore, the aquatic endpoints were first adjusted to account for their expected dissipation under natural conditions prior to deriving the combination toxicity estimates. Although field data on diquat suggest a more rapid half-life, the more conservative water DT₅₀ of 7.0 days for paraquat has been utilised for both chemicals to avoid artificially skewing the relative toxicity contributions toward paraquat.

After considering the exposure periods for each of the aquatic endpoints and rapid dissipation under natural conditions, the diquat/paraquat combination products were predicted to have moderate toxicity to fish (LC₅₀ 1.7 mg acs/L for most sensitive species) and aquatic invertebrates (lowest LC₅₀ 0.15 mg acs/L, *Hyalella azteca*), and high toxicity to primary producers (geomean ER₅₀ 0.0066 mg acs/L, 3 algal and 2 aquatic plant species). Therefore, the following protection statement is required on diquat/paraquat combination product labels.

Very toxic to aquatic life. DO NOT contaminate wetlands or watercourses with this product or used containers.

Based on available data, the diquat/paraquat combination products were predicted to have moderate toxicity to bees by contact exposure (LD₅₀ 26 µg acs/bee, *Apis mellifera*) and oral exposure (LD₅₀ 16 µg acs/bee, *Apis mellifera*). For the protection of pollinator areas, the RAL for the spray drift assessment is 4333 g acs/ha based on the predicted contact LD₅₀ 26 µg acs/bee and a conversion factor of LOC 0.4 / ExpE 2.4 * 1000 as per APVMA's Spray drift risk assessment manual (SDRAM): <https://apvma.gov.au/node/51826>.

Based on the available data, the LR₅₀ values for the indicator species of predatory arthropods (predatory mite *Typhlodromus pyri*) were predicted to be 2.3 g acs/ha (tier 1) and 5.6 g acs/ha (tier 2). Insufficient data were available on the indicator species of parasitic arthropod (parasitic wasp *Aphidius rhopalosiphii*) to estimate combination toxicity. The diquat/paraquat combination products were not expected to be toxic to ground arthropods such as rain beetles (*Pterostichus melanarius*), wolf spiders (*Pardosa* sp.), and rove beetles (*Aleochara bilineata*).

Based on available data, any toxicity to soil macro-organisms such as earthworms would be attributed to diquat. The diquat/paraquat combination products are not expected to adversely influence soil processes such as nitrification.

Because both diquat and paraquat have low toxicity to non-target terrestrial plants following pre-emergent exposure (seedling emergence tests), only post-emergent exposure data (vegetative vigour tests) were considered. Based on available data, predicted ER₅₀ values following post-emergent exposure ranged 19 g acs/ha for the most sensitive species (cabbage or rough cocklebur) to 224 g acs/ha for soybean. An SSD analysis was performed on the post-emergent ER₅₀ values for 7 non-target terrestrial plant species. An HR₅ of 18 g acs/ha was derived (Table 36), which is lower than the lowest ER₅₀ value. As such, 18 g acs/ha was selected as the RAL for the protection of vegetation areas.

The regulatory acceptable levels for the environmental risk assessment are proposed in Table 37, which are based on predicted toxicity values. The RAL values for the spray drift assessment are 0.66 µg acs/L for the protection of natural aquatic areas, 4333 g acs/ha for the protection of pollinator areas, and 18 g acs/ha for the protection of vegetation areas.

Table 36: Diquat/paraquat combination products - Predicted toxicity endpoints for non-target terrestrial plants (post-emergent exposure) used in SSD analysis

Species	Predicted ER ₅₀
Sensitive species (<i>Brassica oleracea</i> / <i>Xanthium strumarium</i>)	19 g acs/ha
<i>Beta vulgaris</i>	50 g acs/ha
<i>Lolium perenne</i>	61 g acs/ha
<i>Brassica napus</i>	88 g acs/ha
<i>Allium cepa</i>	173 g acs/ha
<i>Zea mays</i>	206 g acs/ha
<i>Glycine max</i>	224 g acs/ha
	HR ₅ 18 g acs/ha (95% CI 9.0-38)

Table 37: Diquat/paraquat combination products: regulatory acceptable levels for non-target species

Group	Exposure	Endpoint	AF	RAL
Mammals	Acute	LD ₅₀ 76 mg acs/kg bw	10	7.6 mg acs/kg bw
Birds	Acute	LD ₅₀ 42 mg acs/kg bw	10	4.2 mg acs/kg bw
Aquatic species	Acute	EC ₅₀ 6.6 µg acs/L*	10	0.66 µg acs/L
Adult bees	Contact	LD ₅₀ 26 µg acs/bee	2.5	10 µg acs/bee
	Oral	LD ₅₀ 16 µg acs/bee	2.5	6.4 µg acs/bee
Foliar arthropods	Contact	LR ₅₀ 5.6 g acs/ha	1	5.6 g acs/ha
Ground arthropods	Contact	Not expected to be toxic		
Soil macro-organisms	Acute	Any toxicity would be attributed to diquat		
Soil micro-organisms	Chronic	Not expected to be toxic		
Terrestrial plants	Post-emergent	HR ₅ 18 g acs/ha	1	18 g acs/ha

*Aquatic endpoints have been adjusted to account for rapid dissipation from the water column under natural conditions (adjusted endpoint = measured endpoint / (1 - EXP (exposure days * (-ln(2)/DT₅₀ 7.0 days))) * (exposure days * ln(2)/DT₅₀ 7.0 days)

Risks to non-target species

The risk assessment for combination products considers only short-term risks to non-target species following direct exposure to combined residues of the active constituents (diquat + paraquat cations) immediately after one application.

The assessment for terrestrial vertebrates assumes 100% of food items are obtained from the treatment area on the day of application. The use patterns were divided up into groups which consist of crops that have similar growing patterns (Table 38). Weed control largely occurs at the early growth stages of crops (or in fallow) and fall under a 'bare soil' scenario. Cotton desiccation occurs at the latest growth stage of the crop (BBCH ≥90).

Risks to wild mammals were determined to be acceptable with the exception of small herbivorous mammals in cotton desiccation situations. Risks were not acceptable at the lowest rate of 300 g ac/ha (1.2 L/ha) in this situation Table 40. The EFSA representative species in this group is a vole; Australian species at risk in this group might include a hopping mouse, native rat, possum, or bettong species.

When used for weed control, risks to birds were only acceptable at the lower rates in the registered range with granivorous birds being at greatest risk. The maximum supported rate was 175 g acs/ha (700 mL/ha) in this situation (Table 40). The EFSA representative species in this group is a finch which is relevant to Australia; additional Australian species in this group might include dove, button-quail, parrot, quail or pigeon species.

Risks of runoff of diquat and paraquat to aquatic species are considered separately and have been considered in their respective risk assessments. Both require the following restraints which also apply to the diquat/paraquat combination products.

DO NOT apply if heavy rains or storms are forecast within 3 days.

DO NOT irrigate to the point of field runoff for at least 3 days after application.

The assessment for bees assumes the worst-case scenario of a direct overspray of blooming plants that are frequented by bees in order to identify those substances and associated uses that do not pose a risk. Risks of exposure to foliar residues (contact exposure) were acceptable at the highest rate of 425 g acs/ha (1.7 L/ha); however, acceptable risks of oral exposure (via pollen and nectar) to foraging bees could only be concluded at rates up to 225 g ac/ha (900 mL/ha; Table 41). To mitigate risks of oral exposure, the following protection statement is advised for any combination product containing 115 g/L diquat and 135 g/L paraquat where rates exceed 225 g acs/ha (900 mL/ha).

Harmful to bees. DO NOT apply to flowering weeds or crops at rates exceeding 900 mL/ha. DO NOT allow spray drift to flowering weeds or crops in the vicinity of the treatment area. Before spraying, notify beekeepers to move hives to a safe location with an untreated source of nectar and pollen, if there is potential for managed hives to be affected by the spray or spray drift.

The assessment for other arthropod species assumes that predatory and parasitic arthropods are exposed to fresh-dried residues within the treatment area immediately after application. The combination product is not expected to be toxic to ground arthropods; however, risks to foliar arthropods could not be concluded at the lowest rate (Table 42). Therefore, the following protection statement is advised for all combination products containing 115 g/L diquat and 135 g/L paraquat.

Toxic to beneficial arthropods. Not compatible with integrated pest management (IPM) programs utilising beneficial arthropods. Minimise spray drift to reduce harmful effects on beneficial arthropods in non-crop areas.

No protection statements are required for soil organisms to address risks of diquat or paraquat alone, as per their individual environmental assessments. When considering their combination (115 g/L diquat + 135 g/L paraquat), toxicity to soil macro-organisms such as earthworms would be attributed to diquat. The combination products are not expected to adversely affect soil processes such as nitrogen transformation and therefore risks are considered to be acceptable.

As indicated in the previous section, the RAL values for the spray drift assessment are 0.66 µg acs/L for the protection of natural aquatic areas, 4333 g acs/ha for the protection of pollinator areas, and 18 g acs/ha for the protection of vegetation areas. Risks of spray drift are addressed separately, as needed.

Table 38: Diquat/paraquat combination products: crop groups for terrestrial vertebrate assessment

EFSA 2009 crop group	Crop / situation	Application rates
Bare soil	As an aid to cultivation in fallow (full or minimum disturbance), as an aid in establishing sugarcane or controlling weeds in a fallow prior to sugarcane, as an aid in post-harvest weed control in fallow (minimum disturbance), sugarcane plant and ratoon	From 150 to 425 g acs/ha
Cotton	Dessicant to aid in harvest in cotton	From 300 to 325 g acs/ha

Risk assessment scenarios as described in section 3; seasonal exposure rates based on indicated application rate, frequency and DT₅₀

Table 39: Diquat/paraquat combination products: acute risks to terrestrial vertebrates

Crop group	Generic focal species	Crop stage	Shortcut value	Exposure rate (g/ha)	DDD (mg/kg bw/d)	RQ
Wild mammals (RAL 7.6 mg acs/kg bw)						
Bare soil	Small omnivore	BBCH <10	14.3	425	6.1	0.80
Cotton	Small herbivore	BBCH ≥50	34.1	300	10	1.3
	Small insectivore	BBCH ≥20	5.4	325	1.8	0.23
	Small omnivore	BBCH ≥50	4.3	325	1.4	0.18
Birds (RAL 4.2 mg acs/kg bw)						
Bare soil	Small granivore	BBCH <10	24.7	200	4.9	1.2
				175	4.3	1.0
	Small omnivore	BBCH <10	17.4	275	4.8	1.1
				250	4.4	1.0
Small insectivore	BBCH <10	10.9	425	4.6	1.1	
			400	4.4	1.0	
Cotton	Small omnivore	BBCH ≥50	4.4	325	1.4	0.34
	Small insectivore	BBCH ≥20	3.0	325	0.98	0.23

Crop groups as indicated in Table 9; generic focal species and shortcut values for indicated crop groups from EFSA (2009)

DDD = daily dietary dose (mg/kg bw/d) = shortcut value * rate (kg ac/ha)

RAL = regulatory acceptable level from Table 37

RQ = risk quotient = DDD/RAL, where acceptable RQ ≤1

Table 40: Summary of risk assessment outcomes for risks of combination products containing 115 g/L diquat and 135 g/L paraquat to terrestrial vertebrates

Crop / situation	Product rate (L/ha)	Wild mammal assessment	Bird assessment	Max application rate supported
Dessicant to aid harvest in cotton	From 1.2 to 1.3 L/ha (300 to 325 g acs/ha)	Not supported	Acceptable risk	900 mL/ha (225 g acs/ha)

Crop / situation	Product rate (L/ha)	Wild mammal assessment	Bird assessment	Max application rate supported
As an aid to cultivation in fallow (full disturbance)	From 0.6 to 1.7 L/ha (150-425 g acs/ha)	Acceptable risk	Acceptable up to 175 g acs/ha	700 mL/ha (175 g acs/ha)
As an aid to cultivation in fallow (minimum disturbance)	From 0.8 to 1.7 L/ha (200-425 g acs/ha)	Acceptable up to 225 g acs/ha	Not supported	700 mL/ha (175 g acs/ha)
As an aid in establishing sugarcane or controlling weeds in a fallow prior to sugarcane	From 1.2 to 1.7 L/ha (300 to 425 g acs/ha)	Not supported	Not supported	700 mL/ha (175 g acs/ha)
As an aid in post-harvest weed control in fallow (minimum disturbance)	From 1.6 to 1.7 L/ha (400-425 g acs/ha)	Not supported	Not supported	700 mL/ha (175 g acs/ha)
Sugarcane plant & ratoon	From 1.6 to 1.7 L/ha (400-425 g acs/ha)	Not supported	Not supported	700 mL/ha (175 g acs/ha)

Table 41: Screening level assessment of risks of combination products containing 115 g/L diquat and 135 g/L paraquat to bees

Life stage	Exposure	Rate (g/ha)	Predicted total dose (µg/bee)	RAL (µg/bee)	RQ
Adults	Acute contact	425	1.0	10	0.10
		250	7.2	6.4	1.1
	Acute oral	425	12	6.4	1.9
		225	6.4	6.4	1.0

Predicted total dose calculated using USEPA BeeREX tool for adult worker bee foraging for nectar and larval drone within the hive

RAL = regulatory acceptable level from Table 37

RQ = risk quotient = PEC / RAL, where acceptable RQ ≤ 1

Table 42: Assessment of risks of combination products containing 115 g/L diquat and 135 g/L paraquat to other non-target arthropods

Group	Exposure	Scenario	Rate (g acs/ha)	RAL (g acs/ha)	RQ
Foliar arthropods	Contact	Worst-case	425	5.6	76
		Best-case	150	5.6	27

RAL = regulatory acceptable level from Table 37

RQ = risk quotient = PEC / RAL, where acceptable RQ ≤ 1

Recommendations

Uses supported from the viewpoint of environmental safety are listed in Table 43 with the required protection statements and restraints. Uses that are not supported from the viewpoint of environmental safety are listed in Table 44.

Table 43: Supported uses from the viewpoint of environmental safety

Situation	Protection statements and restraints
All supported uses	<p>DO NOT apply if heavy rains or storms are forecast within 3 days DO NOT irrigate to the point of field runoff for at least 3 days after application.</p> <p>Toxic to birds and native mammals. However, the use of this product as directed is not expected to have adverse effects on birds and native mammals.</p> <p>Very toxic to aquatic life. DO NOT contaminate wetlands or watercourses with this product or used containers.</p> <p>Toxic to beneficial arthropods. Not compatible with integrated pest management (IPM) programs utilising beneficial arthropods. Minimise spray drift to reduce harmful effects on beneficial arthropods in non-crop areas.</p>
General weed control in fallow, bananas, rice, and peanuts at rates up to 231 g paraquat/ha (noting banana use is supported up to 175 g ac/ha only)	Harmful to bees. DO NOT apply to flowering weeds or crops at rates exceeding [175 g ac/ha]. DO NOT allow spray drift to flowering weeds or crops in the vicinity of the treatment area. Before spraying, notify beekeepers to move hives to a safe location with an untreated source of nectar and pollen, if there is potential for managed hives to be affected by the spray or spray drift.
Spray topping in pulses (other than vetch) up to 149 g paraquat/ha	(No additional protection statements or restraints required)
Combination products containing 115 g/L diquat and 135 g/L paraquat as an aid to cultivation in fallow (full disturbance) up to 700 mL/ha	

Table 44: Uses not supported from the viewpoint of environmental safety

Situation	Basis
<p>General weed control in non-agricultural situations, around sheds, roadways, paths, firebreaks, market gardens, orchards, potatoes, lucerne, pasture²⁰, potatoes, row crops, vineyards, vegetables</p> <p>Combination products containing 115 g/L diquat and 135 g/L paraquat for general weed control in lucerne, public service areas, rights of way, pasture, spray topping in grasses, forests, orchards, plantations, vineyards, or sugarcane plant & ratoon; as an aid in establishing sugarcane or controlling weeds in a fallow prior to sugarcane; as an aid in post-harvest weed control in fallow (minimum disturbance)</p> <p>Combination products containing amitrole for general weed control in fallow at rates exceeding 231 g paraquat/ha</p> <p>Combination products containing amitrole for general weed control in non-agricultural situations, around sheds, roadways, paths, firebreaks, orchards, vineyards, potatoes, pasture (including hay freezing and spray topping)</p>	Unacceptable risk to wild mammals and birds
Spray topping in pulses at rates exceeding 149 g paraquat/ha	Unacceptable risk to wild mammals
Spot application of combination products containing 115 g/L diquat and 135 g/L paraquat in avocado, custard apples, lychees, mangos	

²⁰ Includes spray topping to prevent ryegrass toxicity

Situation	Basis
Combination products containing 115 g/L diquat and 135 g/L paraquat as a desiccant to aid harvest in cotton	
General weed control in hops, sugarcane	Unacceptable risk to birds
General weed control in fallow, bananas, rice, and peanuts at rates exceeding 231 g paraquat/ha	
Combination products containing 115 g/L diquat and 135 g/L paraquat as an aid to cultivation in fallow (minimal disturbance)	
Combination products containing 115 g/L diquat and 135 g/L paraquat as an aid to cultivation in fallow (full disturbance) at rates exceeding 700 mL/ha	

Spray drift

The APVMA's approach to spray drift management set out in the [APVMA Spray Drift Policy July 2019](#) specifies consideration of spray drift in bystander areas, livestock areas, natural aquatic areas, pollinator areas and vegetation areas. The regulatory acceptable levels (RALs) for each area for paraquat summarised in Table 28 is the maximum amount of spray drift exposure that is not expected to cause undue harm to sensitive areas.

Table 45: Regulatory acceptable levels of paraquat resulting from spray drift

Area considered	Regulatory acceptable level
Natural aquatic areas	0.41 µg ac/L
Pollinator areas	2667 g ac/ha
Vegetation areas	19 g ac/ha
Bystander areas	5.21 g ac/ha
Livestock areas	9.62 mg/kg

The APVMA has considered spray drift implications for uses of paraquat that are supported by worker health and safety, residues, trade and environmental risk assessments. These uses include:

- fallows establishment and aid to cultivation
- spray-topping to reduce seed set
- inter-row sprays in banana plantations
- general post-sowing, pre-crop-emergence weed control in rice.

The APVMA has also considered the spray drift risk resulting from combined toxicity of paraquat and diquat present in chemical products co-formulated with both active constituents. The regulatory acceptable levels of the co-formulated products, accounting for the combined toxicity of both paraquat and diquat are listed in Table 46

Table 46: Regulatory acceptable levels of paraquat and diquat resulting from spray drift of chemical products co-formulated with both active constituents

Area considered	Regulatory acceptable level
Natural aquatic areas	0.66 µg ac/L
Pollinator areas	4333 g ac/ha
Vegetation areas	18 g ac/ha
Bystander areas	4.49 g ac/ha
Livestock areas	17.8 mg/kg

Uses of products that contain both paraquat and diquat which are supported by worker health and safety, residues, trade and environmental risk assessments are limited to fallows establishment and aid to cultivation at rates up to 175 g combined active constituents (acs) per hectare (175 g acs/ha).

Based on the acceptable uses the following spray drift restraints and downwind buffer zones would be required for application of paraquat products at the rates listed in Table 47 and for combination products containing paraquat and diquat in Table 48.

SPRAY DRIFT RESTRAINTS

Specific definitions for terms used in this section of the label can be found at apvma.gov.au/spraydrift

DO NOT allow bystanders to come into contact with the spray cloud.

DO NOT apply in a manner that may cause an unacceptable impact to native vegetation, agricultural crops, landscaped gardens and aquaculture production, or cause contamination of plant or livestock commodities, outside the application site from spray drift. The advisory buffer zones in the relevant buffer zone table/s below provide guidance but may not be sufficient in all situations. Wherever possible, correctly use application equipment designed to reduce spray drift and apply when the wind direction is away from these sensitive areas.

DO NOT apply unless the wind speed is between 3 and 20 kilometres per hour at the application site during the time of application.

DO NOT apply if there are surface temperature inversion conditions present at the application site during the time of application. These conditions exist most evenings one to 2 hours before sunset and persist until one to 2 hours after sunrise.

DO NOT apply by a boom sprayer unless the following requirements are met:

- spray droplets not smaller than a MEDIUM spray droplet size category
- minimum distances between the application site and downwind sensitive areas (see 'Mandatory buffer zones' section of the following table titled 'Buffer zones for boom sprayers') are observed.

Table 47: Paraquat – buffer zones for boom sprayers

Application rate	Boom height above the target canopy	Mandatory downwind buffer zones (metres)				
		Bystander areas	Natural aquatic areas	Pollinator areas	Vegetation areas	Livestock areas
Up to 200 g ac/ha	0.5 m or lower	5	70	0	0	0
	1.0 m or lower	35	210	0	15	0
150 g ac/ha or lower	0.5 m or lower	0	55	0	0	0
	1.0 m or lower	30	160	0	10	0
100 g ac/ha or lower	0.5 m or lower	0	40	0	0	0
	1.0 m or lower	20	120	0	10	0

Table 48: Diquat/paraquat co-formulated product buffer zones for boom sprayers

Diquat-paraquat co-formulated chemical products – buffer zones for boom sprayers						
Application rate	Boom height above the target canopy	Mandatory downwind buffer zones (metres)				
		Bystander areas	Natural aquatic areas	Pollinator areas	Vegetation areas	Livestock areas
Up to 175 g acs/ha	0.5 m or lower	5	45	0	0	0
	1.0 m or lower	35	120	0	15	0
150 g acs/ha or lower	0.5 m or lower	5	40	0	0	0
	1.0 m or lower	30	110	0	15	0

Storage and disposal

The agricultural labelling code provides guidance on appropriate statements to ensure that storage of the chemical product and disposal of containers of the product or unused product does not pose an unacceptable risk to human health and the environment.

Storage

Schedule 7 Poisons require the following storage statement, including a direction to store the product in a locked room or place.

Store in a locked room or place away from children, animals, food, feedstuffs, seed and fertilisers. Store in the closed, original container in a cool, well-ventilated area. DO NOT store for prolonged periods in direct sunlight.

Disposal

Disposal statements are matched against the specification of the product and container. As the worker health and safety advised that the products should only be used through closed mixing and loading, containers suitable for closed mixing and loading would require the following disposal instructions:

Empty contents fully into application equipment. Close all valves and return to [point of supply/designated collection point/other specific collection details] for refill or storage.



Appendix

Appendix A – Summary of assessment outcomes

Table 49: Risk assessment outcomes for products containing paraquat

Crop Use or Situation	Weeds controlled / Use	Application Method	Assessment outcome (risk area)
Aid to cultivation; crop, pasture or fallow establishment	Annual grass and broadleaf weed control	Boomspray	Not supported (environment)
	Volunteer canola including Roundup Ready varieties (4-6 leaf stage)		
	Wild oats at 2-5 leaf stage (autumn/winter) low rate		Supported (up to 231 g ac/ha per season)
	Wild oats at 2-5 leaf stage (spring/summer) high rate		Not supported (environment)
Bananas	Annual grasses and broadleaf weeds	Spot spray	Supported (up to 175 g ac/ha per season)
Bananas	Annual grasses and broadleaf weeds	Inter-row boomspray	Not supported (environment)
Fallows	Australian bindweed, barnyard grass, bladder ketmia, fleabane, sowthistle, turnip weed, yellow vine (caltrop)	Optical spot spray technologies	Not supported (environment)
Firebreaks	Annual grasses and broadleaf weeds	Boomspray	Not supported (environment)
	Knock down weed growth to eliminate fire hazard or assist firebreak burn.		
Hay freezing (grass pasture dessication)	Maximum retention of protein in standing dry feed	Boomspray	Not supported (environment)
Hops	Annual grasses and broadleaf weeds	Inter-row spray	Not supported (environment)
Lucerne (Autumn / early winter)	Annual grass and some broadleaf weeds	Boomspray	Not supported (environment)
Lucerne (late winter / early spring)	Annual grass and some broadleaf weeds	Boomspray	Not supported (environment)

Crop Use or Situation	Weeds controlled / Use	Application Method	Assessment outcome (risk area)
Non-agricultural situations (around sheds, roadways, paths)	Annual grasses and broadleaf weeds, columbus grass	Boomspray, spot spray	Not supported (environment)
Orchards, Vineyards	Annual grasses and broadleaf weeds	Spot spray, inter-row spray	Not supported (environment)
	Annual weed control		
	Annual grasses and broadleaf weeds / annual weed control		
Walnuts	annual grasses and broadleaf weeds	Boomspray	Not supported (environment)
Pasture (Kikuyu/paspalum)	To suppress growth to oversow winter seed	Boomspray	Not supported (environment)
Pastures (pasture cleaning in winter / early spring - annual and perennial clovers, cocksfoot, perennial ryegrass, Phalaris, Demeter fescue only)	Annual grass and some broadleaf weed control except Paterson's Curse, Sorrel, Dock, Shepherd's Purse and some thistles	Boomspray	Not supported (environment)
	Yorkshire fog grass		
Peanuts	Annual ground cherry (2-3 leaf), Apple-of-Peru (2-4 leaf), Milkweed (2-3 leaf)	Boomspray	Supported (up to 231 g ac/ha per season)
	Bellvine (2-3 leaf), Common morning glory (2 leaf)		
	Datura spp. (2-4 leaf)		
	Stagger weed (2-3 leaf), Blue heliotrope (2-3 leaf), Wandering Jew (2-3 leaf), Anoda weed (2-4 leaf)		
	Bellvine (2-3 leaf), Common morning glory (2 leaf)		High rate not supported (environment)
Perennial Grass, Seed crops (cocksfoot, perennial ryegrass, phalaris and Demeter Fescue only)	Annual grass and some broadleaf weeds	Boomspray	Not supported (environment)

Crop Use or Situation	Weeds controlled / Use	Application Method	Assessment outcome (risk area)
Potatoes	Annual grasses and broadleaf weeds (in crop)	Boomspray	Not supported (environment)
	Annual grasses and broadleaf weeds (pre-harvest weed control)		Not supported (environment)
	General weed control (pre-crop)		Not supported (environment)
Prevention of annual ryegrass toxicity	Annual ryegrass. Spray top, graze to destroy seed heads	Boomspray	Not supported (environment)
Rice	Pre-sowing annual grass and broadleaf weed control	Boomspray	Not supported (environment)
	Post-sowing, pre-crop emergence annual grass and broadleaf weed control		Supported up to 231 g ac/ha per season
Row crops, vegetables, market gardens	Older weeds	Inter-row spray	Not supported (environment)
	Post-emergence, post-emergence and inter-row weed control		Not supported (environment)
Spray topping to reduce seed set (Field peas, Lupins, Lentils, Chickpeas, Faba Beans) ²¹	Annual ryegrass	Boomspray	Supported up 149 g ac/ha per season
Spray topping to reduce seed set (pastures)	Grasses generally (particularly annual ryegrass)	Boomspray	Not supported (environment)
	Saffron thistle		
Sugarcane (plant and ratoon)	Grasses and some broadleaf weeds	Boomspray	Not supported (environment)
		Directed interrow spray (droppers/shields/leaf deflectors)	

²¹ Spray topping in vetch is not supported although these uses are grouped on current labels, as it is a pasture legume rather than a pulse

Table 50: Risk assessment outcomes for products containing paraquat and diquat

Crop	Weeds Controlled / Use	Application Method	Assessment outcome (risk area)
Aid to cultivation (Southern Australia - full disturbance)	Seedling Grasses: Annual Ryegrass (<i>Lolium rigidum</i>), Barley Grass (<i>Hordeum spp.</i>), Brome Grass (<i>Bromus spp.</i>), Volunteer Cereals, Wild Oats (<i>Avena spp.</i>)	Boomspray	Supported up to 175 g/ha of combined active constituents per season (700 mL of product/ha)
	Vulpia (Silver Grass, Sand Fescue) (<i>Vulpia spp.</i>)		
	Seedling Brassica Weeds		
	Other Seedling Broadleaved Weeds		
	Deadnettle (<i>Lamium amplexicaule</i>), Fumitory (<i>Fumitory spp.</i>), Melilotus (<i>Melilotus spp.</i>), Pimpernel (<i>Anagallis spp.</i>), Poppy (<i>Papaver spp.</i>), Saffron Thistle (<i>Carthmus lanatus</i>), Sheepweed (<i>Buglossoides arvensis</i>)		
	Paterson's curse (<i>echium plantagineum</i>)		
	Wireweed (<i>Polygonum aviculare</i>)		
	Marshmallow (<i>Malva parviflora</i>)		
	Volunteer Beans, Peas & Lupins		
	Paterson's curse (<i>echium plantagineum</i>)		
Aid to cultivation (Southern Australia - fallow/minimum disturbance)	Seedling Grasses: Annual Ryegrass (<i>Lolium rigidum</i>), Barley Grass (<i>Hordeum spp.</i>), Brome Grass (<i>Bromus spp.</i>), Volunteer Cereals, Wild Oats (<i>Avena spp.</i>)	Boomspray	Not supported (environment)
	Vulpia (Silver Grass, Sand Fescue) (<i>Vulpia spp.</i>)		
	Seedling Brassica Weeds		

Crop	Weeds Controlled / Use	Application Method	Assessment outcome (risk area)
	Other Seedling Broadleaved Weeds		
	Deadnettle (<i>Lamium amplexicaule</i>), Fumitory (<i>Fumitory spp.</i>), Melilotus (<i>Melilotus spp.</i>), Pimpernel (<i>Anagallis spp.</i>), Poppy (<i>Papaver spp.</i>), Saffron Thistle (<i>Carthmus lanatus</i>), Sheepweed (<i>Buglossoides arvensis</i>)		
	Wireweed (<i>Polygonum aviculare</i>)		
	Marshmallow (<i>Malva parviflora</i>)		
	Volunteer Beans, Peas & Lupins		
	Medic (<i>Medicago spp.</i>), Sub-Clover (<i>Trifolium subterraneum</i>)		
	Sub-Clover (<i>Trifolium subterraneum</i>) - split application		
	Perennial Ryegrass (<i>Lolium perenne</i>) - split application		
	Most Annual Weeds - split application		
	Potato Weed (<i>Heliotropium europaeum</i>)		
Aid to cultivation (Northern Australia - full disturbance)	Seedling Grasses	Boomspray	Not supported (environment)
	Sorghum (<i>Sorghum bicolor</i>), Stink Grass (<i>Eragrostis cilianensis</i>)		
	Seedling Broadleaved Weeds		
	Native Jute (<i>Corchorus trilocularis</i>)		
	Annual Ground Cherry (<i>Physalis angulata</i>), Turnip Weed (<i>Rapistrum rugosum</i>)		

Crop	Weeds Controlled / Use	Application Method	Assessment outcome (risk area)
	Boggabri (<i>Amaranthus mitchellii</i>), Hexham Scent (<i>Melilotus indicus</i>), Wild Carrot (<i>Daucus glochidiatus</i>), Speedy Weed (<i>Flaveria australasica</i>)		
Aid to cultivation (Northern Australia - fallow/minimum disturbance)####	Seedling Grasses	Boomspray	Not supported (environment)
	Seedling Broadleaved Weeds		
	Volunteer Cotton (including Roundup® Ready Cotton) (<i>Gossypium hirsutum</i>)		
	Boggabri (<i>Amaranthus mitchellii</i>), Hexham Scent (<i>Melilotus indicus</i>), Wild Carrot (<i>Daucus glodcidiatus</i>), Phyllanthus (<i>Phyllanthus spp.</i>)		
Aid in Post-Harvest weed control (Northern Australia – after Winter Cereals)	Volunteer Barley (<i>Hordeum vulgare</i>), Volunteer Wheat (<i>Triticum aestivum</i>), Bladder Ketmia (<i>Hibiscus trionum</i>), Milk Thistle (<i>Sonchus oleraceus</i>), New Zealand Spinach (<i>Tetragonia tetragonioides</i>)	Boomspray	Not supported (environment)
Sugarcane - establishment and fallows prior to planting	Seedling Grasses: (not regrowth or rhizomes) Barnyard Grass (<i>Echinochloa spp.</i>), Liverseed Grass (<i>Urochloa panicoides</i>), Stink Grass (<i>Eragrostis cilianensis</i>)	Boomspray	Not supported (environment)
	Seedling Broadleaved Weed		Not supported (environment)
	Seedling Phyllanthus (<i>Phyllanthus spp.</i>)		Not supported (environment)
	Mature grasses, broadleaf weeds and Phyllanthus (<i>Phyllanthus spp.</i>)	Boomspray	Not supported (environment)
Sugarcane - plant and ratoon	Most Seedling Broadleaf Weeds including Sicklepod (<i>Senna (Cassia) obtusifolia</i>), Bluetop (<i>Ageratum houstonianum</i>), Phyllanthus (<i>Phyllanthus spp.</i>), Calopo (<i>Calapogonium muconoides</i>)	Boomspray or directed interrow spray	Not supported (environment, residues [post-emergent boomspray])

Crop	Weeds Controlled / Use	Application Method	Assessment outcome (risk area)
	Most Seedling Grasses including Awnless Barnyard Grass (<i>Echinochloa colona</i>), Summer Grass (<i>Digitaria ciliaris</i>), Guinea Grass (<i>Panicum maximum</i>), Hamil Grass (<i>Panicum maximum cv Hamil</i>), Green Summer Grass (<i>Brachiaria miliiformis</i>)		
Cotton	Desiccant to aid harvest	Boomspray	Not supported (environment, residues)
Lucerne (established at least 1 year old)	Most annual weeds including Capeweed and Erodium. For improved grazing, hay or seed production or over sowing, enhanced control of some broadleaf weeds, and short term residual weed control.	Boomspray	Not supported (environment)
Public Service Areas, Rights-of-Way, Market Gardens and Nurseries, Orchards (including Bananas), Vineyards and Forests - ring weeding around trees with brown bark and strip spraying in Orchards and Vineyards	Most Annual Grasses and Broadleaved Weeds	High Volume or Power Sprayer	Not supported (environment)
Vegetable crops	Weed control prior to crop emergence - most Annual Grasses and Broadleaved Weeds	High Volume or Power Sprayer	Not supported (environment)
Potatoes	General weed control - most Annual Grasses and Broadleaved Weeds	High Volume or Power Sprayer	Not supported (environment)
	Weed destruction prior to digging - most Annual Grasses and Broadleaved Weeds	High Volume or Power Sprayer	
Avocados, Custard Apples, Lychees, Mangoes	Most Annual and Perennial Broadleaf Weeds and Grasses	High Volume or Power Sprayer	Not supported (environment)
Rice (pre-emergent use only)	Annual Weeds including Barnyard Grass (on rice stubble after burning)	Boomspray	Not supported (environment)

Crop	Weeds Controlled / Use	Application Method	Assessment outcome (risk area)
	Clover control		
	Annual Pasture - not properly managed		
Pasture (Kikuyu/paspalum)	To suppress growth to oversow winter feed	Boomspray	Not supported (environment)
Pasture (Established - Perennial Grass Crops, Cocksfoot, Perennial Ryegrass, Phalaris and Demeter Fescue)	Control of annual weeds including: capeweed and erodium for improved grazing, hay or seed production.	Boomspray	Not supported (environment)
Pasture (Improvement)	To increase the perennial grass and/or the sub-clover or white clover content	Boomspray	Not supported (environment)
Grasses (particularly Annual Ryegrass)	To control grass seed set (Spray Top technique)	Boomspray	Not supported (environment)
Duboisia	Annual weeds	Direct spray	Not supported (environment)
		Spot Spray	Not supported (environment)
Tea Trees (<i>Melaleuca alternifolia</i>)	Grasses and broadleaf weeds	Boomspray	Not supported (environment)

Table 51: Risk assessment outcomes for products containing paraquat and amitrole

Crop or Situation	Weeds Controlled	Application Method	Assessment outcome (risk area)
Aid to cultivation. Weed control prior to crop establishment - <u>winter crops</u> (canola, cereals (wheat, barley, oats, rye, triticale), field peas, lupins) and pastures (sub clover, Medic.)	Young seedling plants only**, annual ryegrass, brome grass, barley grass, capeweed, indian hedge mustard, turnip weed, volunteer cereals (barley, oats, triticale, wheat), wild oats, wild radish	Boomspray	Supported up to 231 g/ha of paraquat per season
Aid to cultivation. Weed control prior to crop establishment - <u>summer crops</u> (cotton, mung beans, sorghum)	Young seedling plants only**, wild oat control at 2-5 leaf stage, annual grass and broadleaf weed control	Boomspray	Not supported (environment)
	Young seedling plants only**		Not supported (environment)

Crop or Situation	Weeds Controlled	Application Method	Assessment outcome (risk area)
Fallow establishment and maintenance	Flaxleaf fleabane, yellow vine (Caltrop), sowthistle, barnyard grass, bladder ketmia, Turnip weed	Boomspray or optical spot spray	
Firebreaks	Knock down weed growth to eliminate fire hazard or assist firebreak burn.	Boomspray	Not supported (environment)
Hay freezing	Maximum retention of protein in standing dry feed	Boomspray	Not supported (environment)
Non-agricultural situations (sheds, roadways, paths)	Annual weed control, columbus grass, flaxleaf fleabane	Boomspray	Not supported (environment)
Non-agricultural situations. Non disturbed areas on farm - fire breaks, fencelines, around yards, buildings and other areas including tree plantings.	Young seedling plants only**	boomspray or optical spot spray	Not supported (environment)
Orchards, vineyards	Annual weed control, columbus grass, flaxleaf fleabane, young seedling plants only**	boomspray or spot spray	Not supported (environment)
Pastures (selective weed control autumn / early winter - annual and perennial clover)	Annual grasses and some broadleaf weed control except Paterson's Curse, Sorrel, Dock, Shepherd's Purse and some Thistles, Barley Grass, Saffron thistle	Boomspray	Not supported (environment)
Potatoes	Pre-harvest weed control	Boomspray	Not supported (environment)
Prevention of annual ryegrass toxicity	Annual ryegrass. Spray top, graze to destroy seed heads	Boomspray	Not supported (environment)
Spray topping to reduce seed set	Grasses (particularly annual ryegrass)	Boomspray	Not supported (environment)
<p>** Annual ryegrass, brome grass, barley grass, capeweed, Indian hedge mustard, turnip weed, volunteer cereals (barley, oats, triticale, wheat), wild oats, wild radish, barnyard grass (max early tillering), bladder ketmia, cowvine/peachvine, cranesbill, dove's foot, dwarf amaranth, fleabane (max 6 leaf), field peas, goosefoot, marshmallow, medics, mignonette (cut-leaf), Paterson's curse, soursob, speedwell (not ivy-leaf), Australian stoncrop, storksbills, sub clover, thistles (artichoke, milk/sow, spear, stemless, variegated), 3 cornered jack, volunteer cotton, volunteer canola, wireweed, wild lettuce</p>			

Appendix B – Listing of environmental endpoints

Table 52: Paraquat – Dissipation in animal food items

Substance	Matrix	Result	Reference
Paraquat	Insects	Beetles: DT ₅₀ 4.1 d	Bakker 2005a
		Spiders: DT ₅₀ 4.6 d	
Paraquat	Insects	Spiders: DT ₅₀ 3.5 d	Bakker 2005b
		Lepidoptera: DT ₅₀ 3.5 d	
		Geomean DT ₅₀ 3.9 d	

Table 53: Paraquat – Fate and behaviour in soil

Substance	Study	Result	Reference	
Paraquat	Soil photolysis	Stable	Pack 1982	
	Biodegradability	Intrinsically biodegradable in soil pore water	Kuet et al, 2001, Ricketts 1999	
Paraquat	Aerobic laboratory soil	Sandy loam: stable <0.1% mineralisation after 180 d 0.7% bound residues after 180 d	Vickers et al, 1989a	
	Anaerobic laboratory soil	Sandy loam: stable <0.1% mineralisation after 90 d 0.75% bound residues after 90 d		
Paraquat	Adsorption/desorption	<u>Soil</u>	Robbins et al, 1988	
		Loam		<u>% clay</u> 21 <u>Kd (mL/g)</u> 50000
		Loamy sand		8 5900
		Silty clay loam		29 9400
		Sand		2 480
		$\log_{10} Kd = (1.32 \times \log_{10} \% \text{ clay}) + 2.84$ at the SAC-WB concentration of the soil, based on data from 242 soils	Dyson et al, 1994	

Substance	Study	Result	Reference	
Paraquat	Terrestrial field dissipation	AU-Western Australia	DT ₅₀ >10 years	Muller & Roy 1997
		US-North Carolina	DT ₅₀ >10 years	Anderson et al, 1992(a), Dyson et al, 1995(a), 1995(b)
		US-California	DT ₅₀ >10 years	Anderson et al, 1992(b)
		US-Illinois	DT ₅₀ >10 years	Anderson et al, 1992(c)
		US-Mississippi	DT ₅₀ >10 years	Anderson et al, 1992(d)
		US-Delaware	DT ₅₀ >10 years	Earl et al, 1989
		UK-Frenshem	DT ₅₀ 20 years	Dyson & Chapman 1995
		UK-Yarnton	DT ₅₀ 6.6 years	Hance et al, 1980
		Malaysia	DT ₅₀ >10 years	Lane & Ngim 2000
	Thailand	DT ₅₀ 41 days	Amondham et al, 2006	

Table 54: Paraquat – Fate and behaviour in water and sediment

Substance	Study	Result	Reference
Paraquat	Hydrolysis	pH 4, 50°C: stable pH 7, 50°C: stable pH 10, 50°C: stable	White 2010
		pH 5, 25°C: stable pH 7, 25°C: stable pH 9, 25°C: stable pH 5, 40°C: stable pH 7, 40°C: stable pH 9, 40°C: stable	Upton et al, 1985
	Aqueous photolysis	Stable (pH 7 buffer)	Parker & Leahey 1988
		Stable (natural river water)	Dean 2000
	Degradation in water/sediment	2systems: Virginia Water, Old Basing Max 91% paraquat in sediment (time 0) Stable in sediment <0.1% mineralisation after 100d 4.2-4.5% bound residues after 100d	Long et al, 1996

Table 55: Paraquat – Fate and behaviour in air

Substance	Study	Result	Reference
Paraquat	Photochemical oxidative degradation	DT ₅₀ 6.0 h	Hayes 2006

Table 56: Paraquat – Monitoring data

Substance	Medium	Result	Reference
Paraquat	Vegetation	No detectable uptake of paraquat residues from soil into the grain of wheat, corn or soybeans following annual applications of 1 kg ac/ha or one application up to 114 kg ac/ha	Dyson et al, 1995

Substance	Medium	Result	Reference
Paraquat	Soil	Max 4.7 mg/kg in 10 soils following cumulative exposure up to 13 kg ac/ha after 10 years	Stevens et al, 1988
		Max 3.3 mg/kg in 31 soils following cumulative exposure up to 50 kg ac/ha over many years. One soil contained 38 mg/kg following cumulative exposure of 24 kg ac/ha.	Stevens & Bewick 1991
		<40% residue decline was observed within 6 years of treatments ranging 0-120% SAC-WB in 3 soils (SAC-WB 65, 80 and 300 mg/kg)	Lane et al, 1992, Lane & Bouwman 2000
	Water	No detectable residues in water from a furrow irrigation system following application of SL 276 g/L formulation in sweet corn up to 1725 g ac/ha	Evans 2006

Table 57: Paraquat – Laboratory studies on terrestrial vertebrates

Substance	Group	Exposure	Species	Toxicity value ²²	Reference		
Paraquat	Mammals	Acute	<i>Rattus norvegicus</i>	LD ₅₀ 103 mg ac/kg bw	Duerden 1994		
				LD ₅₀ 105 mg ac/kg bw	Kimbrough & Gaines 1970		
				LD ₅₀ 126 mg ac/kg bw	Murray & Gibson 1972		
			Geomean LD ₅₀ 111 mg ac/kg bw				
			<i>Mus musculus</i>	LD ₅₀ 102 mg ac/kg bw	Fletcher 1967		
				LD ₅₀ 166 mg ac/kg bw	Heylings & Farnworth 1992		
				LD ₅₀ 203 mg ac/kg bw	Heylings & Farnworth 1992		
			Geomean LD ₅₀ 151 mg ac/kg bw				
			<i>Cavia porcellus</i>	LD ₅₀ 22 mg ac/kg bw	Murray & Gibson 1972		
				<i>Oryctolagus cuniculus</i>	LD ₅₀ 45 mg ac/kg bw	Farnworth et al, 1993	
					<i>Macaca fascicularis</i>	LD ₅₀ 50 mg ac/kg bw	Murray & Gibson 1972
			Geomean LD ₅₀ 61 mg ac/kg bw (5 mammal species)				
				Chronic	<i>Rattus norvegicus</i>	NOAEL 7.2 mg ac/kg bw/d	Igarashi 1980
						NOAEL 3.8 mg ac/kg bw/d	Lindsay 1982(a),1982(b)
				Birds	Acute	<i>Anas platyrhynchos</i>	LD ₅₀ 54 mg ac/kg bw
	<i>Colinus virginianus</i>	LD ₅₀ 124 mg ac/kg bw	Fink et al, 1979				
	<i>Taeniopygia guttata</i>	LD ₅₀ 27 mg ac/kg bw	Hubbard et al, 2014				
	Geomean LD ₅₀ 57 mg ac/kg bw (3 bird species)						
	Dietary	<i>Anas platyrhynchos</i>	LD ₅₀ 292 mg ac/kg bw/d		Hill et al, 1975		
		<i>Colinus virginianus</i>	LD ₅₀ 71 mg ac/kg bw/d		Hill et al, 1975		
		<i>Coturnix coturnix</i>	LD ₅₀ 70 mg ac/kg bw/d		Hill et al, 1975		
		<i>Phasianus colchicus</i>	LD ₅₀ 106 mg ac/kg bw/d		Hill et al, 1975		
	Chronic	<i>Anas platyrhynchos</i>	NOAEL 2.7 mg ac/kg bw/d	Fink et al, 1982(a)			

²² All toxicity values are reported in terms of the active constituent which is defined as the paraquat cation. Dietary endpoints in mg ac/kg feed were converted to mg ac/kg bw/d using a default conversion factor (0.1) when food consumption data were not available

Table 58: Paraquat – Monitoring data on terrestrial vertebrates

Substance	Crop	Exposure	Effect	Reference
Paraquat	Various	Various	Deaths attributed to paraquat include 1 hedgehog, 1 hare and no birds in UK (1990-94); no vertebrate deaths attributed to paraquat in France (1994-95) or the Netherlands (1990-94)	de Snoo et al, 1999
			Hare deaths attributed to paraquat were 2/104 in UK (1974-97) and 8/13588 in France (1986-96)	Edwards et al, 2000
			Hare deaths attributed to paraquat were 3/112 in UK (1974-2002) and 9/21999 in France (1986-99); no deaths were attributed to paraquat in 216 bird and 8 mammal deaths in the Netherlands (1990-94)	Sutton et al, 2004

Table 59: Paraquat – Effects on aquatic species

Substance	Group	Exposure	Species	Toxicity value	Reference	
Paraquat	Fish	Acute	<i>Oncorhynchus mykiss</i>	LC ₅₀ 19 mg ac/L	Tapp et al, 1990(a)	
				LC ₅₀ 18 mg ac/L	Tapp et al, 1990(b)	
				LC ₅₀ >33 mg ac/L	Scheerbaum 2007(a)	
			<i>Cyprinodon variegatus</i>	LC ₅₀ >41 mg ac/L	Claude et al, 2014(a)	
			<i>Pimephales promelas</i>	LC ₅₀ 4.7 mg ac/L	Claude et al, 2014(b)	
			<i>Cyprinus carpio</i>	LC ₅₀ 98 mg ac/L	Tapp et al, 1990(c)	
			Chronic	<i>Pimephales promelas</i>	NOEC 0.74 mg ac/L	Claude et al, 2014(c)
		<i>Cyprinodon variegatus</i>		NOEC 1.8 mg ac/L	Claude et al, 2014(d)	
		<i>Oncorhynchus mykiss</i>		NOEC 8.5 mg ac/L	Tapp et al, 1990(d)	
		Invertebrates	Acute	<i>Daphnia magna</i>	EC ₅₀ 4.4 mg ac/L	Allison & Hamer 1990
					EC ₅₀ 4.3 mg ac/L	Noack 2007
					Geomean EC ₅₀ 4.3 mg ac/L	
				<i>Americamysis bahia</i>	LC ₅₀ 0.23 mg ac/L	Claude et al, 2014(e)
				<i>Crassostrea virginica</i>	EC ₅₀ 23 mg ac/L	Claude et al, 2014(f)
Chronic	<i>Daphnia magna</i>			NOEC 0.097 mg ac/L	Claude et al, 2014(g)	
	<i>Americamysis bahia</i>			NOEC 0.038 mg ac/L	Claude et al, 2014(h)	
Sediment-dwellers	Acute	<i>Hyalella azteca</i>	LC ₅₀ 39 mg ac/kg ds	Bradley 2015(a)		
			<i>Leptocheirus plumulosus</i>	LC ₅₀ >100 mg ac/kg ds	Bradley 2015(b)	
			<i>Chironomus dilutus</i>	LC ₅₀ >100 mg ac/kg ds	Bradley 2015(c)	
	Chronic	<i>Chironomus riparius</i>	NOEC 0.37 mg ac/L	Hamer & Ashwell 1997		
			NOEC 100 mg ac/kg ds	Hamer 1998		

Substance	Group	Exposure	Species	Toxicity value	Reference
Paraquat	Algae	Chronic	<i>Navicula pelliculosa</i>	E _r C ₅₀ 0.00034 mg ac/L	Smyth et al, 1992(b)
			<i>Anabaena flos-aquae</i>	EC ₅₀ 0.0078 mg ac/L	Smyth et al, 1992(c)
			<i>Chlamydomonas reinhardtii</i>	E _r C ₅₀ 0.0056 mg ac/L	Tanaka et al, 2011
				E _r C ₅₀ 0.043 mg ac/L	Cheloni & Slaveykova 2021
				E _r C ₅₀ 0.067 mg ac/L	Jamers & de Coen 2010
			Geomean E _r C ₅₀ 0.025 mg ac/L		
		Chronic	<i>Raphidocelis subcapitata</i>	E _r C ₅₀ 0.20 mg ac/L	Smyth et al 1990a
				E _r C ₅₀ 0.23 mg ac/L	Smyth et al, 1992(a)
				E _r C ₅₀ 0.20 mg ac/L	Scheerbaum 2007(b)
				E _r C ₅₀ 0.48 mg ac/L	Grillo et al, 2015
			E _r C ₅₀ 0.26 mg ac/L	Smyth et al, 1990(b)	
		Geomean E _r C ₅₀ 0.26 mg ac/L			
		<i>Chlorella vulgaris</i>	E _r C ₅₀ 0.53 mg ac/L	Baltazar et al, 2014	
		<i>Skeletonema costatum</i>	E _r C ₅₀ 5.9 mg ac/L	Smyth et al, 1992(d)	
	Aquatic plants	Chronic	<i>Lemna minor</i>	E _r C ₅₀ 0.015 mg ac/L	Tagun & Boxall 2018
<i>Lemna gibba</i>			E _r C ₅₀ 0.031 mg ac/L	Mohammad et al, 2010	
			EC ₅₀ 0.037 mg ac/L	Smyth et al, 1992e	
			Geomean E _r C ₅₀ 0.034 mg ac/L		

Table 60: Paraquat – Effects on bees

Substance	Species	Life stage	Exposure	Toxicity value	Reference
Paraquat	<i>Apis mellifera</i>	Adult	Acute contact	LD ₅₀ 82 µg ac/bee	Bull & Wilkinson 1987
			Acute oral	LD ₅₀ 22 µg ac/bee	Bull & Wilkinson 1987
				LD ₅₀ 14 µg ac/bee	Bruhnke 2007
				LD ₅₀ >35 µg ac/bee	Stevenson 1978
SL 200 g/L	<i>Apis mellifera</i>	Adult	Acute contact	LD ₅₀ 16 µg ac/bee	Bull & Wilkinson 1987
			Acute oral	LD ₅₀ 13 µg ac/bee	Bull & Wilkinson 1987

Table 61: Paraquat – Laboratory studies on other arthropod species

Substance	Group	Species	Test substrate	Toxicity value	Reference
SL 200 g/L	Predatory arthropods	<i>Typhlodromus pyri</i>	Glass plate	100% mortality at 1100 g ac/ha	Gill & Austin 1996

Substance	Group	Species	Test substrate	Toxicity value	Reference
SL 100 g/L	Predatory arthropods	<i>Typhlodromus pyri</i>	Glass plate	LR ₅₀ 1.9 g ac/ha	Austin & Elcock 1999a
			Bean leaf disc	LR ₅₀ 8.2 g ac/ha ER ₅₀ >4.0 g ac/ha	Austin 1999a
		<i>Pterostichus melanarius</i> <i>Pardosa spp.</i>	Loamy sand Loamy sand	LR ₅₀ >1000 g ac/ha LR ₅₀ >1000 g ac/ha	Jackson et al, 1991
	Parasitic arthropods	<i>Aleochara bilineata</i>	Quartz sand	ER ₅₀ >600 g ac/ha	Petto 1993

Table 62: Paraquat – Field studies on other arthropod species

Substance	Crop	Exposure	Effect	Reference
SL 100 g/L	Winter wheat	1× 300 g ac/ha post-harvest	Short-term effects on arthropod populations were observed, this may in part be attributable to loss of vegetation; recovery was observed by following spring/summer	Kendall et al, 1989

Table 63: Paraquat – Laboratory studies on soil organisms

Substance	Group	Exposure	Species	Toxicity value	Reference
SL 200 g/L	Macro-organisms	Acute	<i>Eisenia fetida</i>	LC ₅₀ >1000 mg ac/kg ds	Edwards & Coulson 1993, Lane & Vaughan 1997

Table 64: Paraquat – Field studies on soil organisms

Substance	Exposure	Effect	Reference
Paraquat	0, 90, 198 and 720 kg ac/ha (0, 50, 110 and 400% SAC) incorporated to 150 mm	No adverse effects on soil micro-organisms were observed	Drew & Davies 1980
	0, 90, 198 and 720 kg ac/ha (0, 50, 110 and 400% SAC) incorporated to 150 mm	Reduced abundance of Collembola and Gamisina observed in 720 kg ac/ha treatment after one year – though this may have been due to changes in vegetation cover	Cole & Wilkinson 1980
	0, 15, 33 and 120 kg ac/ha (0, 50, 110 and 400% SAC) incorporated to 25 mm	Reduced earthworm abundance and/or biomass was observed in 120, 198 and 720 kg ac/ha treatments after one year and abundance only at 720 kg ac/ha after 6 years. No effect on biomass was observed after 6 years.	Edwards 1980
	1× 2.24, 114, 561 and 1700 kg ac/ha Multiple applications to achieve total rates of 260 and 565 kg ac/ha	Effects on earthworms were investigated. No adverse effects on <i>lumbricidae</i> or <i>enchytraeid</i> abundance, attributable to paraquat, were reported. SAC not reported	Wilkinson & Edwards 1993

Table 65: Paraquat – Effects on non-target terrestrial plants

Substance	Exposure	Species	ER ₂₅	ER ₅₀	Reference
SL 240 g/L	Pre-emergent	<i>Brassica napus</i>	>1166 g ac/ha	>1166 g ac/ha	Martin 2014(a)
		<i>Zea mays</i>	>1166 g ac/ha	>1166 g ac/ha	
		<i>Allium cepa</i>	>1267 g ac/ha	>1267 g ac/ha	
		<i>Avena sativa</i>	712 g ac/ha	>1267 g ac/ha	
		<i>Cucumis sativus</i>	>1267 g ac/ha	>1267 g ac/ha	
		<i>Glycine max</i>	>1267 g ac/ha	>1267 g ac/ha	
		<i>Lolium perenne</i>	>639 g ac/ha	>1267 g ac/ha	
		<i>Lycopersicon esculentum</i>	>1267 g ac/ha	>1267 g ac/ha	
		<i>Phaseolus vulgaris</i>	>1267 g ac/ha	>1267 g ac/ha	
		<i>Raphanus sativus</i>	>1267 g ac/ha	>1267 g ac/ha	
	Post-emergent	<i>Lolium perenne</i>	23 g ac/ha	35 g ac/ha	Martin 2014(b)
		<i>Zea mays</i>	30 g ac/ha	80 g ac/ha	
		<i>Avena sativa</i>	47 g ac/ha	108 g ac/ha	
		<i>Allium cepa</i>	23 g ac/ha	136 g ac/ha	
		<i>Lycopersicon esculentum</i>	47 g ac/ha	188 g ac/ha	
		<i>Cucumis sativus</i>	99 g ac/ha	267 g ac/ha	
		<i>Glycine max</i>	24 g ac/ha	297 g ac/ha	
		<i>Brassica napus</i>	36 g ac/ha	>314 g ac/ha	
		<i>Phaseolus vulgaris</i>	>314 g ac/ha	>314 g ac/ha	
		<i>Raphanus sativus</i>	182 g ac/ha	>314 g ac/ha	
SL 300 g/L	Post-emergent	<i>Xanthium strumarium</i>	14 g ac/ha	25 g ac/ha	Canning & White 1992
		<i>Beta vulgaris</i>	20 g ac/ha	68 g ac/ha	
		<i>Brassica napus</i>	46 g ac/ha	83 g ac/ha	
		<i>Abutilon theophrasti</i>	50 g ac/ha	135 g ac/ha	
		<i>Ipomoea hederacea</i>	111 g ac/ha	201 g ac/ha	
		<i>Zea mays</i>	198 g ac/ha	536 g ac/ha	
		<i>Glycine max</i>	101 g ac/ha	>763 g ac/ha	

Table 66: Diquat/paraquat combination products: short-term effects on terrestrial vertebrates

Group	Species	0.46 diquat ²³	0.54 paraquat ²⁴	1.00 combination ²⁵
Mammals	<i>Rattus norvegicus</i>	LD ₅₀ 120 mg ac/kg bw Rittenhouse 1979	LD ₅₀ 111 mg ac/kg bw Duerden 1994 Kibrough & Gaines 1970 Murray & Gibson 1972	Measured: LD ₅₀ 119 mg acs/kg bw Pooles 2005 Predicted: LD ₅₀ 115 mg acs/kg bw MDR 0.97
	<i>Mus musculus</i>	LD ₅₀ 125 mg ac/kg bw Clark & Hurst 1970	LD ₅₀ 151 mg ac/kg bw Fletcher 1967 Heylings & Farnworth 1992	Predicted: LD ₅₀ 138 mg acs/kg bw Relative toxicity: 51% + 49%
	<i>Cavia porcellus</i>	LD ₅₀ ~100 mg ac/kg bw Clark & Hurst 1970	LD ₅₀ 22 mg ac/kg bw Murray & Gibson 1972	Predicted: LD ₅₀ 34 mg acs/kg bw Relative toxicity: 16% + 84%

²³ All formulations contain 115 g/L diquat, which comprises 46% of the total active constituent

²⁴ All formulations contain 135 g/L paraquat, which comprises 54% of the total active constituent

²⁵ Refer to **APVMA Risk Assessment Manual – Environment** for calculation method to predict combination toxicity

Group	Species	0.46 diquat ²³	0.54 paraquat ²⁴	1.00 combination ²⁵
Mammals	<i>Oryctolagus cuniculus</i>	LD ₅₀ 101 mg ac/kg bw Clark & Hurst 1970	LD ₅₀ 45 mg ac/kg bw Farnworth et al, 1993	Predicted: LD ₅₀ 60 mg acs/kg bw Relative toxicity: 28% + 72%
Geomean LD ₅₀ 76 mg acs/kg bw (4 mammal species)				
Birds	<i>Anas platyrhynchos</i>	LD ₅₀ 71 mg ac/kg bw Fink et al, 1982b	LD ₅₀ 54 mg ac/kg bw Johnson 1998	Predicted: LD ₅₀ 61 mg acs/kg bw Relative toxicity: 39% + 61%
	<i>Taeniopygia guttata</i>	LD ₅₀ 31 mg ac/kg bw Hubbard 2013	LD ₅₀ 27 mg ac/kg bw Hubbard et al, 2014	Predicted: LD ₅₀ 29 mg acs/kg bw Relative toxicity: 43% + 47%
Geomean LD ₅₀ 42 mg acs/kg bw (2 bird species)				

Table 67: Diquat/paraquat combination products: short-term effects on aquatic species²⁶

Group	Species	0.46 diquat ²⁷	0.54 paraquat ²⁸	1.00 combination ²⁹
Fish	<i>Cyprinodon variegatus</i>	meas. 4d LC ₅₀ 49 mg ac/L adj. LC ₅₀ 59 mg ac/L Nicholson 1987	meas. 4d LC ₅₀ >41 mg ac/L adj. LC ₅₀ >50 mg ac/L Claude et al, 2014(a)	Predicted: LC ₅₀ >54 mg acs/L Relative toxicity: ≤42% + ≥58%
	<i>Sander vitreus</i>	meas. 4d LC ₅₀ 0.75 mg ac/L adj. LC ₅₀ 0.91 mg ac/L Paul et al, 1994	No data ³⁰	Predicted: LC ₅₀ 1.7 mg acs/L Relative toxicity: 84% + 16%
	<i>Pimephales promelas</i>	No data	meas. 4d LC ₅₀ 4.7 mg ac/L adj. LC ₅₀ 5.7 mg ac/L Claude et al, 2014(b)	Predicted: LC ₅₀ 1.7 mg acs/L Relative toxicity: 84% + 16%
Invertebrates	<i>Americamysis bahia</i>	meas. 4d LC ₅₀ 0.42 mg ac/L adj. LC ₅₀ 0.51 mg ac/L Hoberg 1987	meas. 4d LC ₅₀ 0.23 mg ac/L adj. LC ₅₀ 0.28 mg ac/L Claude et al, 2014(e)	Predicted: LC ₅₀ 0.35 mg acs/L Relative toxicity: 32% + 68%
	<i>Daphnia magna</i>	meas. 2d EC ₅₀ 2.5 mg ac/L adj. EC ₅₀ 2.8 mg ac/L	meas. 2d EC ₅₀ 4.3 mg ac/L adj. EC ₅₀ 4.8 mg ac/L	Predicted: EC ₅₀ 3.6 mg acs/L

²⁶ All 'measured' endpoints have been adjusted to account for rapid dissipation from the water column under natural conditions (adjusted EC₅₀ = measured EC₅₀ / (1 - EXP (exposure days * (-ln(2)/DT₅₀ 7.0 days))) (exposure days * ln(2)/DT₅₀ 7.0 days). The more conservative water DT₅₀ of 7 days for paraquat has been utilised to adjust the endpoints for both chemicals to avoid artificially skewing the relative toxicity contributions toward paraquat.

²⁷ All formulations contain 115 g/L diquat, which comprises 46% of the total active constituent

²⁸ All formulations contain 135 g/L paraquat, which comprises 54% of the total active constituent

²⁹ Refer to **APVMA Risk Assessment Manual – Environment** for calculation method to predict combination toxicity; predicted values are based on adjusted toxicity values to account for rapid dissipation of both active constituents from the water column

³⁰ Where toxicity data are not available, the endpoint for the most sensitive species was selected to predict combination toxicity

Group	Species	0.46 diquat ²⁷	0.54 paraquat ²⁸	1.00 combination ²⁹
		Volz 2004	Allison & Hamer 1990 Noack 2007	Relative toxicity: 59% + 41%
Invertebrates	<i>Crassostrea virginica</i>	meas. 4d EC ₅₀ 141 mg ac/L adj. EC ₅₀ 171 mg ac/L Dionne 1987	meas. 4d EC ₅₀ 23 mg ac/L adj. EC ₅₀ 28 mg ac/L Claude et al, 2014f	Predicted: EC ₅₀ 46 mg acs/L Relative toxicity: 12% + 88%
	<i>Hyalella azteca</i>	meas. 4d LC ₅₀ 0.084 mg ac/L adj. LC ₅₀ 0.10 mg ac/L Bender 2006a	No data	Predicted: LC ₅₀ 0.15 mg acs/L Relative toxicity: 70% + 30%
Algae	<i>Navicula pelliculosa</i>	meas. 3d E _r C ₅₀ 0.0012 mg ac/L adj. E _r C ₅₀ 0.0014 mg ac/L Smyth et al, 1998(a)	meas. 3d E _r C ₅₀ 0.00034 mg ac/L adj. E _r C ₅₀ 0.00041 mg ac/L Smyth et al, 1992(a)	Predicted E _r C ₅₀ : 0.00061 mg acs/L Relative toxicity: 20% + 80%
	<i>Raphidocelis subcapitata</i>	meas. 4d EC ₅₀ 0.0055 mg ac/L adj. EC ₅₀ 0.0067 mg ac/L Nagai 2019	meas. 4d EC ₅₀ 0.26 mg ac/L adj. EC ₅₀ 0.31 mg ac/L Smyth et al, 1990(a), 1990(b), 1992(b) Scheerbaum 2007(b) Grillo et al, 2015	Predicted: EC ₅₀ 0.014 mg acs/L Relative toxicity: 98% + 2%
	<i>Anabaena flos-aquae</i>	meas. 3d E _r C ₅₀ 0.025 mg ac/L adj. E _r C ₅₀ 0.029 mg ac/L Smyth et al, 1998b	meas. 3d E _r C ₅₀ 0.0078 mg ac/L adj. E _r C ₅₀ 0.0099 mg ac/L Smyth et al, 1992(c)	Predicted E _r C ₅₀ : 0.014 mg acs/L Relative toxicity: 23% + 77%
	<i>Skeletonema costatum</i>	meas. 3d E _r C ₅₀ 12 mg ac/L adj. E _r C ₅₀ 14 mg ac/L Smyth et al, 1998c	meas. 3d E _r C ₅₀ 5.9 mg ac/L adj. E _r C ₅₀ 7.1 mg ac/L Smyth et al, 1998(d)	Predicted: E _r C ₅₀ 9.2 mg acs/L Relative toxicity: 30% + 70%
Aquatic plants	<i>Lemna gibba</i>	meas. 14d EC ₅₀ 0.0032 mg ac/L adj. EC ₅₀ 0.0059 mg ac/L Magor & Shillabeer 2001	meas. 7/14d* E _r C ₅₀ 0.034 mg ac/L adj. E _r C ₅₀ 0.054 mg ac/L Mohammad et al, 2010 Smyth et al, 1992e	Predicted: EC ₅₀ 0.011 mg acs/L Relative toxicity: 89% + 11%
	<i>Lemna minor</i>	No data	meas. 7d E _r C ₅₀ 0.015 mg ac/L adj. E _r C ₅₀ 0.021 mg ac/L Tagun & Boxall 2018	Predicted: EC ₅₀ 0.0096 mg acs/L Relative toxicity: 75% + 25%
Primary producers			Geomean EC ₅₀ 0.0066 mg acs/L (5 species, excl. <i>S.costatum</i>)	

*7d E_rC₅₀ 0.031 and 14d E_rC₅₀ 0.037 mg ac/L

Table 68: Diquat/paraquat combination products: short-term effects on bees

Group	Species	0.46 diquat ³¹	0.54 paraquat ³²	1.00 combination ³³
Bees (contact)	<i>Apis mellifera</i>	LD ₅₀ 105 µg ac/bee Gough et al, 1987	LD ₅₀ 16 µg ac/bee Bull & Wilkinson 1987	Predicted: LD ₅₀ 26 µg acs/bee

³¹ All formulations contain 115 g/L diquat, which comprises 46% of the total active constituent³² All formulations contain 135 g/L paraquat, which comprises 54% of the total active constituent³³ Refer to **APVMA Risk Assessment Manual – Environment** for calculation method to predict combination toxicity

Group	Species	0.46 diquat ³¹	0.54 paraquat ³²	1.00 combination ³³
				Relative toxicity: 11% + 89%
Bees (oral)	<i>Apis mellifera</i>	LD ₅₀ 22 µg ac/bee Gough et al, 1987	LD ₅₀ 13 µg ac/bee Bull & Wilkinson 1987	Predicted: LD ₅₀ 16 µg acs/bee Relative toxicity: 33% + 67%

Table 69: Diquat/paraquat combination products: effects on other terrestrial arthropods

Group	Species	0.46 diquat ³⁴	0.54 paraquat ³⁵	1.00 combination ³⁶
Predatory arthropods	<i>Typhlodromus pyri</i>	Tier 1 LR ₅₀ 2.9 g ac/ha Austin & Elcock 1999b	Tier 1 LR ₅₀ 1.9 g ac/ha Austin & Elcock 1999a	Predicted tier 1: LR ₅₀ 2.3 g acs/ha Relative toxicity: 36% + 64%
		Tier 2 LR ₅₀ 4.1 g ac/ha Austin & Elcock 1999c	Tier 2 LR ₅₀ 8.2 g ac/ha Austin 1999a	Predicted tier 2: LR ₅₀ 5.6 g acs/ha Relative toxicity: 63% + 37%
	<i>Pterostichus melanarius</i>	ER ₅₀ >1600 g ac/ha Gough et al, 1991	ER ₅₀ >1000 g ac/ha Jackson et al, 1991	Not expected to be toxic
	<i>Pardosa</i> spp.	ER ₅₀ >1600 g ac/ha Gough et al, 1991	ER ₅₀ >1000 g ac/ha Jackson et al, 1991	Not expected to be toxic
Parasitic arthropods	<i>Aphidius rhopalosiphi</i>	Tier 1 LR ₅₀ 3.2 g ac/ha Austin 1999b	No data	Insufficient data
		Tier 2 LR ₅₀ 758 g ac/ha Austin 1999c	No data	Insufficient data
	<i>Aleochara bilineata</i>	ER ₅₀ >1000 g ac/ha Beech 1997	ER ₅₀ >600 g ac/ha Petto 1993	Not expected to be toxic

Table 70: Diquat/paraquat combination products: short-term effects on soil organisms

Group	Species/process	0.46 diquat ³⁷	0.54 paraquat ³⁸	1.00 combination ³⁹
Macro-organisms	<i>Eisenia fetida</i>	LC ₅₀ 94 mg ac/kg ds Bender 2006b	LC ₅₀ >1000 mg ac/kg ds Bender 2006b	Any toxicity would be attributed to diquat
Micro-organisms	Nitrification	NOEC 500 mg ac/kg ds Schulz 2007b	NOEC 120 mg ac/kg ds Drew & Davies 1980	Not expected to be toxic

³⁴ All formulations contain 115 g/L diquat, which comprises 46% of the total active constituent³⁵ All formulations contain 135 g/L paraquat, which comprises 54% of the total active constituent³⁶ Refer to **APVMA Risk Assessment Manual – Environment** for calculation method to predict combination toxicity³⁷ All formulations contain 115 g/L diquat, which comprises 46% of the total active constituent³⁸ All formulations contain 135 g/L paraquat, which comprises 54% of the total active constituent³⁹ Refer to **APVMA Risk Assessment Manual – Environment** for calculation method to predict combination toxicity

Table 71: Diquat/paraquat combination products: effects on non-target terrestrial plants (post-emergent exposure)

Group	Species	0.46 diquat ⁴⁰	0.54 paraquat ⁴¹	1.00 combination ⁴²
Monocotyledons	<i>Zea mays</i>	ER ₅₀ 205 g ac/ha Bellet 1990b Martin 2013 Porch & Krueger 1999	ER ₅₀ 207 g ac/ha Canning & White 1992 Martin 2014	Predicted: ER ₅₀ 206 g acs/ha Relative toxicity: 46% + 54%
	<i>Allium cepa</i>	ER ₅₀ 252 g ac/ha Bellet 1990b Martin 2013	ER ₅₀ 136 g ac/ha Martin 2014	Predicted: ER ₅₀ 173 g acs/ha Relative toxicity: 31% + 69%
	<i>Lolium perenne</i>	ER ₅₀ 445 g ac/ha Martin 2013	ER ₅₀ 35 g ac/ha Martin 2014	Predicted: ER ₅₀ 61 g acs/ha Relative toxicity: 6% + 91%
	<i>Avena sativa</i>	ER ₅₀ >500 g ac/ha Martin 2013	ER ₅₀ 108 g ac/ha Martin 2014	Predicted: ER ₅₀ >169 g acs/ha Relative toxicity: ≤16% + ≥84%
Dicotyledons	<i>Brassica oleracea</i>	ER ₅₀ 15 g ac/ha Martin 2013	No data ⁴³	Predicted: ER ₅₀ 19 g acs/ha Relative toxicity: 59% + 41%
	<i>Beta vulgaris</i>	ER ₅₀ 38 g ac/ha Martin 2013	ER ₅₀ 68 g ac/ha Canning & White 1992	Predicted: ER ₅₀ 50 g acs/ha Relative toxicity: 60% + 40%
	<i>Brassica napus</i>	ER ₅₀ 57 g ac/ha Martin 2013	ER ₅₀ 161 g ac/ha Canning & White 1992 Martin 2014	Predicted: ER ₅₀ 88 g acs/ha Relative toxicity: 71% + 29%
	<i>Glycine max</i>	ER ₅₀ 138 g ac/ha Bellet 1990b Martin 2013	ER ₅₀ 476 g ac/ha Canning & White 1992 Martin 2014	Predicted: ER ₅₀ 224 g acs/ha Relative toxicity: 75% + 25%
	<i>Xanthium strumarium</i>	No data	ER ₅₀ 25 g ac/ha Canning & White 1992	Predicted: ER ₅₀ 19 g acs/ha Relative toxicity: 59% + 41%

⁴⁰ All formulations contain 115 g/L diquat, which comprises 46% of the total active constituent⁴¹ All formulations contain 135 g/L paraquat, which comprises 54% of the total active constituent⁴² Refer to **APVMA Risk Assessment Manual – Environment** for calculation method to predict combination toxicity⁴³ Where toxicity data are not available, the endpoint for the most sensitive species was selected to predict combination toxicity

Appendix C – Terrestrial vertebrate assessments

Risks to terrestrial vertebrates following dietary exposure to contaminated food items are assessed using a tiered approach. The acute assessment assumes 100% of food items are obtained from the treatment area on the last day of application, while the chronic assessment assumes 50% of food items are obtained from the treatment area for the first 21 days after the last application (PT 0.5). Acute risks were determined to be higher risk than long-term risks for both wild mammals and birds. Therefore, the assessment in this Appendix focuses only on the acute risks.

The use patterns were divided up into groups which consist of crops that have similar growing patterns (Table 72). It is assumed that the exposure of a 'generic focal species' within each group will be the same as they relate to feeding habits and other ecological needs. A 'generic focal species' is not a real species; however, it is considered to be representative of all those species potentially at risk. The APVMA utilises the EFSA (2009) generic focal species which are considered protective of species that occur in Australia. Interception of the spray by the crop is taken into account by calculating the residue level on the several food types, depending on the growth stage of the crop. This consideration is reflected in the EFSA (2009) shortcut values.

Acute risks to wild mammals are summarised in Table 73; acute risks to birds are summarised in Table 74.

Table 72: Seasonal exposure estimates for paraquat in animal food items

Use pattern	EFSA 2009 crop group	Situation	Application rate and frequency	Seasonal exposure rate (g/ha)	
				Foliage, seeds (DT50 10 d)	Insects (DT50 4.6 d)
General weed control	Bare soil	Potatoes	1x 700 g ac/ha	700	700
		Fallow, lucerne, market gardens, row crops, vegetables	1x 600 g ac/ha	600	600
		Bananas	1x 175 g ac/ha	175	175
		Hops, rice, sugarcane	1x 420 g ac/ha	420	420
		Peanuts	1x 250 g ac/ha	250	250
	Grassland	Non-agricultural situations, around sheds, roadways, paths, firebreaks	1x 1120 g ac/ha	1120	1120
		Pasture	1x 300 g ac/ha	300	300
Orchards	Orchards	1x 800 g ac/ha	800	800	
Vineyards	Vineyards	1x 800 g ac/ha	800	800	
Pulses	Spray topping in pulses	1x 200 g ac/ha	200	200	

Use pattern	EFSA 2009 crop group	Situation	Application rate and frequency	Seasonal exposure rate (g/ha)	
				Foliage, seeds (DT50 10 d)	Insects (DT50 4.6 d)
Combination products containing diquat	Bare soil	Fallow (minimal disturbance)	2 x 432 g ac/ha 7d interval	698	582
		Bananas, duboisia, market gardens, nurseries, potatoes, rice, vegetables	1x 432 g ac/ha	432	432
		Fallow (full disturbance), lucerne	1x 324 g ac/ha	324	324
		Sugarcane	1x 270 g ac/ha	270	270
	Grassland	Public service areas, rights of way, pasture	1x 432 g ac/ha	432	432
	Orchards	Forests, orchards, plantations	1x 432 g ac/ha	432	432
		Spot application in avocado, custard apples, lychees, mangos ⁴⁴	2x 324 g ac/ha 14d interval	179	146
	Vineyards	Vineyards	1x 432 g ac/ha	432	432
Cotton	Cotton dessicant	1x 216 g ac/ha	216	216	
Combination products containing amitrole	Bare soil	Fallow	1x 600 g ac/ha	600	600
		Potatoes	1x 525 g ac/ha	525	525
	Grassland	Industrial vegetation management	1x 500 g ac/ha	500	500
		Pasture	1x 300 g ac/ha	300	300
	Orchards	Orchards	1x 500 g ac/ha	500	500
	Vineyards	Vineyards	1x 500 g ac/ha	500	500

Risk assessment scenarios as described in section 2; seasonal exposure rates based on indicated application rate, frequency and DT₅₀

Table 73: Acute risks of paraquat to wild mammals (RAL 6.1 mg/kg bw)

Crop group	Generic focal species	Crop stage	Shortcut value	Exposure rate (g/ha)	DDD (mg/kg bw/d)	RQ
General weed control in bananas, duboisia, fallow, hops, lucerne, market gardens, nurseries, row crops, peanuts, potatoes, rice, sugarcane, vegetables						
Bare soil	Small omnivore	BBCH <10	14.3	525	7.5	1.2
				432	6.1	1.0
General weed control in industrial vegetation management, pasture, public service areas, rights of way						
Grassland	Small herbivore	All season	136.4	300	41	6.7
	Large herbivore	All season	32.6	300	9.8	1.6

⁴⁴ Assuming a maximum of 40% of an orchard is treated, each application is equivalent to 130 g ac/ha across the entire orchard

Crop group	Generic focal species	Crop stage	Shortcut value	Exposure rate (g/ha)	DDD (mg/kg bw/d)	RQ
	Small omnivore	New sown or late season	14.4	500 432	7.2 6.2	1.2 1.0
	Small insectivore	Late season	5.4	1120	6.0	0.99
General weed control in forests, orchards, plantations; Spot application in avocado, custard apples, lychees, mangos						
Orchards	Small herbivore	Ground directed	136.4	179	24	4.0
	Large herbivore	Ground directed	35.1	432 179	15 6.3	2.5 1.0
	Small omnivore	Ground directed	17.2	432 179	7.4 3.1	1.2 0.50
	Small insectivore	Ground directed	5.4	800	4.3	0.71
General weed control in vineyards						
Vineyard	Small herbivore	Ground directed	136.4	432	59	9.7
	Large herbivore	Ground directed	27.2	432	12	1.9
	Small omnivore	Ground directed	17.2	432	7.4	1.2
Spray topping in pulses						
Pulses	Small herbivore	BBCH ≥50	40.9	200	8.2	1.3
	Large herbivore	BBCH ≥50	10.5	200	2.1	0.34
	Small omnivore	BBCH ≥50	5.2	200	1.0	0.17
		BBCH 81-99	14.4	200	2.9	0.47
	Small insectivore	BBCH ≥20	5.4	200	1.1	0.18
Pre-harvest desiccation in cotton						
Cotton	Small herbivore	BBCH ≥50	34.1	216	7.4	1.2
	Small insectivore	BBCH ≥520	5.4	216	1.2	0.19
	Small omnivore	BBCH ≥50	4.3	216	0.93	0.15

Crop groups as indicated in Table 72; generic focal species and shortcut values for indicated crop groups from EFSA (2009) Seasonal exposure rates selected from Table 72 for the indicated crop groups represent worst-case scenario (if acceptable) or best-case scenario (if not acceptable). Yellow highlighted cells represent acceptable risks at lower registered rates

DDD, acute = acute daily dietary dose (mg/kg bw/d) = shortcut value * rate (kg ac/ha)

RAL = regulatory acceptable level = geometric LD₅₀ 61 mg/kg bw (Duerden 1994, Farnworth et al, 1993, Fletcher 1967, Heylings & Farnworth 1992, Kimbrough & Gaines 1970, Murray & Gibson 1972) and assessment factor of 10

RQ = risk quotient = DDD/RAL, where acceptable RQ ≤1

Table 74: Acute risks of paraquat to birds (RAL 5.7 mg/kg bw)

Crop group	Generic focal species	Crop stage	Shortcut value	Exposure rate (g/ha)	DDD (mg/kg bw/d)	RQ
General weed control in bananas, duboisia, fallow, hops, lucerne, market gardens, nurseries, peanuts, potatoes, rice, row crops, sugarcane, vegetables, vineyards ⁴⁵						

⁴⁵ No avian focal species have been identified for ground directed application in vineyards; therefore, a 'bare soil' scenario was considered

Crop group	Generic focal species	Crop stage	Shortcut value	Exposure rate (g/ha)	DDD (mg/kg bw/d)	RQ
Bare soil	Small granivore	BBCH <10	24.7	250	6.2	1.1
				175	4.3	0.76
	Small omnivore	BBCH <10	17.4	420	7.3	1.3
				324	5.6	0.99
	Small insectivore	BBCH <10	10.9	582	6.3	1.1
				525	5.7	1.0
General weed control in industrial vegetation management, pasture, public service areas, rights of way						
Grassland	Large herbivore	Growing shoots	30.5	250	7.6	1.3
				175	5.3	0.94
	Small insectivore	Growing shoots	26.8	250	6.7	1.2
				175	4.7	0.82
	Small granivore	Late season	24.7	250	6.2	1.1
				175	4.3	0.76
New sown		20.4	300	6.1	1.1	
			250	5.1	0.89	
General weed control in orchards, forests, plantations; Spot application in avocado, custard apples, lychees, mangos						
Orchards	Small insectivore	Spring/summer	46.8	270	13	2.2
	Small granivore	Ground directed	27.4	270	7.4	1.3
	Small insectivore/ worm feeder	Ground directed	7.4	800	5.9	1.0
Spray topping in pulses						
Pulses	Small insectivore	BBCH ≥20	25.2	200	5.0	0.88
	Small granivore	BBCH ≥50	7.4	200	1.5	0.26
	Small omnivore	BBCH ≥50	7.2	200	1.4	0.25
Pre-harvest desiccation in cotton						
Cotton	Small omnivore	BBCH ≥50	4.4	216	0.95	0.17
	Small insectivore	BBCH ≥20	3.0	216	0.65	0.11

Crop groups as indicated in Table 72; generic focal species and shortcut values for indicated crop groups from EFSA (2009) Seasonal exposure rates selected from Table 72 for the indicated crop groups represent worst-case scenario (if acceptable) or best-case scenario (if not acceptable). Yellow highlighted cells represent acceptable risks at lower registered rates

DDD, acute = acute daily dietary dose (mg/kg bw/d) = shortcut value * rate (kg ac/ha)

RAL = regulatory acceptable level = geometric LD₅₀ 57 mg/kg bw (Fink et al, 1979, Hubbard et al, 2014 and Johnson 1998) and assessment factor of 10

RQ = risk quotient = DDD/RAL, where acceptable RQ ≤ 1

Appendix D – PBT and POP assessments

The Stockholm Convention provides scientifically based criteria for potential POPs (persistent organic pollutants) and a process that ultimately may lead to elimination of a POP substance globally. POPs are persistent, bioaccumulative, and toxic (PBT) and also have potential for long-range transport.

Persistence criterion

The criteria for persistence in Annex D of the convention are expressed as follows:

1. Evidence that the half-life of the chemical in water is greater than 2 months (60 days), or that its half-life in soil is greater than 6 months (180 days), or that its half-life in sediment is greater than 6 months (180 days); or
2. Evidence that the chemical is otherwise sufficiently persistent to justify its consideration within the scope of the Convention.

As paraquat is not considered readily biodegradable, a weight of evidence approach is followed.

- A measured degradation half-life for paraquat in sediment is not available. However, in a water sediment system >90% of the applied paraquat was present in sediment after 100 days (Long et al, 1996). Therefore, it is reasonable to conclude the DT50 in sediment is >180 days.
- Paraquat was determined to be stable for 180 days in an aerobic study (Vickers et al, 1989a). Additionally DT50 values in excess of a year have been observed in several field dissipation studies (Anderson et al, 1992(a), Anderson et al, 1992(b), Anderson et al, 1992(c), Anderson et al, 1992(d), Dyson & Champman 1995, Dyson et al, 1995(a), Dyson et al, 1995(b), Earl et al, 1989, Hance et al, 1980, Lane & Ngim 2000 and Muller & Roy 1997).

Overall, these results show that the degradation of paraquat in freshwater sediment and soil exceeded the persistence threshold. It can thus be concluded that paraquat meets the persistence criterion.

Bioaccumulation criterion

The criteria for bioaccumulation in Annex D of the Stockholm Convention are given as follows:

3. Evidence that the bioconcentration factor or bioaccumulation factor in aquatic species for the chemical is greater than 5000 or, in the absence of such data, that the log Kow is greater than 5;
4. Evidence that a chemical presents other reasons for concern, such as high bioaccumulation in other species, high toxicity or ecotoxicity; or
5. Monitoring data in biota indicating that the bioaccumulation potential of the chemical is sufficient to justify its consideration within the scope of the Convention.

Paraquat is considered not bioaccumulative based on a log Kow of -4.2 (Platford 1983).

Toxicity criterion

The criteria for toxicity in Annex D of the POPs convention are given as follows:

6. Evidence of adverse effects to human health or to the environment that justifies consideration of the chemical within the scope of this Convention; or
7. Toxicity or ecotoxicity data that indicate the potential for damage to human health or to the environment.

The lowest aquatic long-term effect value is below 10 µg/L (lowest NOEC is 0.64 µg/L, Smyth et al, 1992). Therefore, paraquat is considered to meet the toxicity criterion.

Potential for long-range environmental transport

The criteria for long-range transport in Annex D of the Stockholm convention are given as follows:

8. Measured levels of the chemical in locations distant from the sources of its release that are of potential concern;
9. Monitoring data showing that long-range environmental transport, with the potential for transfer to a receiving environment, (via air, water or migratory species); or
10. Environmental fate properties and/or model results that demonstrate that the chemical has a potential for such transportation, with the potential for transfer to a receiving environment in locations distant from the sources of its release. For a chemical that migrates significantly through the air, its half-life in air should be greater than 2 days.

The modelled atmospheric half-life of paraquat is <2 days (Hayes 2006); therefore it is unlikely to travel long distances through the air. There is no other evidence to suggest paraquat is transported long distances in the environment.

Conclusion

Paraquat does not fulfil the PBT criteria (not PBT) and has low potential for long-range transport and does not meet the bioaccumulation criterion. Therefore, paraquat does not meet the criteria for POPs in Annex D of the Stockholm Convention.

Acronyms and abbreviations

Shortened term	Full term
ac	active constituent
acs	active constituents
APVMA	Australian Pesticide and Veterinary Medicines Authority
AF	assessment factor
BBCH	B iologische Bundesanstalt, B undessortenamt und C hemische Industrie
bw	body weight
CC	Codex Commodity Code
CCPR	Codex Committee on Pesticide Residues
CI	confidence interval
cm	centimetre(s)
d	day(s)
DDD	daily dietary dose
DM	dry matter
ds	dry soil or sediment
DT50	period required for 50 percent dissipation
dw	dry weight
ECX	concentration causing X% effect (ErCX is used for growth rate; EbCX is used for biomass; EyC50 is used for yield)
EFSA	European Food Safety Authority
ERX	rate causing X% effect
ESI	export slaughter interval
ExpE	exposure estimate
g	gram(s)
h	hour(s)
ha	hectare(s)

Shortened term	Full term
HCX	hazardous concentration for X% of the species
HR	high residue
HRX	hazardous rate for X% of the species
IPM	integrated pest management
JMPR	Joint FAO/WHO Meeting on Pesticide Residues
Kd or Kf	(Freundlich) adsorption constant
kg	kilogram(s)
Kp	sediment sorption coefficient
L	litre(s)
LCX	lethal concentration to X% of the tested population
LDX	lethal dose to X% of the tested population
LOC	level of concern
LOD	limit of detection
LOQ	limit of quantification
LRX	lethal rate to X% of the tested population
m	metre(s)
max	maximum
mg	milligram(s)
mL	millilitre(s)
mm	millimetre(s)
mol	mole(s)
NEDI	National Estimated Daily Intake
NESTI	National Estimated Short Term Intake
NOAEL	No observable adverse effect level
NOEC	no observed effect concentration
NOEL	no observable effect level
nm	nanometre(s)

Shortened term	Full term
OC	organic carbon
Pa	pascals
PBT	persistent – bioaccumulative – toxic
PEC	predicted environmental concentration
PHI	post harvest interval
POP	persistent organic pollutant
Pow	octanol-water partition coefficient
PT	proportion of an animal's daily diet obtained in habitat treated with pesticide
RAL	regulatory acceptable level
RQ	risk quotient
SAC-WB	strong adsorption capacity – wheat bioassay
SDRAM	spray drift risk assessment manual
SSD	species sensitivity distribution
SL	soluble concentrate
STMR	supervised trial median residue
TK	technical concentrate
µg	micrograms
USEPA	United States Environmental Protection Agency
UV	ultraviolet
w/w	weight per weight

Glossary

Term	Description
active constituent	The substance that is primarily responsible for the effect produced by a chemical product
adsorption constant	A measure of the tendency of a chemical to bind to soils
acute exposure	Contact between a pesticide and a target occurring over a short time (e.g., less than a day)
acute toxicity	Adverse effects of finite duration occurring within a short time (up to 14 d) after administration of a single dose (or exposure to a given concentration) of a test substance or after multiple doses (exposures), usually within 24 h of a starting point (which may be exposure to the toxicant, or loss of reserve capacity, or developmental change, etc.)
adverse effect	Change in the morphology, physiology, growth, development, reproduction or life span of an organism, system, or subpopulation that results in impairment of the capacity to compensate for additional stress, or an increase in susceptibility to other influences
agricultural crop	Any terrestrial plant species grown commercially for food, fibre, foliage, fuel or medicinal production, with the exception of plants that are not part of a crop under management at the time of pesticide application (eg blackberries or volunteer grain plants that have escaped from a cropped area and become weeds in another area)
aquatic	Relating to water or sediment, as distinct from land or air
assessment factor	Reductive factor by which an observed or estimated endpoint of a pesticide is divided to arrive at a regulatory acceptable level
bioaccumulation	Progressive increase in the amount of a substance in an organism or part of an organism that occurs because the rate of intake exceeds the organism's ability to remove the substance from the body
bioconcentration	Uptake of a pesticide residue from an environmental matrix, usually through partitioning across body surfaces to a concentration in the organism that is usually higher than in the environmental matrix
bioconcentration factor	Ratio between the concentration of pesticide in an organism or tissue and the concentration in the environmental matrix (usually water) at apparent equilibrium during the uptake phase
bound residue	Residue associated with one or more classes of endogenous macromolecules that cannot be disassociated by extraction or digestion without alteration
cation	Monatomic or polyatomic species having one or more elementary charges of the proton
catchment	Landform that collects precipitation and retains it in an impoundment or drains it through a single outlet
chronic exposure	Continued or intermittent long-term contact between an agent and a target
chronic toxicity	Adverse effects following chronic exposure
concentration	Amount of a material, agent (e.g., pesticide) dissolved or contained in unit quantity in a given medium or system

Term	Description
dissipation	Loss of pesticide residues from an environmental compartment due to degradation and transfer to another environmental compartment
dissociation constant	The ratio of concentration of dissociated ions to the concentration of original acid
dose	Total amount of a pesticide or agent administered to, taken up or absorbed by an organism, system, or (sub-) population
dry weight basis	Pesticide residue concentration reported as if the residue were wholly contained in the dry matter of the sample
effect assessment	Combination of analysis and inference of possible consequences of the exposure to a pesticide based on knowledge of the dose–effect relationship associated with that agent in a specific target organism, system, or (sub-) population
endpoint	Measurable ecological or toxicological characteristic or parameter of the test system that is chosen as the most relevant assessment criterion
environmental fate	Destiny of a pesticide or chemical after release to the environment involving considerations such as transport through air, soil, or water, bioconcentration, degradation, etc.
environmental risk	Probability that an adverse effect on humans an environmental system/receptor will be observed for a given exposure to a pesticide based on the probability of that exposure and the sensitivity of the system/receptor
exposure	Concentration or amount of a particular substance that is taken in by an individual, population or ecosystem in a specific frequency over a certain amount of time
exposure assessment	Evaluation of the exposure of an organism, system, or (sub-) population to a pesticide or agent (and its derivatives)
exposure assessment	Evaluation of the exposure of an organism, system, or (sub-) population to a pesticide or agent (and its derivatives)
formulation	A combination of both active and inactive constituents to form the end use product
half-life	The time taken for the reactant concentration to fall to one-half its initial value
hazard	Inherent property of a pesticide having the potential to cause adverse effects when an organism, system, or (sub-) population is exposed to that agent or situation
Henry's law constant	A gas law that states the amount of gas absorbed by a given volume of liquid at a given temperature is directly proportional to the partial pressure of that gas in equilibrium with that liquid. As such it provides an indication of the preference of a chemical for air relative to water i.e. its volatility
herbicide	Pesticide used for the control of unwanted plants or weeds
hydrolysis	Chemical decomposition induced by water
indicator species	Species whose presence shows the occurrence of defined environmental conditions

Term	Description
integrated pest management	Use of pest and environmental information in conjunction with available pest control technologies to prevent unacceptable levels of pest damage by the most economical means and with the least possible hazard to persons, property, and the environment
larva	Recently hatched insect, fish, or other organism that has different physical characteristics than those seen in the adult, requiring metamorphosis to reach the adult body structure
median effective concentration	Statistically derived concentration of a pesticide in an environmental medium expected to produce a certain effect in 50 % of the test organisms in a given population under defined conditions
median lethal concentration	Statistically derived concentration of a substance in an environmental medium expected to kill 50 % of test organisms in a given population under defined conditions
metabolite	Any intermediate or product resulting from metabolism
mineralisation	Conversion of an element from an organic form to an inorganic form. Mineralisation of pesticides most commonly refers to the microbial degradation to carbon dioxide as a terminal metabolite
mode of action	Biochemical effect that occurs at the lowest dose or concentration or is the earliest among a number of biochemical effects that could, understandably, lead to the death of the pest
no observed effect level	Greatest concentration or amount of a substance, found by experiment or observation, which causes no detectable adverse alteration of morphology, functional capacity, growth, development, or life span of the target organism under defined conditions of exposure
non-selective herbicide	Herbicide that is generally toxic to all plants treated
non-target species	Organisms that are not the intended targets of a particular use of a pesticide
partition coefficient	log Pow is the logarithm (base-10) of the partition coefficient between n-octanol and water
persistence	Residence time of a chemical species (pesticide and/or metabolites) subjected to degradation or physical removal in a soil, crop, animal, or other defined environmental compartment
photolysis	Chemical decomposition induced by light or other radiant energy
regulatory acceptable level	Criterion or standard that is considered safe or without appreciable risk
runoff	Portion of the wet precipitation on the land that ultimately reaches streams and, eventually, the sea
soil incorporation	Application of a pesticide to soil by mixing or injection into the soil body
solubility in water	The mass of a given substance (the solute) that can dissolve in a given volume of water
soluble concentrate	A liquid homogenous preparation to be applied as a true solution of the active constituent after dilution with water

Term	Description
strong adsorption capacity – wheat bioassay	A system of calibration by laboratory bioassay for the capacity of the soil to deactivate paraquat by adsorption
terrestrial	Relating to land, as distinct from water or air
translocation	Movement of a substance within the test system or organism
vapour pressure	The pressure at which a liquid is in equilibrium with its vapour at a given temperature. It is a measure of the tendency of a material to vaporise. The higher the vapour pressure the greater the potential
volatile	Any substance which evaporates quickly
watercourse	A river, creek or other natural watercourse (whether modified or not) in which water is contained or flows (whether permanently or from time to time); and includes: a dam or reservoir that collects water flowing in a watercourse a lake or 'wetland' through which water flows a channel into which the water of a watercourse has been diverted part of a watercourse an estuary through which water flows.
wetland	An area of land where water covers the soil—all year or just at certain times of the year. They include: swamps, marshes billabongs, lakes, lagoons saltmarshes, mudflats mangroves, coral reefs bogs, fens, and peatlands. A 'wetland' may be natural or artificial and its water may be static or flowing, fresh, brackish or saline.

References

- Alary J, Vergnes J-L, Coeur A and Cantin D, 1974. Residues of Herbicides Derived from Bipyridylium in Foodstuffs. II Detection and Determination of Diquat and Paraquat in Potatoes.
- Allison N, Hamer MJ, 1990. Acute toxicity to first instar *Daphnia magna* of technical concentrate YF6219. Reference no. RJ0851B
- Amondham W, Parkpian P, Polprasert C, DeLaune RD, Jugsujinda A, 2006. Paraquat adsorption, degradation, and remobilisation in tropical soils of Thailand. J Environ Science Health B41: 485-407
- Anderson L, 1994, Paraquat: Validation of a Residue Analytical Method for the Determination of Paraquat in Animal Products. Report No. RJ 1600B.
- Anderson L, 1997. Standard Operating Procedure No. RAM/004/07. The Determination of Residues of Paraquat in Animal Products – a High Performance Liquid Chromatographic Method.
- Anderson L, 1995. Paraquat: Storage Stability of the Residue in Frozen Carrot, Cabbage and Wheat Grain-Final Report. Report No RJ 2011B.
- Anderson L, Boseley AD and Earl M, 1991(a). Paraquat: Storage Stability of the Residue in Frozen Eggs. Report No RJ 0912B.
- Anderson L, Boseley AD and Earl M, 1991(b). Paraquat: Storage Stability of the Residue in Frozen Hen Muscle Tissue. Report No RJ 0908B.
- Anderson L and Earl M, 1993. Paraquat: Residues in Olives from Trials carried out in Spain During 1991/92. RJ 1292B.
- Anderson L and Boseley AD, 1995. Paraquat and Diquat: Validation of an HPLC Analytical Method for the Determination of the Residues in Crops and Soil. Report No. RJ 2013B.
- Anderson L, and Boseley AD, 1997. Standard Operating Procedure No. RAM/272/01. The Determination of Residues of Paraquat and Diquat in Crops and Soil – a High Performance Liquid Chromatographic Method.
- Anderson L, Hoag RE, Anders CW, Earl M, 1992a. Paraquat: field soil dissipation under in-use conditions in the USA during 1987-91 (Goldsboro, North Carolina). Reference no. RJ1146B
- Anderson L, Hoag RE, Anders CW, Earl M, 1992b. Paraquat: field soil dissipation under in-use conditions in the USA during 1987-91 (Visalia, California). Reference no. RJ1191B
- Anderson L, Hoag RE, Safford J, Anders CW, Earl M, 1992c. Paraquat: field soil dissipation under in-use conditions in the USA during 1987-91 (Champaign, Illinois). Reference no. RJ1187B
- Anderson L, Hoag RE, Safford J, Anders CW, Earl M, 1992d. Paraquat: field soil dissipation under in-use conditions in the USA during 1987-89 (Leland Mississippi). Reference no. RJ1206B

- Anderson L, Lant MS and Bonfanti F, 1995. Paraquat and Diquat: Residue Levels in Rice Grain and Straw from Trials in Italy During 1993. Report No. RJ 1728B.
- Anderson L and Lant MS, 1994. Paraquat and Diquat: Residue Levels in Maize from Trials carried out in Italy During 1993. Report No. RJ 1731B.
- Anon., 1965(a). Field Data Sheets: Paraquat: Bananas, Honduras. (1964/1965). Report No. RIC4708.
- Anon., 1965(b). Residue Data Sheets: Paraquat: Pineapple, Hawaii. (1964/1965). Report No. RIC4729.
- Anon., 1965(c). Residue Data Sheet: Paraquat, Walnut, California 1965, Report No RIC 4743.
- Anon., 1966. Residue Data Sheet: Paraquat, Almonds, California (1965/1966) Report No RIC 4706.
- Anon., 1967. Gramoxone (paraquat): Inter-row weeding. Residues in Soft Fruit and Row Crops.. Report No. RIC4737.
- Anon., 1970(a). Paraquat Residues in Potato Tubers. RIC 4731.
- Anon., 1970(b) Residues in Sorghum Grain Following Desiccation with Paraquat and Diquat. Report No. RIC3424, D3.2.6/02.
- Anon. 1970(c). Residues in Sorghum Grain Following Desiccation with Paraquat and Diquat. Report No. RIC4735, R3/66.
- Anon., 1971(a). Residues of Paraquat Found in Apples, Plums, Peaches, Grapes and. Potato Tubers. Report No. AMB/KJC.
- Anon., 1971(b). Residue Data Sheet: Paraquat, Pecans, Texas. Report No RIC 4728.
- Anon., 1972(a). Summary of Paraquat Residues Found in Soya Beans Following desiccation with Gramoxone as at 1 May 1972. Report No. RIC4736.
- Anon., 1972(b). Bipyridyl Residues in Rice Following Desiccation: Paraquat. Report No. GAW/AES7472.
- Anon., 1972(c). Summary of Paraquat Residues Found in Rice Following Desiccation with Gramoxone as at 1st May 1972. Report No. GAP/KJC 8/5/72.
- Anon., 1973. Paraquat: Residues in Olive Fruit and Extracted Oil after Weed Killing around Tree. Report No. AMB/PTV.
- Anon., 1974. Paraquat: Potato: UK: Residue Data Sheets.
- Anon., 1976. Paraquat: Residues in Poultry Feed and Safety to Poultry. Report No. R3/32.
- Anon., 1977. Residue Chemistry Data to Support the Addition of Pistachios to Label for Paraquat CL Use on Orchards. Report No RIC 4730.

- Anon., 1978. Paraquat/Diquat Residue Data Sheets, Soya, Kovin Yugoslavia. Report No. RIC 4748.
- Anon., 1979. Paraquat Residues Hops (Germany. Trial Nos 7859R IV(1&2) & V(1&2) 1978 Report No. RIC 4718.
- Anon., 1985. Paraquat Residues Data (Non-Desiccation Uses). Report No. RIC 2632.
- Anon., 1985. Residues in Milk from the Ingestion of Paraquat by Cows. Report No RIC 2486.
- Anon., 1987. Paraquat: Guide to Data and Documentation. Residues in Olives and Hazelnuts. Report No. RIC0284. Anon., 1971(a). Paraquat: Pome and Stone Fruit from Trials Carried out in Germany During 1990. Report No. AMB/KJC 27/9/71.
- Anon., no date(a). Paraquat: Residues in Citrus Fruit from Trials Carried out in the USA. Report No RIC 2253.
- Anon., no date(b). Bipyridylum Herbicides: Residues of Paraquat in Food Crops from 1964 and 1965 Field Trials. ICI Report No. A.126,597.
- Anon., no date(c). Bipyridylum Herbicides: Residues in Treated Crops. Results of Canadian Trials 1970-1972. Report No. RIC 2491.
- Anon., no date(d). A Comprehensive Study of Grain Residues in Sorghum after Desiccation with Gramoxone or Reglone was made on Trials Carried out in North Mexico During 1968 and 1969. Report No. R3/18, AR 2I634.
- Anon., no date(e). Summary of Paraquat Residues Found in Lucerne Following Desiccation with Gramoxone. Report No RIC 4720.
- APVMA (Australian Pesticides and Veterinary Medicines Authority), 2022. [Agricultural and Veterinary Chemicals Code \(Agricultural Active Constituents\) Standards 2022](https://www.legislation.gov.au/F2022L00137/latest/text), <https://www.legislation.gov.au/F2022L00137/latest/text>
- APVMA (Australian Pesticides and Veterinary Medicines Authority), 2016(a). [Paraquat toxicology report – summary](#)
- APVMA (Australian Pesticides and Veterinary Medicines Authority), 2016(b). [Paraquat toxicology report – supplement I toxicology](#)
- APVMA (Australian Pesticides and Veterinary Medicines Authority), 2016(c). [Paraquat toxicology report – supplement II neurotoxicology](#)
- Ashby R and Finn JP, 1983 Paraquat: Toxicity and carcinogenicity study in dietary administration to rats. Interim report 1: 0-52 weeks. CM4 9PE.
- Austin HM, 1999(a). Paraquat: a tier 2 laboratory study to determine the LC₅₀ of a 100 g/L SL formulation to the predatory mite *Typhlodromus pyri*. Reference no. ER-99-25
- Austin HM, 1999b. Diquat: a tier 1 laboratory study to determine the LC₃₀ and LC₅₀ of a 200 g/L SL formulation to the parasitic wasp *Aphidius rhopalosiphi*. Reference no. ER-99-13, PP901/0546

- Austin HM, 1999c. Diquat: a tier 2 laboratory study to determine the LC₅₀ of a 200 g/L SL formulation to the parasitic wasp *Aphidius rhopalosiphi*. Reference no. ER-99-HMA312, PP901/0550
- Austin HM, Elcock VL, 1999a. Paraquat: a tier 1 laboratory study to determine the LC₅₀ of a 100 g/L SL formulation to the predatory mite *Typhlodromus pyri*. Reference no. ER-99-12
- Austin HM, Elcock V, 1999b. Diquat: a tier 1 laboratory study to determine the LC₃₀ and LC₅₀ of a 200 g/L SL formulation to the predatory mite *Typhlodromus pyri*. Reference no. ER-99-11, PP901/0545
- Austin HM, Elcock V, 1999c. Diquat: a tier 2 laboratory study to determine the LC₅₀ of a 200 g/L SL formulation to the predatory mite *Typhlodromus pyri*. Reference no. ER-99-27, PP901/0548
- Bakker F, 2005a. ZA0148 (paraquat): a field study to determine residues of a 200 g/L SL formulation (A3879BV) in row crop use (melon) in invertebrates as potential food items for birds and small mammals. Reference no. S011IRM
- Bakker F, 2005b. ZA0148 (paraquat): a field study to determine residues of a 200 g/L SL formulation (A3879BV) in apple orchard invertebrates as potential food items for birds and mammals. Reference no. SA012IRA
- Baltazar MT, Dinis-Oliveira RJ, Martins A, de Lourdes Bastos M, Duarte JA, Guilhermino L, Carvalho F, 2014. Lysine acetylsalicylate increases the safety of a paraquat formulation to freshwater primary producers: a case study with the micro-alga *Chlorella vulgaris*. *Aquat Toxicol* 146: 137-143
- Beech P, 1997. An extended laboratory test to determine the effects of the herbicide Reglone (YF7017A), a soluble liquid formulation of diquat (200 g/L), on *Aleochara bilineata*. Reference no. PP901/0554
- Bellet E, 1990. Effect of diquat on terrestrial plants - a tier 3 study. Reference no. PP901/0581
- Bender EP, 2006a. Diquat technical: acute toxicity to *Hyalella azteca* under static conditions. Reference no. 1666-CRA-510-05
- Bender EP, 2006b. Reward: acute toxicity with earthworm (*Eisenia fetida*). Reference no. 1639-EF-502-05, PP901/1967
- Bradley MJ, 2015a. Paraquat dichloride: 10-day toxicity test exposing amphipods (*Hyalella azteca*) to paraquat dichloride applied to sediment under static-renewal conditions. Reference no. 1781.7017
- Bradley MJ, 2015b. Paraquat dichloride: 10-day toxicity test exposing estuarine amphipods (*Leptocheirus plumulosus*) to paraquat dichloride applied to sediment under static-renewal conditions. Reference no. 1781.7018
- Bradley MJ, 2015c. Paraquat dichloride: 10-day toxicity test exposing midge (*Chironomus dilutus*) to paraquat dichloride applied to sediment under static-renewal conditions. Reference no. 1781.7016
- Brown N, 1994(a). Paraquat: Residues in Chick Peas (Seed and Straw) from a Trial in Australia During 1993. Report No. 94-05.
- Brown N, 1994(b). Paraquat: Residues in Field Peas (Seed and Straw) from a Trial in Australia During 1993. Report No. 94-06.

Brown N, 1994(c). Paraquat: Residues in Lupins (Seed and Straw) from a Trial in Australia During 1993. Report No. 94-07.

Brown N, 1994(d). Paraquat: Residues in Wheat (Grain and Straw) from a Trial in Australia During 1993. No. 94-04.

Brown N, 1994(e). Paraquat: Residues in Barley (Grain and Straw) from a Trial in Australia During 1993. ICI Australia Research Group Report No. 94-03.

Brown N and Marcus K, 1996. Paraquat and Diquat: Residues in Cotton from Trials in Australia During 1995. Report No. 951698.

Bruhnke C, 2007. Paraquat technical: acute effects on the honeybee *Apis mellifera* (Hymenoptera: Apidae). Reference no. IBA112271

Brown MP and Whitney JC, 1984. Paraquat: Combined toxicity and carcinogenicity study in rats. Photomicrography of selected tissues. IL23 7PX

Bugg L and Duerden L, 1994. Paraquat dichloride technical concentrate: Eye irritation to the rabbit. Report No. CTL/P/4566.

Bull JM, Wilkinson W, 1987. Paraquat: acute 5-day contact and oral toxicity to honey bees (*Apis mellifera*). Reference no. RJ0578B

Bullock CH, 1983. The comparative four-hour skin irritation potential of aqueous dilutions of paraquat CL (SX-1420).

Calderbank A and Yuan SH, 1963. Bipyridylium Herbicides: Residues of Diquat and Paraquat in Food Crops. Report No. PP/2/231.

Calderbank A and McKenna RH, 1964. Bipyridylium Herbicides: Residues of Diquat and Paraquat in Food Crops from 1963 Trials. Report No. PP/E/292.

Calderbank A and Slade P, 1966. The Fate of Paraquat in Plants. Outlook on Agriculture 5(2): 55-59.

Calderbank A and McKenna RH, 1966. Excretion of the N-Methyl Quaternary Salt of Isonicotinic Acid (QINA) in the milk of a Cow. Report No. A 126,363

Calderbank A, McKenna RH, Stevens MA and Walley JK, 1966. Bipyridylium Herbicides: Paraquat Grazing Trial. Report No A.126,382

Calderbank A, McKenna RH, Stevens MA and Walley JK, 1968. Grazing Trials on Paraquat Treated Pasture. J.Sci. Fd. Agric. 19

California Chemical Company, 1965. Paraquat-14C on Sugar Cane. Test Number T-612.

Canning L, White JS, 1992. Paraquat: a glasshouse study to evaluate the effects on vegetative vigour of a 300 g ac/L (2.5 ac/US gal) soluble concentrate formulation on terrestrial non-target plants. Reference no. 92JH088

- Cheloni G, Slaveykova VE, 2021. Morphological plasticity in *Chlamydomonas reinhardtii* and acclimation to micropollutant stress. *Aquat Toxicol* 231: 105711
- Clark DG, Hurst EW, 1970. The toxicity of diquat. *Brit J Industr Med* 27: 51-55
- Claude MB, Martin KH, Gallagher SP, 2014(a). Paraquat dichloride: a 96-hour flow-through acute toxicity test with the sheepshead minnow (*Cyprinodon variegatus*). Reference no. 528A-264
- Claude MB, Martin KH, Gallagher SP, 2014(b). Paraquat dichloride: a 96-hour flow-through acute toxicity test with the fathead minnow (*Pimephales promelas*). Reference no. 528A-258
- Claude MB, Martin KH, Gallagher SP, Bodle ES, Krueger HO, 2014(c). Paraquat dichloride: an early life-stage toxicity test with the fathead minnow (*Pimephales promelas*). Reference no. 528A-262
- Claude MB, Martin KH, Gallagher SP, Bodle ES, Krueger HO, 2014(d). Paraquat dichloride: an early life-stage toxicity test with the sheepshead minnow (*Cyprinodon variegatus*). Reference no. 528A-263
- Claude MB, Martin KH, Gallagher SP, 2014(e). Paraquat dichloride: a 96-hour flow-through acute toxicity test with the saltwater mysid (*Americamysis bahia*). Reference no. 528A-257
- Claude MB, Martin KH, Gallagher SP, 2014(f). Paraquat dichloride: a 96-hour shell deposition test with the eastern oyster (*Crassostrea virginica*). Reference no. 528A-259
- Claude MB, Martin KH, Gallagher SP, 2014(g). Paraquat dichloride: a flow-through life-cycle toxicity test with the cladoceran (*Daphnia magna*). Reference no. 528A-260
- Claude MB, Chafey KW, Gallagher SP, Bodle ES, Krueger HO, 2014(h). Paraquat dichloride: a flow-through life-cycle toxicity test with the saltwater mysid (*Americamysis bahia*). Reference no. 528A-261
- Cole JFH, Wilkinson W, 1980. Paraquat and diquat: long-term high rate trial, Frensham, UK. 5. Effect on soil microarthropods. Reference no. RJ0017B
- Coombe NB, 1990. Paraquat: Residue Analysis in Lucerne from a Trial Carried out in South Africa During 1989. Report No. CEMR-031.
- Coombe NB, 1994. Paraquat: Animal Tissue Method Validation SOP RAM/004/03. Report No. CEMS 299.
- Coombe NB, 1995. Storage Stability of Paraquat and Diquat Residues in Frozen Milk. Report No CEMS-319.
- Coombe NB, 1995. Storage Stability of Paraquat and Diquat Residues in Frozen Coffee Beans and Bananas. Report No CEMS-300.
- Cowdy C, 1976. Residue Data Sheet: Paraquat Sunflowers Bulgaria.
- Daniel JW, Edwards MJ, Slade P and Walker GH, 1971. Milk Residues Arising from the Ingestion of ¹⁴C-Paraquat by the Cow. Report No. AR 2282 A

de Snoo GR, Scheidegger NMI, de Jong FMW, 1999. Vertebrate wildlife incidents with pesticides: a European survey. *Pestic Sci* 55: 47-54

Dean GM, 2000. Paraquat: determination of the rate of photolytic degradation in natural water under laboratory conditions. Reference no. ZCA/053

Dick JP, Taylor PS and Bonfanti F, 1995(a). Paraquat: Residues in Oranges from Trials Carried out in Italy during 1993(a). Report No RJ 1808B.

Dick JP, Taylor PS and Bonfanti F, 1995(b). Paraquat and Diquat: Residues in Olive Fruit and Oil from Trials carried out in Italy During 1993. RJ 1810B.

Dionne E, 1987. Acute toxicity of diquat concentrate to eastern oysters (*Crassostrea virginica*). Reference no. PP901/0565

Drew EA, Davies PI, 1980. Paraquat and diquat: long-term high rate trial, Frensham, UK. 4. Effect on soil micro-organisms and their activities. Reference no. RJ0016B

Duerden L, 1994(a). Paraquat dichloride technical concentrate: Skin irritation to the rabbit. Report No. CTL/P/4411

Duerden L, 1994(b). Paraquat dichloride technical concentrate: acute oral toxicity to the rat. Reference no. CTL/P/4424

Duerden L, 1994(c) Paraquat dichloride technical concentrate: acute dermal toxicity to the rat. Report No. CTL/P/4412

Dyson JS, Chapman P, 1995. Paraquat: long-term high-rate trial, Frensham, UK, 1971-1991 - fate of soil residues. Reference no. TMJ3430B

Dyson JS, Ferguson RE, Lane MCG, 1994. Paraquat: adsorption and desorption properties in temperate soils. Reference no. TMJ3225B

Dyson JS, Chapman P, Farmer K, 1995a. Paraquat: long-term soil trial at Goldsboro, USA, 1979-1991 - fate of soil residues. Reference no. TMJ3329B

Dyson JS, Kirsch O, Stevens JEB, 1995b. Paraquat: long-term soil trial at Goldsboro, USA, 1979-1991 - trial description and crop measurements. Reference no. TMJ3328B

Earl M and Anderson L, 1991. Paraquat: Residue in Potatoes from Trials Carried out in West Germany During 1990. Report No. RJ 1040B

Earl M and Muir GT, 1988. Paraquat/Diquat: Residues in Soyabeans from a Trial carried out in Brazil during 1986. Report No M4827B.

Earl M, Boseley AD, Muir GT and Anderson L, 1989(a). Paraquat: Storage Stability of the Residue in Frozen Carrot, Cabbage and Wheat Grain at <-18oC (Interim). Report No RJ0729B.

- Earl M, Anderson L, Muir GT, 1989(b). Paraquat: short-term field soil dissipation under in-use conditions in the USA (Sussex County, Delaware) during 1987-89. Reference no. RJ0776B
- Earl M and Boseley AD, 1988(a). Paraquat: Storage Stability of the Residue in Frozen Hen Muscle Tissue. Report No M4846B.
- Earl M and Boseley AD, 1988(b). Paraquat: Storage Stability of the Residue in Frozen Eggs. Report No M4847B.
- Earl M and Boseley AD, 1988(c). Paraquat: Residue Transfer Study with Laying Hens on a Diet Containing the Herbicide. Report No. RJ0703B.
- Edwards MJ, 1974. Paraquat Residue Summary: Residues in Vegetables and Grapes Following Post-Emergence Treatment with Paraquat for Weed Control. Report No TMJ 1030 A(R).
- Earl M and Anderson L, 1992. Paraquat: Residues in Grapes from Trials Carried out in Germany During 1990. Report No. RJ 1051B
- Edwards MJ, 1974. Paraquat Residue Summary: Residues in Vegetables and Grapes Following Post-Emergence Treatment with Paraquat for Weed Control. Report No TMJ 1030 A(R).
- Edwards MJ, Hemingway GJ, Kinch RJ, and Slade DA, 1974. Paraquat: Residue and Toxicology Trial with Cows Fed on Treated Grass. Report No. AR 2465A.
- Edwards MJ, Hayward GJ, Ward RJ and Iswaran TJ, 1977. Paraquat: Residue and Toxicology Trial with Cows Fed Grass Sprayed with Gramoxone under Dry Conditions. Report No. AR 2713A.
- Edwards PJ, 1980. Paraquat and diquat: long-term high rate trial, Frensham, UK. 3. Effect on earthworms. Reference no. RJ0015B
- Edwards PJ, Coulson JM, 1993. Paraquat: toxicity to the earthworm *Eisenia foetida* of a 200 g/L SL formulation. Reference no. TMJ3067B
- Edwards PJ, Fletcher MR, Berny P, 2000. Review of the factors affecting the decline of the European brown hare, *Lepus europaeus* (Pallas, 1778) and the use of wildlife incident data to evaluate the significance of paraquat. *Agric Ecosyst Environ* 79: 95-103
- EFSA (European Food Safety Authority), 2009. Guidance document on risk assessment for birds & mammals on request from EFSA. *EFSA Journal* 7(12): 1438, doi: 10.2903/j.efsa.2009.1438
- EFSA (European Food Safety Authority), 2020. Scientific report of EFSA on the 'repair action' of the FOCUS surface water scenarios. *EFSA Journal* 18(6):6119, 301 pp. doi.org/10.2903/j.efsa.2020.6119
- Evans PG, 2006. The fate of paraquat in an irrigated sweet corn plot in Thailand. Reference no. 05-N508
- Farnworth MJ, Jones BK, 1993. The toxicity of paraquat to rabbits following oral administration. Reference no. CTL/R/1164
- Farnworth M, Foster J, Lock E, 1993. The toxicity of paraquat to rabbits following oral administration.

FAO (Food and Agriculture Organisation of the United Nations), 2021. FAO Specifications and evaluations for agricultural pesticides – Paraquat dichloride, <https://openknowledge.fao.org/server/api/core/bitstreams/05621e49-cae8-4985-865d-9be6f1c6be40/content>

Fink R, Beavers JB, Grimes JB, Joiner G, Faulcon J, Cadby V, Anthony M, Brown R, 1979. Paraquat dichloride technical salt (SX-1142): acute oral LD₅₀ bobwhite quail. Reference no. 162-121

Fink R, Beavers JB, Joiner G, Faulcon J, Morgan S, Cadby V, Tiller N, Merriken D, Diener M, Rohde CH, 1982a. Paraquat technical (SX-1305): one-generation reproduction - mallard duck. Reference no. 162-145

Fink R, Beavers J, Joiner G, 1982b. Diquat technical (SX1260): acute oral LD₅₀ - mallard duck. Reference no. 4143

Fletcher K, 1967. Toxicity tests on gramoxone (LTS) for registration in the USSR. Reference no. IHR/213

Fletcher IC, 1972 Residue Data Sheets, Paraquat and Diquat, Pasture, Australia. Trial Ref. No. AIWP-72-MB101.

Fletcher D, 1974. Residue Study with Paraquat Dichloride in White Leghorn Chickens. Report No. 651-05403.

Gill A, Austin HM, 1996. The effects of paraquat on the predatory mite *Typhlodromus pyri*. Reference no. ER-96-06

Gough HJ, Collins I, Jackson D, 1987. Diquat: acute 5-day contact and oral toxicity to honey bees (*Apis mellifera*). Reference no. RJ055B

Gough HJ, McMullin LC, Canning L, Jackson D, White JS, 1991. Diquat: laboratory toxicity to the carabid beetle *Pterostichus melanarius*, a lycosid spider *Pardosa* spp and larvae of the green lacewing *Chrysoperla carnea* of residues of a 200 g/L aqueous formulation. Reference no. RJ0922E

Gowman MA, Wilkison W, Riley D, 1993. Paraquat: long-term ecological trial at Jealott's Hill, UK, 1964-90. 2. Residues in the soil. Reference no. TMJ3053B

Grillo R, Clemente Z, de Oliveira JL, Campos EVR, Chalupe VC, Jonsson CM, de Lima R, Sances G, Nishisaka CS, Rosa AH, Oehlke K, Greiner R, Fraceto L, 2015. Chitosan nanoparticles loaded the herbicide paraquat: the influence of humic substances on the colloidal stability and toxicity. J Hazard Mater 286: 562-572

Grout SJ, 1994a. Paraquat: Quantification and Characterisation of Radioactive Residues in Root and Leafy Crop after Preplant Soil Treatment. Report Number RJ1595B.

Grout SJ, 1994b. Paraquat: Quantification and Characterisation of Radioactive Residues in Root and Oilseed Crop after Desiccant Treatment of Foliage. Report No RJ1683.

Grout SJ, 1996. Addendum number 1 to Paraquat: Quantification and Characterisation of Radioactive Residues in Root and Oilseed Crop after Desiccant Treatment of Foliage. Report Number RJ1683-ADD1.

Hamer MJ, 1998. Paraquat: sediment toxicity test with *Chironomus riparius*. Reference no. RJ2649B

- Hamer MJ, Ashwell JA, 1997. Paraquat: BBA toxicity test with sediment-dwelling *Chironomus riparius*. Reference no. RJ2392B
- Hance RJ, Byast TH, Smith PD, 1980. Apparent decomposition of paraquat in soil. *Soil Biol Biochem* 12: 447-448
- Hathaway D, 1966. Report to ICI Ltd: acute aerosol inhalation toxicity study on paraquat dichloride. Industrial Bio-Test Laboratories Inc.
- Hayes SE, 2006. Paraquat dichloride: calculation half-life by reaction with atmospheric hydroxyl radicals. Reference no. T003479-01
- Hayward GJ and Robbins AJ, 1981. Paraquat Residues on Soyabean from 1981 Brazil Trials. Report No PP148B022.
- Hayward GJ and Robbins AJ, 1981. Paraquat Residues on Soyabean from a 1981 Trial in Brazil. ICI Plant Protection, Berkshire, UK. Report No PP148B030.
- Hendley P, Leahey JP, Spinks CA, Neale D and Carpenter PK, 1976(a). Paraquat: Metabolism and Residue Studies in Goats. Report No. AR2694A
- Hendley P, Leahey JP and Spinks CA, 1976(b). Paraquat: Metabolism and Residues in Hens. Report No. AR 2676 A
- Hemingway RJ, Edwards MJ, Jagatheeswaran T, Davis JA and Hayward G, 1975. Paraquat: Residue Transfer and Toxicology Trial in Young Growing Pigs. Report No. AR 2572A.
- Hemingway RJ, Leahey JP, Griggs RE and Davis JA, 1972. Paraquat: Metabolism in Sheep. Report No. AR 2359 A
- Heylings JR, Farnworth MJ, 1992. Paraquat: acute oral toxicity and absorption in the mouse. Reference no. CTL/R/1119
- Hill EF, Heath RG, Spann JW, Williams JD, 1975. Lethal dietary toxicities of environmental pollutants to birds. Special Scientific Report - Wildlife no. 191
- Hoberg J, 1987. Acute toxicity of diquat concentrate to mysid shrimp (*Mysidopsis bahia*). Reference no. 981.0287.6111.510
- Hodge MCE, Palmer S, Weight TM, Wilson J, 1978. Paraquat dichloride: teratogenicity study in the rat. Reference no. CTL/P/365
- Hodge MCE, Banham PB, Davies S, Doss A and Taylor K, 1980. 28-day study to determine the toxicity of technical paraquat liquor in the Charles River CD rat. Report no. CTL/P/435.
- Hubbard PM, 2013. Diquat dibromide: an acute oral toxicity study with the zebra finch using a sequential testing procedure. Reference no. 528-366
- Hubbard P, Martin K, Beavers J, 2014. Paraquat dichloride: an acute oral toxicity study with zebra finch using a sequential testing procedure. Reference no. 528-416

Igarashi A, 1980. Paraquat dichloride: AT-5 rats three gen IIAR 1. Reference no. RIC2814

Ishmael J and Godley M, 1983. Paraquat: Lifetime feeding study in rats. Histopathological examination of lungs.

Ishmael J, 1987. Paraquat: Lifetime feeding study in rats. A histopathological review of slides from the head region.

Jackson D, McMullin LC, Canning L, White JS, 1991. Gramoxone 100: investigation of the toxicity of the formulation (containing paraquat dichloride) to the carabid beetle *P. melanarius* and a lycosid spider. Reference no. RJ0928B

Jamers A, de Coen W, 2010. Effect assessment of the herbicide paraquat on a green alga using differential gene expression and biochemical biomarkers. Environ Toxicol Chem 29(4): 893-901

Johnson A, 1998. Paraquat: acute oral LD50 to the mallard duck. Reference no. ISN399/963860

JMPR (Joint FAO/WHO Meeting on Pesticide Residues), 2003. <https://apps.who.int/pesticide-residues-jmpr-database/Document/176>

JMPR (Joint FAO/WHO Meeting on Pesticide Residues), 2004. http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/JMPR/Reports_1991-2006/report2004jmpr.pdf

Kalinowski AE, Doe JE, Chart IS, Gore CW, Godley MJ, Hollis K, Robinson M and Woolen B, 1983(a). Paraquat: 1 Year feeding study in dogs.

Kalinowski AE, Doe JE, Chart IS, Gore CW, Godley MJ, Hollis K, Robinson M and Woolen B, 1983(b). Paraquat: 1 Year feeding study in dogs. Individual animal data.

Kennedy SH and French DA, 1981. Residues in Apples Following use of a Mixed Paraquat/MCPA Formulation for Weed Control in Orchards. Trial Nos: 8053 Rs – V1/V2/V3/V4.

Kennedy SH and Robbins AJ, 1982. Paraquat Residues on Soyabean from 1982 Brazil Trials. Report No PP148B029.

Kennedy SH, Robbins AJ and Ruskin Y, 1983. Paraquat Residues on Soyabean Grains from 1983 Brazilian Trials. Report No PP148B032.

Kennedy SH, 1984(a). Paraquat/Diquat: Residues on Vegetables from Trials Carried out During 1983 in West Germany. Report No. M3720B.

Kennedy SH, 1984(b). Diuron/Paraquat: Residues on Beans from Trials Carried out During 1983 in Guatemala. Report No. M3756B

Kennedy SH, 1984(c). Diquat/Paraquat: Residues on Rice from Trials carried out during 1983 in Guatemala. Report No. M3739B.

- Kennedy SH, 1984(d). Diuron/Paraquat: Residues on Maize from Trials carried out During 1983 in Guatemala. Report No. M3740B.
- Kennedy SH, 1985. Paraquat: Residues in Olive Oil from a trial carried out during 1985 in Greece. M3982B.
- Kennedy SH, 1987. Paraquat/Diquat: Residues in Olives from Trials carried out in Spain During 1987. M 4580B.
- Kendall DA, Smith BD, Chinn NE, 1989. A field study of the effects of paraquat and glyphosate herbicides on the invertebrate fauna of arable farmland in SW England. Reference no. RIC1821
- Kimbrough RD, Gaines TB, 1970. Toxicity of paraquat to rats and its effect on rat lungs. Toxicol Appl Pharmacol 17: 679-690
- Kuet SF, Pinheiro SI, Laverty B, 2001. Paraquat: rate of intrinsic biodegradability. Reference no. 01JH005
- Lane MCG, Bouwman JJ, 2000. Paraquat: long-term high rate trials in the Netherlands III - paraquat residues in soil and effects on crops 1992-1996. Reference no. 92JH117
- Lane MCG, Bouwman JJ, Bewick DW, 1992. Paraquat: long-term high rate trials in the Netherlands (1986-1991). Reference no. RJ1186B
- Lane MCG, Ngim JCK, 2000. Paraquat: long-term high rate trials Malaysia (1989-1999). Reference no. 89JH331
- Lane MCG, Vaughan P, 1997. Paraquat strong adsorption capacity – wheat bioassay of earthworm testing soil
- Leahey J, 1975. The Evaluation of the Hazards of Pesticide Residues on Crops Used for Animal Feedstuff, Illustrated by Recent Studies for the Fate of the Bipirydyl Herbicides in Animals. Report No. R3/33.
- Leahey JP, Hemingway RJ, Davis JA and Griggs RE, 1972. Paraquat: Metabolism in a Cow. Report No.AR2374A
- Leary JB, 1974. Paraquat-Chicken Feeding Study. File No. 741.11 PQ.
- Life Science Research Institute, 1984. Paraquat: Combined toxicity and carcinogenicity study in rats. Volume IX, Final report. Report no: CTL/C/1225.
- Lindsay S, Banham PB, Godley MJ, Moreland S, Wickramaratne GA, Woolen BH, 1982(a). Paraquat: multigeneration reproduction study in rats - three generations. Reference no. CTL/P/719
- Lindsay S, Banham PB, Godley MJ, Moreland S, Wickramaratne GA, Woolen BH, 1982(b). Paraquat: multigeneration reproduction study in rats - two generations. Reference no. CTL/P/649
- Litchfield MH, 1969. Grazing Trial on Paraquat-Treated Pasture. Report No IHR/257
- Long KWJ, Dempsey M, Gillings E, Shillbeer N, 1996. Paraquat: degradation of ¹⁴C-labelled material in natural sediment-water systems. Reference no. BL5569/B
- Leahey JP, Hendley P and Spinks CA, 1976. Metabolism and Residues in Pigs Using ¹⁴C-Methyl Labelled Paraquat. Report No. AR 2694 A

Lythgoe RE, and Howard EF, 1995a. Paraquat: Excretion and Tissue Retention of a Single Oral Dose (1mg/kg) in the Rat. Report no. CTL/P4683.

Lythgoe RE, and Howard EF, 1995b. Paraquat: Excretion and Tissue Retention of a Single Oral Dose (50 mg/kg) in the Rat. Report no. CTL/P4684.

Lythgoe RE, and Howard EF, 1995c. Paraquat: Excretion and Tissue Retention of a Single Oral Dose (1mg/kg) in the Rat Following Repeat Dosing. Report no. CTL/P4685.

MacPherson D, 1995 Paraquat: Biotransformation in the Rat. Report no. CTL/P4806.

Magor SE, Shillabeer N, 2001. Diquat dibromide: toxicity to duckweed (*Lemna gibba*). Reference no. PP901/0571

Maita K and Saito T, 1980. AT-5: subacute toxicity study in mice. Report no. RIC2566. Lab and Sponsor: Toxicology Division, Institute of Environmental Toxicology, Kodaira, Tokyo, Japan. Unpublished.

Maita K, Saito T, Tsuda S and Shirasu Y, 1980. Report on subacute toxicity of AT-5 in rats. Report no. RIC2565. Lab/Sponsor: Toxicology Division, Institute of Environmental Toxicology, Kodaira, Tokyo, Japan. Unpublished.

Marcus K, 1993 (a). Paraquat: Residues in Chick Peas (Whole Plant & Seed) from a Trial in Australia During 1992. Report No. 93-06.

Marcus K, 1993(b). Paraquat: Residues in Lupins (Whole Plant & Seed) from a Trial in Australia During 1992. Report No. 93-05.

Marcus K, 1993(c). Paraquat: Residues in Field Peas (Whole Plant & Seed) from a Trial in Australia During 1992. Report No. 93-04.

Marcus K, 1996. Paraquat: Residues in Canola (Seeds and Whole Plant) from Trials in Australia During 1994. Report No. 961253/379.

Martin JA, 2013. Diquat dibromide: evaluation of the phytotoxicity to non-target terrestrial plants vegetative vigor test. Reference no. PP901-10893, 1781.6872

Martin JA, 2014a. Paraquat dichloride (A7813Q): seedling emergence test. Reference no. 1781.6948

Martin JA, 2014b. Paraquat dichloride (A7813Q): vegetative vigor test. Reference no. 1781.6947

Massey JA, 1987(a). Paraquat/Diquat: Residues in Olives from Trials carried out in Spain During 1986. M 4531B.

Massey J. 1987(b). Paraquat/Diquat: Residues on Vegetables from Trials Carried out During 1983 in West Germany. Report No. M4415B.

Massey J, 1987(c). Paraquat: Residues in Vegetables from Trials Carried out in New York State, USA During 1986. Report No. M4539B.

Massey J, (1987(d). Paraquat/Diquat: Residues in Lettuce from Trials Carried out in West Germany During 1984. Report No. M4416B.

- Mohammad M, Itoh K, Suyama K 2010 Effects of herbicides on *Lemna gibba* and recovery from damage after prolonged exposure. Arch Environ Contam Toxicol 58: 605-612
- Muller K, Roy B, 1997. Paraquat and diquat: long term trial on a soil with a very low SAC-WB at Meckering, Western Australia, 1971-1995: trial description, crop measurements and fate of soil residues. Reference no. TMJ3653B
- Murray RE and Gibson JE, 1972. A comparative study of paraquat intoxication in rats, guinea pigs and monkeys. Exp Mol Pathol 17: 317-325.
- Murray RE, Gibson J, 1974. Paraquat disposition in rats, guinea pigs and monkeys. Toxicol Appl Pharmacol 27: 283-291
- Nagai T, 2019. Sensitivity differences among seven algal species to 12 herbicides with various modes of action. J Pestic Sci 44:225-232
- Nicholson R, 1987. Acute toxicity of diquat concentrate to sheepshead minnow (*Cyprinodon variegatus*). Reference no. 981.0287.6110.500
- Noack M, 2007. Paraquat technical: acute immobilisation test (static 48h) to *Daphnia magna*. Reference no. DAI112272
- Oliver C and Hemingway RJ, 1974a. A Study of the Metabolism and Residues in Hens and their Eggs. Report No. AR 2511 A
- Oliver C and Hemingway RJ, 1974b. A Study of the Metabolism and Residues in Hens and their Eggs (Addendum to AR 2511A). Report No. TMJ 1015A
- Pack DE, 1982. Long-term exposure of ¹⁴C-paraquat on a sandy soil to California sunlight. Reference no. RJ0168B
- Parker S, Leahey J, 1988. Paraquat: aqueous photolysis at pH 7. Reference no. R0633B
- Paul E, Simonin H, Symula J, 1994. The toxicity of diquat, endothall and fluridone to the early life stages of fish. J Freshw Ecol 9(3): 229-239
- Petto R, 1993. Effects of Gramoxone 100 on *Aleochara bilineata* Gyll (Coleoptera, Staphylinidae) in the laboratory. Reference no. RCC405000
- Platford RF, 1983. The octanol-water partitioning of some hydrophobic and hydrophilic compounds. Chemosphere 12(7-8): 1107-1111
- Porch J, Krueger H, 1999. Diquat: a toxicity test to determine the effects of the test substance on vegetative vigor of two species of plants. Reference no. PP901/0580
- Reeve N, 1970. Summary of Paraquat Residues Found in Various Cereal Crops, Rice and Sorghum Fodder Crops, Potatoes, Various Fruit and Vegetable Crops. Report No RIC 2635.

Reeve M, 1972. Residue Data Sheets, Paraquat and Diquat, Wheat, NZ. Notebook No. 3145.

Ricketts DC, 1999. The microbial biodegradation of paraquat in soil. *Pestic Sci* 55: 596-598

Rittenhouse JR, 1979. The acute oral toxicity of Diquat Water Weed Killer (SX1085). Reference no. 1396/37:67

Robbins AJ, Lane MCG, Riley D, 1988. Paraquat: adsorption and desorption equilibrium in soils. Reference no. RJ0662B

Roberts TR, Dyson JS, Lane MCG, 2002. Deactivation of the biological activity of paraquat in the soil environment: a review of long-term environmental fate. *J Agric Food Chem* 50: 3623-3631

Roper EM, 1989(a). Stability of Weathered Residues of Paraquat on Birdsfoot Trefoil Forage and Hay in Frozen Storage (WRC-89-091). Report No. TMR 0025B.

Roper EM, 1989(b). Stability of Paraquat Residues in Frozen Prune Samples. (WRC-89-123). Report No. TMR 3661B.

Roper EM, 1989(c). Stability of Paraquat Residues in Frozen Potato Samples. (WRC-89-124). Report No. TMR 3662B.

Roper EM, 1989(d). Stability of Paraquat Residues in Frozen Tomato Samples. (WRC-89-125). Report No. TMR 3663B.

Roper EM, 1989(e). Stability of Paraquat Residues in Frozen Corn Grain Samples. (WRC-89-126). Report No. TMR 3664B.

Roper EM, 1989(f). Stability of Paraquat Residues in Frozen Corn Fodder Samples. (WRC-89-127). Report No. TMR 3665B.

Roper EM, 1989(g). Stability of Paraquat Residues in Frozen Corn Forage Samples. (WRC-89-128). Report No. TMR 3666B.

Roper EM, 1989(h). Stability of Paraquat Residues in Frozen Corn Silage Samples. (WRC-89-129). Report No. TMR 3667B.

Roper EM, 1989(i). Paraquat: Magnitude of Residues in Fresh Market and Dried Prunes (WRC-89-120). Report No. TMU 3657B.

Roper EM, 1989(j). Paraquat: Magnitude of Residues in Olives and Processing Fractions (WRC-89-105). Report No. TMR0039B.

Roper EM, 1989(k). Paraquat: Magnitude of Residues in Fresh and Dried Figs (WRC-89-081). Report No. TMR0015B.

Roper EM, 1989(l). Paraquat: Magnitude of Residues in Hops and Processing Fractions (WRC-89-104). Report No. TMR0038B.

Roper EM, 1989(m). Paraquat: Magnitude of Residues in Potatoes and Processing Fractions (WRC-89-088). Report No. TMR0022B.

Roper EM, 1989(n). Paraquat: Magnitude of Residues in Sugar Beet Tops and Roots (WRC-89-097). Report No. TMR0031B.

Roper EM, 1989(o). Paraquat: Magnitude of Residues in Turnip Tops (WRC-89-096). Report No. TMR0030B.

Roper EM, 1989(p). Paraquat: Magnitude of Residues in Cucumbers, Melons and Summer Squash. (WRC-89-083). Report No. TMR0017B.

Roper EM, 1989(q). Paraquat: Magnitude of Residues in Whole Tomatoes and Processing Fractions (WRC-89-090). Report No. TMR0024B.

Roper EM, 1989(r). Paraquat: Magnitude of Residues in Fresh Market Tomatoes (Exaggerated Rate) (WRC-89-087). Report No. TMR0021B.

Roper EM, 1989(s). Paraquat: Magnitude of Residues in Soybean Forage, Hay, and Seed (WRC-89-115). Report No. TMR0049B.

Roper EM, 1989(t). Paraquat: Magnitude of Residues in Soybean Forage, Hay, and Seed, Harvest Aid Use (WRC-89-107). Report No. TMR0041B.

Roper EM, 1989(u). Paraquat: Magnitude of Residues in Soybean Forage and Hay, (WRC-89-111). Report No. TMR0045B.

Roper EM, 1989(v). Paraquat: Magnitude of Residues in Sunflower Forage and Seeds, (WRC-89-95). Report No. TMR0029B.

Roper EM, 1989(w). Paraquat: Magnitude of Residues in Sorghum (WRC-89-116). Report No. TMR0050B.

Roper EM, 1989(x). Paraquat: Magnitude of Residues in Field Corn Forage, Silage, Kernels and Fodder (WRC-89-106). Report No. TMR0040B.

Roper EM, 1989(y). Paraquat: Magnitude of Residues in Wheat Forage, Straw and Grain (WRC 89-109). Report No. TMR0043B.

Roper EM, 1989(z). Paraquat: Magnitude of Residues in Potatoes and Processing Fractions (WRC-89-088). Report No. TMR0022B.

Roper EM, 1989(aa). Paraquat: Magnitude of Residues in Wheat Processing Fractions. Report No. TMR0034B.

Roper EM, 1989(ab). Paraquat: Magnitude of Residues in Sorghum and Processing Fractions (WRC-89-103). Report No. TMR0037B.

Roper EM, 1989(ac). Paraquat: Magnitude of Residues in Field Corn Grain and Processing Fractions (WRC-89-112). Report No. TMR0046B.

Roper EM, 1989(ad). Paraquat: Magnitude of Residues in Sugarcane and Processing Fractions. Report No. TMR0035B.

Roper EM, 1989(ae). Paraquat: Magnitude of Residues in Sugar Beet Processing Fractions (WRC-89-102). Report No. TMR0036B.

Roper EM, 1989(af). Paraquat: Magnitude of Residues in Pineapple and Processing Fractions 1988 (WRC-89-121). Report No. TMR0058B.

Roper EM, 1989(ag). Paraquat: Magnitude of Residues in Grass Forage and Hay (Eastern Pastures) (WRC-89-98). Report No. TMR0032B.

Roper EM, 1989(ah). Paraquat: Magnitude of Residues in Grass Forage and Hay (Western Use Rangeland)(WRC-89-099). Report No. TMR0033B.

Roper EM, 1989(ai). Paraquat: Magnitude of Residues in Pasture Grass (Western Use Pastures) (WRC 89-110). Report No. TMR0044B.

Roper EM, 1989(aj). Paraquat: Magnitude of Residues in Alfalfa Hay, Forage and Meal (WRC 89-80). Report No. TMR0014B.

Roper EM, 1989(ak). Paraquat: Magnitude of Residues in Green Bean Hay (WRC-89-084). Report No. TMR0018B.

Roper EM, 1989(al). Paraquat: Magnitude of Residues in Green Pea Hay (WRC-89-085). Report No. TMR0019B.

Roper EM, 1989(am). Paraquat: Magnitude of Residues in Clover Forage and Hay (WRC-89-089). Report No. TMR0023B.

Roper EM, 1989(an). Paraquat: Magnitude of Residues in Soybean Forage and Hay (WRC 89-111). Report No. TMR0045B.

Roper EM, 1989(ao). Gramoxone Super: Residues of Paraquat: in Birdsfoot Trefoil Forage and Hay, 1988 (WRC-89-130). Report No. TMU 3672B.

Roper EM, 1989(ap). Paraquat: Magnitude of Residues in Sweet Corn Forage and Ears (WRC-89-086). Report No. TMR0020B.

Roper EM, 1989(aq). Paraquat: Magnitude of Residues in Field Corn Forage, Silage, Kernels and Fodder (WRC-89-106). Report No. TMR0040B.

Roper EM, 1990. Gramoxone Super: Magnitude of the Residues of Paraquat: in Cotton Gin Trash. Report No. RR 90-056B.

Roper EM, 1993. Gramoxone Extra: Residues of Paraquat in Soybean Grain Dust Following Harvest Aid Application (WRC-93-145). Report No. RR 93-081B.

- Roper EM, 1994. Gramoxone Extra: Residues of Paraquat: in Cotton Seed Following-Emergence and Pre-Harvest Desiccation Applications. Report No. RR 94-038B.
- Roper EM, 1995. Paraquat: Magnitude of the Residues of Paraquat on Sunflowers from Trials Conducted in the USA During 1994. Report No. RR 95-057B
- Roper EM and Elvira DJ, 1996(a). Paraquat: Residue levels on Soybean Aspirated Grain Fractions from a Trial in the United States (WRC-96-047) (WINO 13627). Report No. RR 96-031B.
- Roper EM and Elvira DJ, 1996(b). Gramoxone Extra: Paraquat: Residues on Cotton Seed and Gin Byproducts from Trials Conducted in the United States During 1995. Report No. RR 96-041B.
- Roy W, 1973. Residue Data Sheet: Paraquat Lupins Western Australia ICI Australia Western Australia Notebook No. 3319.
- Sarfety AB, 1963. Diquat & Paraquat: Observational Trials on Toxicity to Sheep and Cattle. Report No. D4.1/02, RIC 3775.
- Sartori F, Vidrio E, 2018. Environmental fate and ecotoxicology of paraquat: a California perspective. *Toxicol Environ Chem* 100: 479-517
- Scheerbaum D, 2007a. Paraquat technical: fish (rainbow trout) acute toxicity test, static 96h. Reference no. FAR112272
- Scheerbaum D, 2007b. Paraquat technical: alga growth inhibition test with *Pseudokirchneriella subcapitata*, 96h. Reference no. SPO112271
- Schulz L, 2007. Diquat SL (A1412A): effects on the activity of soil microflora (nitrogen transformation test). Reference no. 1639-BCN-500-05, PP901/1968
- Sheppard DB, 1981. Paraquat thirteen week (dietary administration) toxicity in beagles. Report no. CTL/C/1027.
- Slade P, 1965. Photochemical Degradation of Paraquat. *Nature* 207: 515-516.
- Slade P, 1966a. Possible Appearance of Degradation Products of Paraquat in Crops.
- Slade P, 1966b. Bipyridylum Herbicides: Residues in Potato Tubers following Haulm Desiccation with 14C-Paraquat. Central File Number A 126,351
- Slade P, 1973. Excretion, Metabolism and Accumulation of Paraquat. Report No. R2/57
- Slade P, and Bell EG, 1966. Bipyridylum Herbicides: The Movement of Paraquat in Plants. Central File Number A 126,364.
- Smyth DV, Shillabeer N, 2000. Paraquat dichloride: toxicity to the freshwater diatom *Navicula pelliculosa* in the presence of sediment. Reference no. AG0463/B

Smyth DV, Tapp JF, Sankey SA, Stanley RD, 1990a. Paraquat: determination of toxicity to the green alga *Selenastrum capricornutum*. Reference no. BL3748/B

Smyth DV, Tapp JF, Sankey SA, Stanley RD, 1990b. Paraquat: determination of toxicity of a 10% formulation (Gramoxone 100) to the green alga *Selenastrum capricornutum*. Reference no. BL3896/B

Smyth DV, Sankey SA, Penwell AJ, 1992a. Paraquat dichloride: toxicity to the green alga *Selenastrum capricornutum*. Reference no. BL4578/B

Smyth DV, Sankey SA, Cornish SK, 1992b. Paraquat dichloride: toxicity to the freshwater diatom *Navicula pelliculosa*. Reference no. BN4464/B

Smyth DV, Sankey SA, Cornish SK, 1992c. Paraquat dichloride: toxicity to the blue-green alga *Anabaena flos-aquae*. Reference no. BL4579/B

Smyth DV, Sankey SA, Penwell AJ, 1992d. Paraquat dichloride: toxicity to the marine alga *Skelenonema costatum*. Reference no. BL4580/B

Smyth DV, Sankey SA, Cornish SK, Penwell AJ, 1992e. Paraquat dichloride: toxicity to the duckweed *Lemna gibba*. Reference no. BL4493/B

Smyth DV, Kent SJ, Shillabeer N, 1998a. Diquat: toxicity to the freshwater diatom *Navicula pelliculosa*. Reference no. PP901/0579, BL6150/B

Smyth DV, Kent SJ, Shillabeer N, 1998b. Diquat: toxicity to the blue-green alga *Anabaena flos-aquae*. Reference no. BL6148/B, PP901/0578

Smyth DV, Kent SJ, Shillabeer N, 1998c. Diquat: toxicity to the marine alga *Skeletonema costatum*. Reference no. BL6149/B, PP901/0577

Sotheran MF, Banham PB, Doss A and Weight TM, 1979. Paraquat: A study to compare the toxicity of pure and technical paraquat in mice at two starting ages. Report No. CTL/P/415.

Spinks CA, Hendley P, Leahey JP and Carpenter PK, 1976. Metabolism and Residues in Pigs Using 14C-Ring Labelled Paraquat. Report No. AR 2692 A

Stevens JEB, Bewick DW, 1991. Paraquat: a survey of residues and deactivation capacities of soils in the United Kingdom. Reference no. RJ0594B

Stevens JEB, Bewick DW, Palmieri R, 1988. Paraquat: a survey of residues and deactivation capacities of soils in Italy. Reference no. RJ0594B

Stevens MA and Walley JK, 1965. Metabolism of 14C-Diquat and 14C-Paraquat in Cattle. Report No. IHR/177

Stevens MA, Walker GH and Walley JK, 1965. Excretion of 14C-Paraquat by the Cow. Report No. IHR/164

Stevens MA and Walley JK, 1966. Tissue and Milk Residues arising from Ingestion of Single Doses of Diquat and Paraquat by Cattle. J. Sci. Fd. Agric. 17 (October).

- Stevenson JH, 1978. The acute toxicity of unformulated pesticides to worker honey bees (*Apis mellifera* L.). Plant Pathol 27(1): 38-40
- Sucahyo D, van Straalen NM, Krave A, van Gestel CAM, 2008. Acute toxicity of pesticides to the tropical freshwater shrimp *Cardina laevis*. Ecotoxicol Environ Saf 69: 421-427
- Sutton P, Bernard JL, Mensink B, Edwards P, 2004. Paraquat: wildlife incident monitoring data for hares - a summary of the available data on hares from WIIS (1974-2002), SAGIR (1984-2003) and CIDC (1983-2002) . Reference no. RAJ0253B
- Swaine H, 1983(a). Paraquat Residue on Onions from Trials Carried out During 1983 in West Germany. Report No. TMR0038B.
- Swaine H, 1983(b). Paraquat Residue Data on Lettuce from Trials Carried out During 1983 in West Germany. Report No. PP148B034.
- Tagun R, Boxall ABA, 2018. The response of *Lemna minor* to mixtures of pesticides that are commonly used in Thailand. Bull Environ Contam Toxicol 100(4): 516-523.
- Tanaka S, Ikeda K, Miyasaka H, Shioi Y, Suzuki Y, Tamoi M, Takeda T, Shigeoka S, Harada K, Hirata K, 2011. Comparison of three *Chlamydomonas* strains which show distinctive oxidative stress tolerance. J Biosci Bioeng 112(5): 462-468
- Tapp JF, Sankey SA, Caunter JE, Stanley RD, Adams DS, 1990(a). Paraquat: determination of acute toxicity to rainbow trout (*Salmo gairdneri*). Reference no. BL3801/B.
- Tapp JF, Sankey SA, Caunter JE, Stanley RD, 1990(b). Paraquat: determination of acute toxicity of a 10% formulation (Gramoxone 100) to rainbow trout. Reference no. BL3914/B.
- Tapp JF, Sankey SA, Caunter JE, Stanley RD, Penwell AJ, 1990(c). Paraquat: determination of acute toxicity to mirror carp (*Cyprinus carpio*). Reference no. BL3800/B.
- Tapp JF, Sankey SA, Caunter JE, Stanley RD, Penwell AJ, 1990(d). Paraquat: determination of the 21-day LC₅₀ to rainbow trout (*Salmo gairdneri*) BL3860/B.
- Thompson JD, Cushman JR and Wong ZA, 1985. Modified Buehler test for the skin sensitisation potential of paraquat 3 concentrate (SX-1465). Study no: SOCAL 2355
- Tinston DJ, 1991(a). Paraquat: Second embryotoxicity study in the rabbit. Report no: CTL/T/2730.
- Tinston DJ, 1991(b) Paraquat: Teratogenicity study in the rabbit. Report no: CTL/T/2749.
- Tinston DJ, 1991(c) Paraquat: Second teratogenicity study in the rabbit. Report no: CTL/T/2763.
- Toral D and Kay BL, 1964. Pasturing of Sheep on Paraquat Treated Forage. Project No. 114-118 W 64-5.
- Upton BP, Hendley P, Skidmore MW, 1985. Paraquat: hydrolytic stability in water at pH 5, 7 and 9. Reference no. RJ0436B.

US EPA, 2021(a). Occupational Pesticide Handler Unit Exposure Surrogate Reference Table.

<https://www.epa.gov/sites/default/files/2021-05/documents/occupational-pesticide-handler-unit-exposure-surrogate-reference-table-may-2021.pdf>

US EPA, 2021(b). Occupational Pesticide Post-application Exposure Data and calculator (March 2021)

Vickers JA, Hurt AD, Bewick DW, 1989(a). Paraquat: degradation in aerobic soil. Reference no. RJ0788B.

Vickers JA, Hurt AD, Bewick DW, 1989(b). Paraquat: degradation in anaerobic soil. Reference no. RJ0810B.

Vickers JA, Hurt AD and Bewick DW, 1990. Paraquat: Rotational Crop Study. Report No RJ 0867B.

Volz E, 2004. Diquat dibromide: acute toxicity to *Daphnia magna* in a 48-hour immobilization test. Reference no. 857211.

Wilkinson W, 1980. Paraquat: and Diquat: Long-term High Rate Trial, Frensham, UK. 1. Management of Site, Effect on Crops and Weeds and Residues in Crops. Report No RJ 0013B.

Walley JK, Calderbank A and McKenna RH, 1966. Bipyridylium Herbicides: Paraquat Grazing Trials - Horses and Cattle. Report No A.126,701.

Ward R, 1979. Paraquat and Diquat: Residues in Sunflower and Sorghum (Argentina). Report No. RIC3487, R3/33.

White GA, 2010. Paraquat dichloride: physical/chemical tests. Reference no. J17306.

WHO, 1984. Paraquat and Diquat. Environmental Health Criteria.

WHO, 2008. Consultations and workshops: Dietary Exposure Assessment of Chemicals in Food: Report of a joint FAO/WHO Consultation, Annapolis, Maryland, USA, 2-6 May 2005.

Wilde DJ, 1978. Residue Data Sheet: Paraquat Sesame Venezuela.

Wilkinson W, Edwards PJ, 1993. Paraquat: long-term ecological trial at Jealott's Hill, UK, 1964-1990. 5. Effect on earthworms (Lumbricidae) and potworms (Enchytraeidae), and residues in earthworms and slugs. Reference no. TMJ3056B

Williams I, 1989(a). Residue Data Sheets, Paraquat, Peanuts, Kingaroy, Australia.

Williams I, 1989(b). Residue Data Sheets, Paraquat/Diquat, Peanuts, Kingaroy, Australia.

Woolsgrove BW, 1983. Paraquat: Combined toxicity and carcinogenicity study in rats. Report no: 82/ILY217/328

Woolsgrove BW and Ashby R, 1985. Paraquat: Combined toxicity and carcinogenicity study in rats.

Supplementary information on numbers of protocol tissues examined. Amended supplement to LSR Report no: 82/ILY217/328.