UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

June 26, 2019

PC Code: 061601
DP Barcode: 430829

MEMORANDUM

SUBJECT: **Paraquat:** Preliminary Ecological Risk Assessment for Registration Review

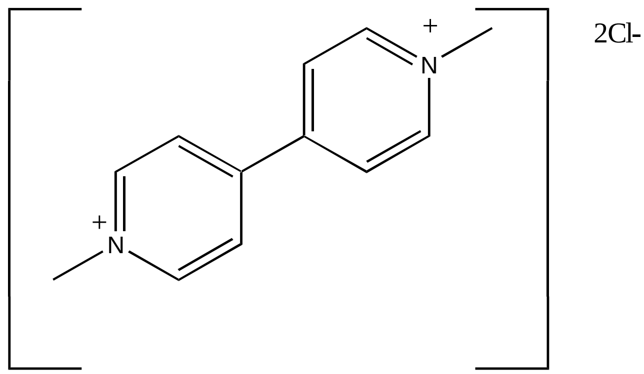
FROM: Donna R. Judkins, Biologist DONNA JUDKINS 2019.06.26 13:01:22 -04'00'
Stephen P. Wente, Senior Scientist Wente, Stephen Digitally signed by Wente, Stephen Date: 2019.06.26 13:37:17 -04'00'
Environmental Risk Branch II
Environmental Fate and Effects Division (7507P)

THRU: James Lin, Environmental Engineer Lin, James Digitally signed by Lin, James Date: 2019.06.26 13:16:05 -04'00'
Melissa Panger, Senior Science Advisor Digitally signed by Panger, Melissa Date: 2019.06.26 13:32:15 -04'00'
Elyssa Arnold, Senior Biologist Digitally signed by Arnold, Elyssa Date: 2019.06.26 13:21:33 -04'00'
Elizabeth Donavan, Acting Risk Assessment Process Leader ELIZABETH DONOVAN Digitally signed by ELIZABETH DONOVAN Date: 2019.06.27 08:16:29 -04'00'
Melanie Biscoe, Acting Branch Chief MELANIE BISCOE Digitally signed by MELANIE BISCOE Date: 2019.06.27 09:56:57 -04'00'
Environmental Risk Branch II
Environmental Fate and Effects Division (7507P)

TO: Marianne Mannix, Chemical Review Manager
Carolyn Schroeder, Team Leader
Kelly Sherman, Branch Chief
Risk Management and Implementation Branch 3
Pesticide Re-evaluation Division (7508P)

The Environmental Fate and Effects Division (EFED) has completed the preliminary environmental fate and ecological risk assessment in support of the Registration Review of the herbicide paraquat dichloride, chiefly as its dissociated cation paraquat. All the major taxonomic groups are assessed to re-evaluate primary risk concerns. This assessment concluded that all registered uses of paraquat pose a potential for direct adverse effects to birds, terrestrial-phase amphibians, reptiles, terrestrial plants, and aquatic plants, and to a lesser degree, to mammals, pollinators, fish, and benthic invertebrates. The pollinator assessment is incomplete pending receipt of the larval and chronic adult toxicity data.

Preliminary Ecological Risk Assessment for the Registration Review of Paraquat



Paraquat; CAS No 1910-42-5
USEPA PC Code: 061601

Prepared by:
Donna R. Judkins, Ph.D., Biologist
Stephen P. Wente, Ph.D., Senior Scientist

Reviewed by:
James Lin, Ph.D., Environmental Engineer
Melissa Panger, Ph.D. Senior Science Advisor
Elyssa Arnold, Senior Biologist

Approved by:
Elizabeth Donovan, Acting Risk Assessment Process Leader
Melanie Biscoe, Acting Branch Chief
Environmental Risk Branch II
Environmental Fate and Effects Division
Office of Pesticide Programs
United States Environmental Protection Agency

June 26, 2019

Table of Contents

1 Executive Summary

1.1 Overview

This Preliminary Risk Assessment (PRA) examines the potential ecological risks associated with labeled uses of paraquat on non-listed non-target organisms. All the major taxonomic groups are assessed to re-evaluate primary risk concerns even though previously completed risk assessments identified plants and terrestrial vertebrates as the chief taxa at risk. Risk to aquatic species was evaluated because of the availability of a more complete toxicity data set for benthic invertebrates, and for chronic effects to aquatic species. The exception to a complete data set is additional bee studies, which were not requested when the problem formulation (USEPA, 2011a) was written, but are needed now to complete the bee assessment following current guidance (USEPA *et al.*, 2014).

The active ingredient, paraquat dichloride, is a quaternary ammonium compound widely used for broadleaf weed control on agricultural, forestry, residential, commercial, and nursery use sites. It is a fast-acting contact herbicide used to suppress or eradicate a wide spectrum of post-emergent weeds and is quickly absorbed by living plant tissue. It is generally applied as a flowable solution and readily dissociates into its cation, paraquat, which is the only stressor of concern (refer to **Appendix A** for structure and degradates).

1.2 Risk Conclusions Summary

Overall Conclusions:

- Paraquat rapidly and almost completely adsorbs to soil and/or sediment, which greatly limits the types of environmental exposures expected from paraquat applications.
- Laboratory fate studies did not detect degradation of paraquat, indicating that it is very persistent in soil/sediment and accumulates in the environment in an adsorbed state.
- It is largely unknown when or if paraquat applications might exceed the adsorptive capacities of the soil/sediment and whether or how fast the excess paraquat would metabolize in the environment.
- Risk conclusions are similar to those previously identified. The main risk drivers are:
    - birds (also terrestrial-phase amphibians and reptiles; incidents have involved bird deaths; application timing may be important to reduce reproductive effects),
    - plants (up to 17 feet from application site or 14 feet using coarse droplets), and
    - aquatic plants (algae more sensitive than aquatic vascular plants).
- Other taxonomic groups at risk are:
    - mammals (at risk, but less sensitive than birds; incidents have involved dogs),
    - bees (adult acute risk due to oral exposure despite low oral toxicity; no contact risk; chronic and larval risks unknown),

- fish (based on incident information; 4 fish-kills possibly resulting from aquatic plant die-offs), and
- benthic aquatic invertebrates.

Table 1-1. Summary of Risk Quotients for Taxonomic Groups from Current Uses of Paraquat.

Taxa	Exposure Duration	Risk Quotient (RQ) Range[1]	RQ Exceeding the LOC for Non-listed Species	Additional Information/ Lines of Evidence
Freshwater fish	Acute	<0.01	No	Although not indicated by the RQs, there is a potential risk to fish based on the available incident data. Paraquat is suspected of being the primary cause in four fish-kills, suggesting potential for harm to non-target aquatic animals. This may result from dissolved oxygen sinks due to aquatic plant die-offs. Also, there is some suggestion of more sensitive fish and aquatic-phase amphibian species. Overall, risk to fish and aquatic-phase amphibians from the use of paraquat is uncertain but cannot be precluded due to fish-kill incidents and the longevity of paraquat.
	Chronic	<0.01-0.01[2]	No	
Estuarine/ marine fish	Acute	<0.01	No	
	Chronic	<0.01}[2]	No	
Freshwater invertebrates	Acute	<0.01	No	Risk to aquatic invertebrates from water column exposure is expected to be low, although there is some suggestion of more sensitive crustacean species.
	Chronic	<1[2]	No	
Estuarine/ marine invertebrates	Acute	<0.01 (Mollusks) <0.01-0.046 (Crustacea)	No	
	Chronic	<1[2]	No	
Benthic invertebrates	Acute and Sub-Chronic	<0.5[2]	No	Paraquat's longevity and tendency to adsorb required different assumptions in modeling than usually used. Overall, risk to benthic organisms was low from short-term sediment exposure (representing both acute and 21-day time-frame). However, when paraquat is allowed to accumulate over time (30-year exposure estimate), estimated amounts show risk to benthic organisms based on the 1.01 lb cation/A application rate; risk would be 50% higher based on the higher rate of 1.5 lb cation/A.
	Chronic (Long-term)	0.07-5.0[2]	Yes	
Mammals	Acute	<0.01-6.6	Yes	Risks exceeding the LOC for all uses, based on multiple applications; risks exceeding the LOC for most uses (1.01 lb/A rate) from a single application only for grass and broadleaf plant consumers. Two dog incidents show potential for mortality, but link to registered use not clearly substantiated.
	Chronic	0.04-81 using repro. data (0.15-609 estimates using prenatal growth data)	Yes	Rat chronic reproduction study had no effects at the dietary level tested. Because that level was below estimated exposure levels, an additional line-of-evidence was investigated by estimating risk using prenatal growth data, which showed risk above the LOC for all uses. Additional chronic data would not likely change the risk conclusion. Application timing may be important to reduce likelihood of reproduction effects and for plant-eaters, the desiccating action of paraquat may reduce palatability and decrease chronic exposure.

Taxa	Exposure Duration	Risk Quotient (RQ) Range[1]	RQ Exceeding the LOC for Non-listed Species	Additional Information/ Lines of Evidence
Birds	Acute	0.01-57	Yes	Risks exceeding the LOC for all uses and for the lowest single application rate by up to 10 times for small birds feeding on short grass. Six bird incidents show potential for mortality, but link to registered use not made in five. One incident was confirmed to be from a registered use.
	Chronic	0.26-4.1	Yes	Risks exceeding the LOC for all uses and for the lowest single application rate except for fruit/pod/seed-eaters. Effects include decreased reproduction and food consumption; application timing may be important to reduce likelihood of reproduction effects and for plant-eaters, the desiccating action of paraquat may reduce palatability and decrease chronic exposure.
Terrestrial invertebrates	Acute Adult	0.01-2.2	Yes	Oral exposure risks exceeding the LOC for all uses and for the lowest single application rate for two honey bee castes. Contact exposure risks not exceeding the LOC for any uses. Multiple uses have the potential to attract pollinators, but application timing, as well as distances of 7-46 feet, coarse droplet size specifications can remove the presumption of risk to adult bees from acute contact exposure from spray drift. One hive damage incident was of 'possible' causality but of 'undetermined' legality, suggesting potential for harm to pollinators but link to registered use not clearly substantiated. More information is needed to fully assess risks to bees.
	Chronic Adult	No data	No data	
	Acute Larval	No data	No data	
	Chronic Larval	No data	No data	
Aquatic plants	N/A	0.02 – 26	Yes for Algae	Risk exceeding LOC for non-vascular species (based on the freshwater diatom) for all uses and for the lowest application rates; no LOC exceedances for vascular plants.
Terrestrial plants	N/A	0.2-3.6	Yes	Risks from spray drift exceeding the LOC for all uses at the lowest application rate for aerial application. Monocots and dicots similarly sensitive to paraquat; effects to growth seen at an order-of-magnitude lower exposure levels than survival and emergence. Twenty-seven plant incidents found, with paraquat as 'probable' or 'highly probable' cause in ten, support potential for harm to plants from registered use of paraquat. Distances of up to 17 feet were estimated to remove the presumption of risk from aerial applications.

Level of Concern (LOC) Definitions: Terrestrial Animals: Acute=0.5; Chronic=1.0; Terrestrial invertebrates=0.4; Aquatic Animals: Acute=0.5; Chronic=1.0; Plants: 1.0.

[1] RQs reflect exposure estimates for paraquat and maximum application rates allowed on labels.

[2] Due to the non-standard timeframe for estimating chronic exposure, these estimates are not considered to be standard RQs, but estimated exposure: toxicity ratios.

Uncertainties with Toxicity Data:

- Plant toxicity data had some minor uncertainties: for the endpoint used for monocot seedling emergence (oat), some variability seen in survival and emergence in mid-range treatments was not considered treatment related, although some uncertainty is acknowledged.

- The rat reproduction endpoint used for chronic risk estimation showed no effects at the same dietary concentration causing reproduction effects to birds (mallard). That level was below estimated exposure levels so risk quotients have some uncertainty, and chronic risk could not be precluded. Additional information, however, would not likely change the risk conclusions because acute risk to mammals was concluded for all registered uses. Also, an additional line-of-evidence was investigated by estimating risk using rat prenatal growth data, which showed chronic risk above the LOC for all uses.
- In sub-chronic sediment toxicity studies, crustacea (freshwater amphipod), were more sensitive than insect larvae (midge); however, the midge was the only taxon for which chronic sediment toxicity data were available. Due to the persistence of paraquat, effects of long-term exposure of benthic organisms is largely unknown, especially via ingestion of sediment-bound paraquat; however, a chronic freshwater amphipod study would not likely provide sufficient information to change risk conclusions due to the difficulties in assessing exposure.
- The daphnid acute and freshwater fish chronic studies used for risk calculations had some minor uncertainties due to variability in the mid-range treatments.
- Information from the open literature suggests that some crustacean, fish, and amphibian species may be more sensitive than the endpoints for which quantitatively usable toxicity data were available.

Uncertainties with Modeling Estimates:

- With its longevity, potential for paraquat presence in many places in the environment is not easily characterized.
- Several labels did not specify the re-application interval, so a 7-day interval was conservatively assumed for exposure estimates.
- There is little fate data available to characterize how paraquat behaves in the environment after soil or sediment adsorption sites become saturated. Based solely on its lack of halogenation and absence of complex ring structures, it is reasonable to infer that any bioavailable (non-adsorbed) paraquat would be readily metabolized.

1.3 Environmental Fate and Exposure Summary

Paraquat rapidly and strongly adsorbs to soil or sediments rather than degrading under environmental conditions. Essentially, the adsorption of paraquat to soil/sediment is so much faster than the microbial degradation of paraquat that degradation of paraquat was not observed in the laboratory metabolism studies. Also, the adsorption in the adsorption-desorption studies was so strong that no paraquat could be detected in the water phase of these studies making it mathematically impossible to calculate reliable soil/water partition coefficients (Kd). Therefore, aquatic environmental exposure estimates to paraquat have a high degree of uncertainty. However, based on the properties of paraquat observed it is likely that: 1) terrestrial exposures would occur on avian and mammalian food items as normally assessed by the Agency; and 2) aquatic exposures would occur through spray drift immediately after a drift event (acute exposure), but would be unlikely to remain in a bioavailable state long enough for a chronic aquatic exposure in the water column. However, since some benthic organisms recycle contaminants by ingesting contaminated sediment and excreting the contaminants back on the surficial layer, conservative exposure estimates (sediment concentrations) are provided for this exposure route (though it is uncertain how much of the adsorbed paraquat might be released in the gut of any particular species of benthic organism).

1.4 Ecological Effects Summary

The ecological effects toxicity dataset is fairly complete, with the exception of a data gap for pollinator toxicity. No chronic adult toxicity data or larval toxicity data were available, so the risks associated with these effects could not be calculated.

Available data indicate that paraquat is moderately toxic to freshwater fish but less toxic to estuarine/marine fish on an acute exposure basis. However, on a chronic exposure basis, the freshwater and saltwater fish endpoints were closer. Paraquat is slightly-to-highly toxic to aquatic invertebrates: moderately toxic to freshwater crustacea, slightly toxic to estuarine/marine mollusks, and highly toxic to estuarine/marine crustacea on an acute exposure basis. Estuarine/marine crustacea were also more sensitive than freshwater crustacea on a chronic exposure basis. However, for benthic invertebrates, a freshwater amphipod (*Hyalella*) was more sensitive than a marine amphipod and a freshwater midge.

Paraquat ranges from moderately toxic to highly toxic to three species of birds, including passerines, and is moderately toxic to mammals on an acute oral exposure basis. Chronic data with birds show effects to reproduction and food consumption; no effects were seen in mammals at similar dietary exposure. Paraquat is practically non-toxic to young adult honey bees on an acute (both contact and oral) exposure basis. Data are not available on the chronic toxicity to adult honey bees or acute and chronic toxicity to larval honey bees. These data are needed to fully assess potential risks to bees.

Available data for terrestrial plants exposed to formulated products containing between 19.2 and 22.4% cation indicated similar sensitivity between monocots and dicots. Paraquat application to foliage resulted in growth effects at treatment levels more than an order-of-magnitude lower than levels causing survival and emergence effects to seeds in treated soils. This is consistent with paraquat's mode of action (see **Section 3.1**) in that it tends to cause plant damage via rapid absorption and locosystemic influence.

1.5 Identification of Data Needs

The full suite of pollinator studies listed below have not been submitted. The higher tier studies are only needed if Tier I results indicate risk concerns and data needs are identified by risk managers. Based on unlikely presence of paraquat in pollen, the full suite may not be needed.

- Terrestrial invertebrate studies:
  - Non-guideline (Tier 1): Honey bee adult acute oral toxicity

- Non-guideline (Tier 1): Honey bee larvae acute toxicity
- Non-guideline (Tier 1): Honey bee adult chronic oral toxicity
- Non-guideline (Tier 1): Honey bee larvae chronic toxicity
- Non-guideline (Tier 2): Semi-field testing for pollinators (tunnel or colony feeding studies)
- Non-guideline (Tier 2): Field trial of residues in pollen and nectar
- OCSPP 850.3040 (Tier 3): Field testing for pollinators

2 Introduction

This Preliminary Risk Assessment (PRA) examines the potential ecological risks associated with labeled uses of paraquat on non-listed non-target organisms. Federally listed threatened/endangered species ("listed") are not evaluated in this document. The PRA uses the best available scientific information on the use, environmental fate and transport, and ecological effects of paraquat. The general risk assessment methodology is described in the *Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs* ("Overview Document") (USEPA, 2004). Additionally, the process is consistent with other guidance produced by the Environmental Fate and Effects Division (EFED) as appropriate. When necessary, risks identified through standard risk assessment methods are further refined using available models and data. This risk assessment incorporates the available exposure and effects data and most current modeling and methodologies.

3 Problem Formulation Update

The purpose of problem formulation is to provide the foundation for the environmental fate and ecological risk assessment being conducted for the labeled uses of paraquat. The problem formulation identifies the objectives for the risk assessment and provides a plan for analyzing the data and characterizing the risk. As part of the Registration Review (RR) process, a detailed problem formulation (USEPA, 2011a) for this PRA was published to the docket (No. 0262 EPA-HQ-OPP-2011-0855) in December of 2011. The following sections summarize the key points of the Problem Formulation and discusses key differences between the analysis outlined there and the analysis conducted in this PRA.

One important update to the problem formulation is that runoff risk is not calculated here due to the fate properties of paraquat that suggest low likelihood that bioavailable paraquat will be present in runoff (see **Section 7.1**).

As summarized in the problem formulation based on previous risk assessments, potential risks associated with the use of paraquat include risks to plants, aquatic invertebrates, mammals, birds, terrestrial-phase amphibians and reptiles. One new use assessment was completed in 2014 (USEPA, 2014a) for paraquat dichloride use on tuberous and corm vegetables; conclusions were similar to those of prior assessments. Since the problem formulation was completed, the following data have been submitted, which fulfill most of the data gaps:

- Ecotoxicity Data
    - Acute toxicity to Eastern oysters (shell deposition study), mysid shrimp, and both fathead and sheepshead minnows (MRIDs 49320301, 49320302, 49320303, and 49320304; all acceptable studies)
    - Chronic toxicity to daphnids, mysid shrimp, and both fathead and sheepshead minnows (MRIDs 49320305, 49320306, 49320307, and 49320308; all acceptable studies)
    - Sub-acute toxicity in whole sediment to midges, and to freshwater and estuarine amphipods (MRIDs 49577001, 49577002, and 49577003; all acceptable studies)
    - Non-guideline 21-day midge emergence sediment toxicity study and algal study with sediment (MRIDs 48877201 and 48844202; both supplemental studies)
    - Acute oral toxicity to mallard ducks and zebra finch (passerine) (MRIDs 49378001 and 49349901; both acceptable studies)
    - Avian reproduction in bobwhites and mallard ducks (MRIDs 00110454 and 00110455; classified as supplemental and acceptable, respectively)
    - Terrestrial plant seedling emergence and vegetative vigor (MRIDs 49320309 and 49320310; acceptable and supplemental studies, respectively)

These new data are described in more detail in the effects characterization (**Section** 6 and in **Appendix B)**. The sub-acute dietary toxicity data for the zebra finch are slightly more sensitive than previously submitted data. The new aquatic and terrestrial studies complete the effects data set, with the exception of additional pollinator studies, which were not requested when the problem formulation was written.

In terms of fate data, anaerobic aquatic metabolism data and a drinking water treatability study (*i.e.*, Jar Test) was requested in the Problem Formulation. The drinking water treatability study was submitted and reviewed (D396402; USEPA 2012a). However, no anaerobic aquatic metabolism data was received.

3.1 Mode of Action for Target Pests

Paraquat dichloride is a quaternary ammonium compound widely used for broadleaf weed control. It is a fast-acting contact herbicide used to suppress or eradicate a wide spectrum of post-emergent weeds. It also functions as a defoliant and desiccant and is most effective on growing plants with abundant green tissue. Paraquat is quickly absorbed by living (especially healthy) plant tissue and produces superoxides during photosynthesis, which destroy plant cells. It is less effective on dry, drought-stressed, woody, or fully mature plants. Because of the quick absorption by living plant tissues, followed by rapid plant death, it is not likely to be transported systemically throughout the plant, but locosystemically.

3.2 Label and Use Characterization

3.2.1 Label Summary

Paraquat is an herbicide and can also be used as a defoliant/desiccant. Use sites include terrestrial food, nonfood, feed, forestry, residential, commercial, and nursery use sites, as well as some indoor use patterns. It is available in two formulation types: an emulsifiable concentrate (EC) and a suspension concentrate/liquid (SC/L). The application equipment includes aircraft, ground, low-pressure backpack or handheld sprayers, brushes or rollers, and coils or wicks. The application method types include banded and broadcast, or spot-treatment sprays and a tree wound treatment. It can be used pre-plant, at plant, post-emergence, prior to harvest, post-harvest, and during dormant season.

The Biological and Economic Assessment Division (BEAD) prepared a Pesticide Label Use Summary (PLUS) Report summarizing all registered uses of paraquat based on actively registered labels on May 31, 2018. The PLUS report was used as the source to summarize representative uses for this PRA. Additionally, the technical registrant responded to some clarifying questions on labels on July 30, 2012 and responses are considered in the use summary.

The uses considered for this Registration Review are listed in **Table 3-1**. Many of the current labels do not contain sufficient information to limit maximum annual numbers of applications or maximum annual application rates and do not specify the minimum retreatment intervals. The highest application rates and shortest minimum application interval appropriate for the use are used in the exposure assessment. Note that these applications rates are based on lb paraquat cation/A. A rate of 1 lb cation/A is equivalent to 1.417 lb paraquat dichloride/A.

Table 3-1. Paraquat Use Sites and Application Characteristics

Use Site	Application Method	Max Single App Rate (lb paraquat cation/acre)	Per Year Basis		Minimum Retreatment Interval
			Max # Apps	Max lbs. paraquat cation/A	
Acerola (West Indies Cherry)	G	1.01	5	NS	NS
Alfalfa	A/G	1.5	3	2	NS
Almond	G	1.01	5	NS	NS
Apple	G	1.01	5	NS	NS
Apricot	G	1.01	3	NS	NS
Artichoke	G	1.01	3	NS	7
Asparagus	A/G	1.01	3	NS	NS
Avocado	G	1.01	5	NS	NS
Banana	G	1.01	5	NS	NS
Barley	A/G	1.01	3	NS	NS
Beans, Dried-Type	A/G	0.5	2	NS	NS
Brassica (Head and Stem) Vegetables	A/G	1.01	3	NS	NS
Bushberries	G	1.01	5	NS	NS
Caneberries	G	1.01	5	NS	NS

Use Site	Application Method	Max Single App Rate (lb paraquat cation/acre)	Per Year Basis		Minimum Retreatment Interval
			Max # Apps	Max lbs. paraquat cation/A	
Carrot (Including Tops)	A/G	1.01	3	NS	NS
Cherry	G	1.01	3	NS	NS
Citrus	G	1.01	5	NS	NS
Clover	A/G	1.5	NS	NS	NS
Cocoa	G	1.01	5	NS	NS
Coffee	G	1.01	5	NS	NS
Coniferous/Evergreen/Softwood (Non-Food)	G	1.01	5	NS	NS
Corn, Field	A/G	1.01	3	NS	NS
Corn, Pop	A/G	1.01	3	NS	NS
Corn, Sweet	A/G	1.01	3	NS	14
Cotton	A/G	1.01	4	NS	7
Cucurbit Vegetables	A/G	1.01	3	NS	NS
Deciduous/Broadleaf/Hardwood (Non-Food)	G	1.01	5	NS	NS
Eggplant	A/G	1.01	3	NS	NS
Fallow Land	A/G	1.01	3	NS	NS
Fig	G	1.01	5	NS	NS
Flowering Plants	G	1.01	2	NS	NS
Fruiting Vegetables	A/G	1.01	3	NS	NS
Garlic	G	1.01	1	NS	NS
Ginger	G	1	6	NS	30
Grapes	A/G	1.01	5	NS	NS
Grass/Turf	A/G	1.01	3	NS	NS
Grasses Grown for Seed	A/G	1.01	3	NS	NS
Guar	G	0.5	3	NS	NS
Guava	G	0.938	4	NS	NS
Hops	G	0.5	3	NS	NS
Kiwi Fruit	G	1.01	3	NS	NS
Leafy Vegetables	A/G	1.01	3	NS	NS
Legume Vegetables	A/G	0.788	1	NS	NS
Lentils	A/G	0.5	2	NS	NS
Lettuce	A/G	1.01	3	NS	NS
Macadamia Nut (Bushnut)	G	0.475	4	NS	NS
Manioc (Cassava)	G	1.01	3	NS	NS
Melons	A/G	1.01	3	NS	NS
Mint	A/G	0.75	2	NS	NS
Nectarine	G	1.01	3	NS	NS
Okra	G	1	2	NS	NS
Olive	G	1.01	4	NS	NS
Onion	G	1.01	1	NS	NS
Papaya	G	1.01	5	NS	NS
Passion Fruit (Granadilla)	G	0.938	5	NS	NS
Pastureland/Rangeland	A/G	0.5	10	0.6	NS
Peach	G	1.01	3	NS	NS
Peanuts	G	0.938	2	NS	28
Pear	G	1.01	5	NS	NS

Use Site	Application Method	Max Single App Rate (lb paraquat cation/acre)	Per Year Basis		Minimum Retreatment Interval
			Max # Apps	Max lbs. paraquat cation/A	
Peas (Unspecified)	A/G	1.01	3	NS	NS
Peas, Dried-Type	A/G	0.5	2	NS	NS
Peas, Pigeon	G	0.5	1	NS	NS
Pepper	A/G	1.01	3	NS	NS
Persimmon	G	0.938	5	NS	NS
Pineapple	G	1.01	3	NS	NS
Pistachio	G	1.01	5	NS	NS
Plum	G	1.01	3	NS	NS
Potato, White/Irish (Or Unspecified)	A/G	0.625	3	NS	5
Premises/Areas	G	1.01	10	NS	NS
Prune	G	1.01	5	NS	NS
Rhubarb	G	1.01	2	NS	NS
Rice	A/G	1.01	3	NS	NS
Root and Tuber Vegetables	A/G	1.01	3	NS	NS
Safflower	A/G	1.01	3	NS	NS
Sage, Clary	A/G	0.75	NS	NS	NS
Sorghum	A/G	1.01	3	1.99	NS
Soybeans	A/G	1.01	3	NS	14
Strawberry	G	0.5	3	NS	NS
Subtropical/Tropical Fruit	G	0.938	4	NS	28
Sugar Beet	A/G	1.01	3	NS	NS
Sugarcane	A/G	0.938	2	NS	NS
Sunflower	A/G	1.01	3	NS	NS
Taro	G	0.788	2	NS	NS
Tobacco	G	0.938	2	NS	NS
Tomato	A/G	1.01	3	NS	NS
Tree Nuts	G	1.01	5	NS	NS
Trees (Non-Food)	G	1.01	5	NS	NS
Tuberous and Corm Vegetables	A/G	0.5	3	NS	NS
Turnip (Greens)	A/G	1.01	3	NS	NS
Tyfon	G	1.01	3	NS	NS
Vegetables (Unspecified)	G	0.75	2	NS	NS
Wheat	A/G	1.01	3	NS	NS
Yam	G	1.01	2	NS	NS

A = aerial applications; G = ground applications; NS = not specified on labels.

3.2.2 Usage Summary

Based on market usage data from 1998-2016, the agricultural usage of paraquat has increased since approximately 2009 (**Figure 1**; USEPA 2018) in terms of both pounds applied and acres treated. The screening-level use assessment (SLUA) estimate (USEPA 2016), which only considers agricultural use, indicates that on average cotton (1,000,000 lbs), soybean (700,000 lbs), and corn (600,000 lbs) are the crops typically receiving the largest cumulative paraquat applications per year. Other crops receiving greater than 100,000 lbs of paraquat per year on average include alfalfa, almonds, grapes, and wheat.

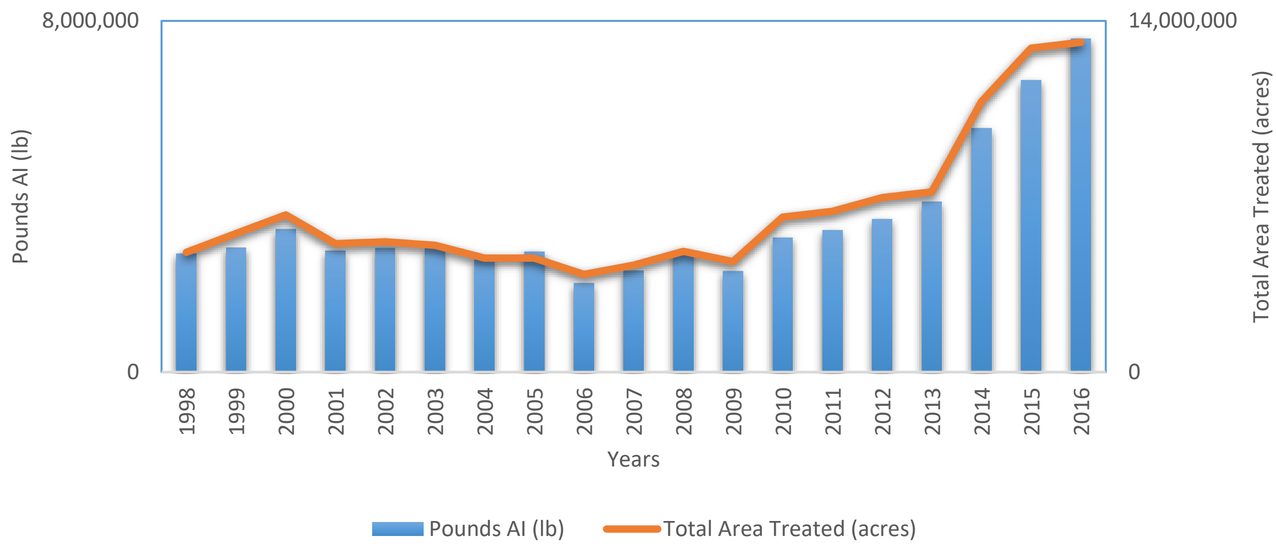


Figure 1. Paraquat dichloride Total Area Treated (acres) and AI Volume (lb.) (1998-2016).
(Does not include crops surveyed only by NASS and Cal DPR)
Source: *Agricultural Market Research Data (AMRD),* 1998-2016

4 Residues of Concern

In this risk assessment, the stressors are those chemicals that may exert adverse effects on non-target organisms. Collectively, the stressors of concern are known as the Residues of Concern (ROC). The residues of concern usually include the active ingredient, or parent chemical, and may include one or more major degradates that are observed in laboratory or field environmental fate studies. Only one minor degradate was identified in any of the paraquat fate studies (no major degradates). Because that degradate (QINA, 4-carboxyl-1-methylpyridinium) was only observed in only one environmental fate study and at minor concentrations, it was not considered a stressor of concern (see problem formulation, USEPA, 2011a). Therefore, the paraquat cation is the only residue of concern considered in this assessment (**Appendix A**).

5 Environmental Fate Summary

Paraquat dichloride readily dissociates into the paraquat cation. It has a high water solubility (700,000 mg/L) and low vapor pressure (1 x 10^{-9} torr). However, rather than stay in solution after application as might be expected, paraquat readily adsorbs to soils. In fact, the primary route of environmental dissipation of paraquat is adsorption to soil clay particles.

Paraquat does not hydrolyze, does not photodegrade in aqueous solutions, and is resistant to microbial degradation under aerobic and anaerobic conditions. Essentially no microbial degradation of paraquat was seen after 180 days of aerobic incubation or after 60 days of anaerobic incubation following a 30-day aerobic incubation.

Paraquat was shown to be very immobile in soil with batch equilibrium studies conducted on four soils in the laboratory. High rates of paraquat were added because at realistic field application rates, paraquat was below detection in the batch equilibrium adsorption solution. There was no detectable desorption.

In laboratory studies with radiolabeled paraquat, no radioactivity volatilized from the soil surface to adsorb to glass or to collect in volatile traps. With low vapor pressure and extremely high adsorption coefficients, paraquat would not be expected to volatilize once applied to the soil, but spray drift could potentially be an issue since paraquat is toxic to plants and animals.

In short and long-term field dissipation studies, paraquat residues were extractable only by acid reflux and were shown to be persistent and to accumulate slightly with repeated applications. Paraquat is dissipated by rapid adsorption to clay particles. Due to the apparent adsorption strength of paraquat for soil clays, these adsorbed residues do not appear to be environmentally available. The summaries of environmental fate studies are presented in **Table 5-1**.

Table 5-1. Environmental Fate Summary of Paraquat Dichloride

Study	Value (units) [1]	MRID #	Study Status
Molecular Weight	257.2 g/mol	http://extoxnet.orst.edu/pips/paraquat.htm	NA
Vapor Pressure	1 x 10^{-9} torr	http://extoxnet.orst.edu/pips/paraquat.htm	NA
Solubility	700,000 mg/L	http://extoxnet.orst.edu/pips/paraquat.htm	NA
Hydrolysis	Stable at pH 5, 7, 9	Upton et al., 1985	Acceptable
Direct Aqueous Photolysis	Stable	40562301	Acceptable
Soil Photolysis	Stable	146807	Acceptable
Aerobic Soil Metabolism	Stable	41319301	Acceptable
Anaerobic Soil Metabolism	Stable	41319302	Acceptable
Anaerobic Aquatic Metabolism	No Study	No Study	No Study
Aerobic Aquatic Metabolism	<2 weeks (only represents water phase. Did not measure amount of paraquat sorbed to the soil)	00055093	Supplemental
$K_{d\text{-}ads}$ / $K_{d\text{-}des}$ (mL/g)	68 – 50,000 (no measurable correlation with % OC)	40762701	Acceptable
Terrestrial Field Dissipation	Half-life not calculated; however, cited reference indicates a half-life of > 10 years	41293202, 42802101, 42738701, 42738702, 42802102	Acceptable
K_{OW} (Log K_{OW})	<0.005 (<-2.35)	48841603	NA
BCF	No study		

[1]All estimated values were calculated according to "*Guidance for Reporting on the Environmental Fate and Transport of the Stressors of Concern in Problem Formulations for Registration Review, Registration Review Risk Assessments, Listed Species Litigation Assessments, New Chemical Risk Assessments, and Other Relevant Risk Assessments*" (USEPA, 2010a).

6 Ecotoxicity Summary

Ecological effects data are used to estimate the toxicity of paraquat to surrogate species. The ecotoxicity data for paraquat and its associated products have been reviewed previously in ecological risk assessments, including a litigation assessment (USEPA, 2009a) and in a problem formulation for Registration Review (USEPA, 2011a). Although only the paraquat dichloride form is currently registered (PC code 061601), toxicity data were also considered for paraquat (PC code 061603), and paraquat bis (methyl sulfate) (PC code 061602). All toxicity values were converted (as needed) to the paraquat cation (molecular weight: 186.258 g/mol). The most sensitive and/or defensible of these data are summarized in **Section 6.1** and **Section 6.2.** Various studies with aquatic animals, birds, and terrestrial and aquatic plants were received since the problem formulation was issued in 2011; the results of these studies are described briefly in this section**.**

A search of the public ECOTOXicology database was conducted in June, 2018 to update information from an ECOTOX refresh report from September, 2016. These queries (using the three paraquat forms listed above) yielded no new data from suitable studies with more sensitive (lower) toxicity endpoints than those previously reviewed for risk assessment.[1] Although supplemental toxicity data were found that qualitatively suggested that some fish and aquatic-phase amphibians may be more sensitive than the fish species used for risk calculations, none of the studies provided quantitatively usable endpoints. Additional information can be found in **Appendix B**, and is briefly discussed in **Section 8.2**.

Table 6-1 and **Table 6-2** summarize the most sensitive measured toxicity endpoints available across taxa. These endpoints are not likely to capture the most sensitive toxicity endpoint for a particular taxon but capture the most sensitive endpoint across tested species for each taxon. All studies in this table are classified as acceptable or supplemental. Non-definitive endpoints are designated with a greater than or less than value. Values that are based on newly submitted data (those submitted since the problem formulation was completed) are designated with an N footnote associated with the MRID number in the tables.

6.1 Aquatic Toxicity

Available data indicate that paraquat TGAI (technical-grade active ingredient) is moderately toxic to freshwater fish but less toxic to estuarine/marine fish on an acute exposure basis—due to a non-definitive acute endpoint, paraquat may be slightly toxic to the sheepshead minnow. The sheepshead minnow LC_{50} (50% lethality concentration of >41,000 µg cation/L, MRID 49320304) was almost an order-of-magnitude less sensitive than the fathead minnow LC_{50} (4700 µg cation/L, MRID 49320303). On a chronic exposure basis, the endpoints are closer, but the freshwater endpoint is still lower; the fathead minnow NOAEC (no-observed adverse effect concentration) is approximately half the sheepshead NOAEC (740 and 1800 µg cation/L, respectively; MRIDs 49320307 and 49320303). Paraquat is slightly to highly toxic to aquatic invertebrates: moderately toxic to freshwater crustacea, slightly toxic to estuarine/marine mollusks, and highly toxic to estuarine/marine crustacea (as represented by mysid shrimp) on an acute exposure basis. Estuarine/marine crustacea were also more sensitive than freshwater on a chronic exposure basis; mysid shrimp (MRID 49320306) were approximately 3 times more sensitive than freshwater daphnids (MRID 49320305).

[1] There were some endpoints that were lower in the ECOTOX report; however, the endpoints were not considered reliable for use in risk assessment.

Sediment toxicity studies were submitted since previous risk assessments and the problem formulation were completed. In a 10-day spiked sediment test using the freshwater amphipod (*Hyalella azteca*), NOAEC/ LOAEC (lowest-observed adverse effect concentration) for reduced survival (84% mortality at the LOAEC) were 30/61 mg cation/kg-dw (based on dry weight of sediment). The *Hyalella* NOAEC is at least 6.5 times lower than that of the midge (*Chironomus riparius*) and at least 3.5 times lower than that of the marine amphipod (*Leptocheirus plumulosus*); see footnotes to **Table 6-1**, as well as **Appendix B** for more information on the sediment toxicity data. However, sensitivity comparisons were not quantifiable because both the midge and marine amphipod endpoints were based on non-definitive endpoints where no measurable effects (to survival and growth for the midge and survival for the marine amphipod) were found at treatment levels tested.

Differences in sensitivity might be expected because *Hyalella*, an amphipod, and *Chironomus*, a dipteran, have different life histories, occupy different taxonomic groups (crustaceans versus insects) and generally interact with sediments in different ways. As described in the harmonized draft guideline (850.1735), *Hyalella* are epibenthic detritivores that burrow into the sediment, while *Chironomus* larvae typically build a tunnel or case within the upper layers of benthic sediments and tend to remain infaunal (submerged in the sediment). Influences of these life-history dissimilarities on the bioavailability of paraquat are not well understood. While the midge might be expected to proportionally consume more contaminated sediment than the amphipod, amphipods appear to be more sensitive. One scenario might be that the movement of the amphipod mechanically re-suspended some of the paraquat and made it bioavailable. With such limited data, a difference in paraquat toxicity based on life history is not well supported and the difference seen here may simply be due to species sensitivities.

The influence of pore water concentrations versus bound amounts of paraquat to sediment toxicity could not be estimated because a comparison could not be made. The *Hyalella* pore water estimates were not usable, because only the lowest and highest treatments had detectable pore water concentrations. The midge had usable pore water measurements. However, the *Hyalella* sediment NOAEC is 6.5x more sensitive than that of the midge. Using midge data (49577001), an adjustment factor based on a simple ratio from sediment to pore water concentration is 0.00233 (0.21 ÷ 90). Similarly, for the two *Hyalella* treatments with measured pore water concentrations, a mean ratio of 0.0020 can be calculated (86% of the midge ratio) using the pore water measurements (see **Appendix B** for more details). Because the midge study was conducted using artificial sediment, and the *Hyalella* study using natural sediment, the pore water estimate using the ratio (0.0020) from the *Hyalella* study seems to be the best estimate and is used here to estimate the NOAEC and LOAEC for screening; although the midge ratio estimate gives some support to this estimate, uncertainty is acknowledged. The natural sediment likely caused greater adsorption of paraquat, but the influence of sediment type is not quantified here. The midge pore water endpoint was actually the one used for risk calculation and is presented below (NOAEC/ LOAEC = 0.21/ >0.21), while the estimated pore water endpoint from the *Hyalella* data (NOAEC/ LOAEC = 0.0117/ 0.0243 µg cation/L) is only used to help characterize the risk.

Although a longer-duration 21-day midge study was available (MRID 48877201), the duration did not cover all the recommended endpoints of growth and reproduction (approximately 50-65 days needed) but contained emergence endpoints. The study lacked pore-water information, but based on the bulk sediment NOAEC/ LOAEC values, the midge 21-day emergence endpoints (68/ >68 mg cation/kg-dw) were not as sensitive as the *Hyalella* 10-day survival endpoints (30/ 61 mg cation/kg-dw). Therefore, no further attempt was made to estimate either pore water concentration. Additionally, neither the 10-day nor the 21-day midge studies provided definitive endpoints (with the 10-day NOAEC actually being higher than the 21-day one) to use in estimating an acute-to-chronic ratio for use with the *Hyalella* acute data. Due to the persistence of paraquat, this is a data gap and chronic sediment toxicity data for *Hyalella* may be needed (although the utility is not clear due to the difficulties in making comparable exposure estimates). For this assessment, the *Hyalella* 10-day endpoints are the most sensitive and used in this assessment to screen for chronic risk, as well.

The freshwater diatom (*Navicula pelliculosa*) was approximately three orders-of-magnitude more sensitive than the marine diatom (*Skeletonema costatum*), with respective EC_{50} and NOAEC of 0.40 and 0.16 µg cation/L (MRID 42601006). Data were available for eight algal species, including 2 marine species and one cyanobacterium.

Table 6-1. Aquatic Toxicity Endpoints Selected for Risk Quotient Calculations for Paraquat

Study Type	Test Substance (% a.i.)	Test Species	Toxicity Value (C.I.) in µg cation/L (unless otherwise specified)	MRID or ECOTOX No./ Classification	Comments
Freshwater Fish (surrogates for vertebrates)					
Acute	TGAI: (paraquat dichloride: 46.3%) 33.5% cation	Fathead Minnow (*Pimephales promelas*)	96-h LC_{50} = 4700 (3000 to 8500) Slope: 4.0	N49320303 Acceptable	Moderately Toxic
Chronic	TGAI: (paraquat dichloride: 46.3%) 33.5% cation	Fathead Minnow (P. *promelas*)	33-day NOAEC = 740 LOAEC = 1500	N49320307 Acceptable	Based on growth—at the LOAEC, significant (p<0.05) reductions of 18.7% and 13.3% in dry and wet weight, respectively.[1]
Estuarine/Marine Fish (surrogates for vertebrates)					
Acute	TGAI: (paraquat dichloride: 46.3%) 33.5% cation	Sheepshead Minnow (*Cyprinodon variegates*)	96-h LC_{50} >41,000	N49320304 Acceptable	No mortality in any treatment.[2]
Chronic	TGAI: (paraquat dichloride: 46.3%) 33.5% cation	Sheepshead Minnow (*C. variegates*)	34-day NOAEC = 1800 LOAEC =3700	N49320308 Acceptable	Based on growth—significant (p<0.05) 5.3% and 11.7%, respective reductions in length and wet weigh, also 5.1% reduction in dry weight.[3]
Freshwater Invertebrates (water column)					
Acute	TGAI: (92.3% paraquat dichloride) 66.8% cation	Water Flea (*Daphnia magna*)	48-h LC_{50} = 1300 (1000-1500) Slope: 4.4	00114473 Supplemental (quantitatively usable)	Moderately Toxic. The endpoint may be used quantitatively.[4]

Study Type	Test Substance (% a.i.)	Test Species	Toxicity Value (C.I.) in µg cation/L (unless otherwise specified)	MRID or ECOTOX No./ Classification	Comments
Chronic	TGAI: (46.3% paraquat dichloride) 33.5% cation	Water Flea (*D. magna*)	3-week NOAEC = 97 LOAEC = 200	N49320305 Acceptable	Based on growth—significant ($p<0.05$) 4% reduction in length and biologically significant 22% reduction in dry weight.[5]
Estuarine/Marine Invertebrates (water column)					
Acute	TGAI: (46.3% paraquat dichloride) 33.5% cation	Mysid (*Americamysis bahia*)	96-h LC_{50} = 228 (188-277) Slope: 4.91	N49320302 Acceptable	Highly Toxic. Most sensitive acute aquatic crustacean endpoint.
Acute	TGAI: (46.3% paraquat dichloride) 33.5% cation	Eastern Oyster (*Crassostrea virgninica*)	96-h EC/IC_{50} = 22,500 (14,000-36,300) Slope: N/A	N49320301 Acceptable	Slightly Toxic. Based on shell deposition impairment. Mollusk endpoint two orders of magnitude higher than crustacean.
Chronic	TGAI: (46.3% paraquat dichloride) 33.5% cation	Mysid (*A. bahia*)	4-week NOAEC = 38 LOAEC = 76	N49320306 Acceptable	Based on survival and reproduction—significant ($p<0.05$) resp. reductions of 38.4% and 20.5% in F_0 and F_1 survival; also 49.7% reduction in offspring/ female.[6]
Freshwater Invertebrates (sediment)					
Sub-Chronic	TGAI (Paraquat dichloride): 99.4% (97.8 % radio-chemical purity)	Freshwater Amphipod (*Hyalella azteca*)	10-day Bulk sediment: NOAEC = 30 mg cation/kg-dw LOAEC = 61 mg cation/kg-dw	N49577003 Acceptable	Based on survival and growth (ash-free dry weight)—significant ($p<0.05$) 84% reduction in survival at the LOAEC; the LOAEC for weight is >30 mg cation/kg-dw.[7] Pore water estimate: NOAEC/ LOAEC = 0.060/ 0.120 mg cation/L.[8] Although a 21-day midge emergence endpoint is available, the 10-day survival endpoint is more sensitive and used for chronic risk screening.[9]
	TGAI (Paraquat dichloride): 99.4% (97.8 % radio-chemical purity)	Midge (*Chironomus riparius*)	10-day Bulk sediment: NOAEC / LOAEC = 90/ >90 mg cation/kg-dw Pour water: NOAEC = 0.21 mg cation/L LOAEC >0.21 mg cation/L	N49577001 Acceptable	Based on no effects ($p<0.05$) to survival or growth (ash-free dry weight).[9] The midge pore water endpoint was the only measured pore water endpoint available.[8]
Estuarine/Marine Invertebrates (sediment)					
Sub-Chronic	TGAI (Paraquat dichloride): 99.4% (97.8 % radio-chemical purity)	Estuarine-Marine Amphipod (*Leptocheirus plumulosus*	10-day Bulk sediment: NOAEC = 99 mg cation/kg-dw LOAEC = >99 mg cation/kg-dw	N49577002 Acceptable	Based on no significant ($p<0.05$) reduction in survival.

Study Type	Test Substance (% a.i.)	Test Species	Toxicity Value (C.I.) in µg cation/L (unless otherwise specified)	MRID or ECOTOX No./ Classification	Comments
Aquatic Plants and Algae					
Vascular	TGAI (Paraquat dichloride 32.7%): 23.7% cation	Duckweed (*Lemna gibba*)	14-day EC_{50} = 71 (63-79) NOAEC = 23[10] LOAEC = 47	42601003 Acceptable	Based on frond number; LOAEC based on significant ($p<0.05$) 18% inhibition.
Non-vascular	TGAI (Paraquat dichloride 32.7%): 23.7% cation	Freshwater Diatom (*Navicula pelliculosa*)	4-d EC_{50} = 0.40 NOAEC = 0.16[10] LOAEC = 0.33	42601006 Acceptable	Based on cell density; LOAEC based on biologically significant 54% inhibition.[11]

TGAI=Technical Grade Active Ingredient; a.i.= active ingredient; h = hour; C.I. = confidence interval; LC/EC/ICxx = lethal/effects/inhibition concentration specifying percent of organisms affected; NOAEC/LOAEC = no/lowest observed adverse effects concentration; N/A = Not available; dw = sediment dry weight; N=Studies submitted since the problem formulation was completed are designated with an N associated with the MRID number; > Greater than values designate non-definitive endpoints where no effects were observed at the highest level tested (USEPA, 2011b).

[1] An acute-to-chronic ratio (ACR) for the fathead minnow can be calculated as 6.4 (4700/740).

[2] Highest concentration tested was 41 mg cation/L mean measured concentration. No sub-lethal effects were observed.

[3] At the LOAEC, length and wet weight were significantly ($p<0.05$) decreased by 5.3 and 11.7%, and dry weight by 5.1%.

[4] Some uncertainty is associated with the EC_{50} because there were no treatment levels with no mortality (three levels total).

[5] At the LOAEC, significant ($p<0.05$) 4% reduction in mean length and 22% reduction in mean dry weight..

[6] At the LOAEC, 49% reduction in offspring/female, 51.7% red. in offspring/reproductive day, with dose-dependent pattern.

[7] At the LOAEC, significant ($p<0.05$) 84% reduction in survival.

[8] *Hyalella* pore water estimates were unreliable, while midge had usable pore water measurements and is used here for screening (see discussion).

[9] A midge 21-day study is available (MRID 48877201), but emergence endpoints (68/ >68 mg cation/kg-dw) were not as sensitive as the *Hyalella* 10-day survival endpoints (30/ 61 mg cation/kg-dw).

[10] The aquatic plant NOAECs are used to calculate listed species RQs; these were not calculated in this assessment.

[11] At the LOAEC, biologically significant 54% inhibition in cell density.

6.2 Terrestrial Toxicity

Available data indicate that paraquat TGAI ranges from moderately toxic to highly toxic to three species of birds, including passerines, and is moderately toxic to mammals on an acute oral exposure basis. Paraquat is practically non-toxic to young adult honey bees on an acute (both contact and oral) exposure basis. Data are not available on the chronic toxicity to adult honey bees or acute and chronic toxicity to larval honey bees.

In an 18-week reproductive toxicity study with the mallard duck (*Anas platyrhynchus*), the NOAEC and LOAEC were 29.4 and 101 mg cation/kg-diet, based on reproduction and food consumption, including significant ($p<0.05$) reductions of 59.0% in eggs laid, 24.7% in viable embryos/egg set, 33.1% in live embryos/egg set, and 8.5% in mean food consumption.

The LD_{50} for laboratory rats was 93 mg cation/kg-bw from a dosing study (MRID 43685001), but rats fed diets containing paraquat up to 108 mg cation/kg-diet for 138-weeks showed no measurable effects in reproductive or offspring body weight (MRID 00126783). The endpoint was from a 3-generation study with two mating periods, rather than a 2-generation study. No measurable effects ($p<0.05$) were observed for reproduction or offspring body weight at the highest treatment tested and, therefore, the endpoint can also be used as a 2-gen endpoint.

Exposure design was 54-138 weeks for females and 43-97 weeks for males, as follows: P females: 1st mating – 12 weeks of exposure prior to mating period, 3 weeks during gestation period, and 3 weeks during lactation period; 2nd mating – 19-21 weeks prior to mating, 3 weeks during gestation period, 4 weeks during lactation period; P males: 1st mating – 12 weeks prior to mating period; 2nd mating – 19-21 weeks prior to mating; F1 females: 1st mating – 11 weeks prior to mating, 3 weeks during gestation period, 4 weeks during lactation period; 2nd mating - 19-21 weeks prior to mating, 3 weeks during gestation period, 4 weeks during lactation period; F1 males: 1st mating – 11 weeks prior to mating; 2nd mating – 19-21 weeks prior to mating; F2 females/males = same as F1. An additional notation is that in the problem formulation document (USEPA, 2011a), Table 6 has a typo showing that 108 is in units of mg cation/kg-bw, but in Appendix A, A2. Terrestrial Organisms states that the study NOAEL was 7.5 mg cation/kg-bw (NOAEC = 108 ppm), which was the highest test concentration. At a lower test concentration (3.75 mg/kg-bw), an increased incidence of alveolar histiocytes was observed in the parents; however, this value is not used for deriving chronic mammalian RQs because the relationship of this endpoint to survival, growth or reproduction has not been established.

An additional line-of-evidence was included here because the rat chronic study showed no reproductive or growth effects at the highest concentration tested. Although a definitive no-effects level was found, the highest concentration tested was below the environmentally relevant concentrations. Effects were seen in rat growth at a similar dosing range (5 mg cation/kg-bw) in a prenatal developmental study (MRID 00113714). In that study, pregnant females were dosed paraquat by gavage on days 6 to 15 of pregnancy and sacrificed at 21 days to examine development of offspring. The treatment levels are not directly comparable to the reproduction study above because of very different dosing methods and schedules (the reproduction study was a dietary study, while in the prenatal study was a dosed study), but this information shows that although no effects were seen at the calculated dosing of 7.5 mg cation/kg-bw in the full reproduction study, dosing in a similar range (5 mg cation/kg-bw) caused significant ($p<0.001$) maternal growth impairment (24% reduction in 3-week maternal weight gain as compared to control) when given at the sensitive gestational stage. The maternal NOAEL/LOAEL of 1/5 mg paraquat cation/kg/day was based on decreased body weight gains, but also on clinical signs of toxicity (piloerection, thin and hunched appearance, croaking). Offspring at that treatment level (5 mg cation/kg-bw) had developmental effects of slightly decreased fetal body weights and delayed ossification. Mortality was observed (following progressive visible deterioration in health) at the next higher treatment of 10 mg cation/kg-bw. Clinical signs of toxicity (staining of neck and subdued nature) were noted in these animals within 2-3 days of the first dose and evolved to more severe signs of distress (thin, hunched, piloerection, staining around nose, forepaws and eyes) prior to death 5-7 days after the initial exposure. Therefore, even though the multi-generational reproduction study showed no measurable effects at 7.5 mg cation/kg-bw, another line of evidence demonstrated that growth and survival effects can occur at 5-10 mg cation/kg-bw.

The available data for terrestrial plants exposed to formulated products containing between 19.2 and 22.4% cation indicate that paraquat exposure to seeds in treated soils resulted in reduced plant (cocklebur) emergence by 20.5% at application rates equivalent to 0.341 lb cation/A and exposure to foliage resulted in reduced plant (soybean) height by 19.8% (followed by dose-dependent increases of 39.0% and 46.2% at the next two higher treatment levels) at application rates equivalent to 0.018 lb cation/A (MRIDs 42639601 and 49320309); corresponding NOAELs were 0.171 and 0.0048 lb cation/A. These data suggest that paraquat exposure through direct spray, as in the vegetative vigor study, is more potent to plants than application to soil or runoff, as in the seedling emergence study.

Table 6-2. Terrestrial Toxicity Endpoints Selected for Risk Estimation for Paraquat

Study Type	Test Substance (% a.i.)	Test Species	Toxicity Value	MRID or ECOTOX No./ Classification	Comments
Birds (surrogates for terrestrial amphibians and reptiles)					
Acute Oral	TGAI: (96.1% paraquat dichloride) 72.4% cation	Zebra Finch *Poephila guttata*	14-day (single-dose) LD_{50} = 26.5 mg cation/kg-bw	N49349901 Acceptable	Highly Toxic.
Sub-Acute Dietary	TEP: (29.1% paraquat dichloride) 21.1% cation	Japanese Quail *Coturnix coturnix*	5-day LC_{50} = 698 (593-821) mg cation/kg-diet Slope: 6.06 (±1.31 sd)	00022923 Acceptable	Moderately Toxic.
Chronic	TGAI: (43.5% paraquat dichloride) 31.5% cation	Mallard Duck *Anas platyrhynchus*	18weeks NOAEC = 29.4 LOAEC = 101 mg cation/kg-diet	00110455 Acceptable	Based on reproduction and food consumption—significant (p<0.05) reductions of 59.0 % in eggs laid, 24.7% in viable embryos/egg set, 33.1% in live embryos/egg set, and 8.5% in mean food consumption.
Mammals					
Acute Oral	TGAI: 33% cation	Rat *Rattus norvegicus*	LD_{50} = 93 mg cation/kg-bw[1]	43685001 Acceptable	Moderately Toxic. Based on female mortality [1]
Chronic (3-Generation Reproduction)[2]	TGAI	Rat *R. norvegicus*	138 weeks[2] NOAEL = 7.5 LOAEL >7.5 mg cation/kg-bw/day (NOAEC = 108 ppm-diet)	00126783, 00149748, 00149749 Acceptable	Based on no measurable effects in reproductive or offspring body weight. [2]
Teratogenicity/ Prenatal Developmental	TGAI: 38% cation	Rat *R. norvegicus*	3 weeks (dosed on days 6-15 of pregnancy) Maternal NOAEL/LOAEL = 1/5 mg paraquat cation/kg/day	00113714 Acceptable	Additional line of evidence used due to uncertainties with the multi-generation study. Maternal NOAEL/LOAEL = 1/5 mg paraquat cation/kg/day based on decreased body weight gains.
Terrestrial Invertebrates					
Acute Contact (adult)	TEP: EC Formulation with 25.2% cation	Honey bee *Apis mellifera* L.	LD_{50} = 52 µg cation/bee	43942603 Acceptable	Practically Nontoxic.

Study Type	Test Substance (% a.i.)	Test Species	Toxicity Value	MRID or ECOTOX No./ Classification	Comments
Acute Oral (adult)	TEP: EC Formulation with 25.2% cation	Honey bee *A. mellifera* L.	LD_{50} = 22 µg cation/bee	43942603 Acceptable	Practically Nontoxic.
Chronic Oral (adult)	TEP	Honey bee *A. mellifera* L.	No Data		
Acute Oral (larval)	TEP	Honey bee *A. mellifera* L.	No Data		
Chronic Oral (larval)	TEP	Honey bee *A. mellifera* L.	No Data		
Terrestrial and Wetland Plants					
Seedling Emergence	TEP: Oat Study: Formulation with 22.4% cation Cocklebur Study: Formulation with approx. 19.2% cation	Various species	Monocots (Oat, *Avena sativa*): 14-day IC_{25} = 0.635 lb cation/acre; NOAEL/LOAEL = 0.28/0.57 lb cation/acre Dicots (Cocklebur, *Xanthium strumarium*): 21-day IC_{25} = 0.67 lb cation/acre; NOAEL/ LOAEL = 0.171/ 0.341 lb cation/acre	N49320310 Supplemental (quantitatively usable) 42639601 Acceptable	Monocot: NOAEL based on significant (p<0.05) 21.1% inhibition in both survival and emergence.[3] Dicot: NOAEL based on biologically significant 20.5% reduction in emergence.[4]
Vegetative Vigor	TEP: Formulation with 22.4% cation	Various species	Monocots (Perennial Ryegrass, *Lolium perenne*): 21-day IC_{25} = 0.0208 (0.016-0.0253) lb cation/acre; NOAEL/ LOAEL= 0.018/ 0.033 lb cation/acre Dicots (Soybean, *Glycine max*): 21-day IC_{25} = 0.0217 (0.0106-0.0406) lb cation/acre; NOAEL/ LOAEL = 0.0048/ 0.018 lb cation/acre	N49320309 Acceptable	Monocot: NOAEL based on significant (p<0.05) 59.5% dry weight inhibition.[5] Dicot: NOAEL based on significant (p<0.05) 19.8% height inhibition.[6]

TGAI=Technical Grade Active Ingredient; a.i.= active ingredient; h = hour; C.I. = confidence interval; LC/EC/ICxx = lethal/effects/inhibition concentration specifying percent of organisms affected; NOAEC/LOAEC = no/lowest observed adverse effects concentration; N/A = Not available; dw = sediment dry weight; N=Studies submitted since the problem formulation was completed are designated with an N associated with the MRID number; > Greater than values designate non-definitive endpoints where no effects were observed at the highest level tested (USEPA, 2011b).

[1] Endpoint is for females and was reported as 283 mg paraquat dichloride technical concentrate/kg-bw (converted to cation using a 0.33 cation purity factor). Male LD_{50} = 113 mg cation/kg-bw (344 mg paraquat dichloride technical concentrate/kg-bw).

[2] The rat reproduction endpoint used is from a 3-generation study. No effects (p<0.05) were measured for reproduction or offspring body weight at the highest treatment tested. An additional notation is that in the problem formulation document (USEPA, 2011a), Table 6 has a typo showing that 108 is in units of mg cation/kg-bw, but in Appendix A, A2. Terrestrial

Organisms states that the study NOAEL was 7.5 mg cation/kg-bw (NOAEC = 108 ppm), which was the highest test concentration.
[3] Monocot (oat): LOAEL was based on significant ($p<0.05$) inhibition in oat survival and emergence; all endpoints were based on measured concentrations. The 0.14 and 0.28 lb cation/A treatments also had a 15.8% reduction, which were not considered treatment related, although some uncertainty is acknowledged.
[4] Dicot (cocklebur): LOAEL was based on a biologically significant (although not statistically significant at $p<0.05$) 20.5% reduction in emergence at the LOAEL, along with demonstration of a dose-related general decrease in emergence.
[5] Monocot (ryegrass): LOAEL was based on significant ($p<0.05$) 59.5% inhibition at the LOAEL of 0.033 lb cation/A, followed by a dose-dependent 95.4% inhibition at 0.11 lb cation/A.
[6] Dicot (soybean): LOAEL was based on significant ($p<0.05$) 19.8% inhibition of height at 0.018 lb cation/A, followed by dose-dependent pattern of inhibition of 39.0% and 46.2% at the next two higher treatment levels.

6.3 Incident Data

The Incident Data System (IDS) provides information on the available ecological pesticide incidents reported since registration and up to June 14, 2018, the date of the most recent search. This database was searched for ecological incidents involving paraquat dichloride (PC code 061601), paraquat (PC code 061603), and paraquat bis (methyl sulfate) (PC code 061602). Although paraquat and paraquat bis (methyl sulfate) are no longer registered for use in the United States, like paraquat dichloride, the active ingredient of both of these chemicals is paraquat. Therefore, it was assumed that incidents associated with paraquat and paraquat bis (methyl sulfate) would be representative of incidents that may occur when paraquat dichloride is applied.

Table 6-3 provides a listing of the available incident reports found (also see **Appendix E**). These include:

- 7 incidents involving dogs and birds (4 were actually outside of the U.S. and not included as domestic incidents, but are provided for characterization purposes),
- 4 fish kills,
- 1 bee kill, and
- 27 plant damage incidents.

Some information is also available as aggregated counts of wildlife, plant, and other non-target species incidents; the totals are presented in
Table 6-4, also see **Appendix E**); these totals show:

- 4 vertebrate wildlife incidents,
- 3 non-vertebrate (other non-target) incidents, and
- 78 plant incidents.

Many of these incidents were previously described in the problem formulation document (USEPA, 2011a) and Appendix H of the litigation (Red-Legged Frog) assessment (USEPA, 2009a). Incident updates are briefly discussed below. Pertinent information is also discussed in the risk assessment sections that follow.

Table 6-3. Paraquat Incidents from the Incident Data System (IDS) with Certainty Index of Possible or Greater Likelihood

Incident Number	Year	State	Product and Additional Active Ingredients	Legality	Certainty Index	Use Site	Species	Distance	Magnitude/Other Notes
Birds and Mammals									
I007334-001	1998	IL	Gramoxone (paraquat) Also involved: Canopy (metribuzin and chlorimuron ethyl) and Dual (s-metolachlor)	Undetermined	Possible	N/R	Corn	Vicinity	4 bird deaths
I008168-001[1]	1998	VA	Gramoxone Extra (paraquat) Also involved: (Simazine), Extrazine II 4L (Atrazine and Simazine), Asana XL (Esfenvalerate)	Registered Use	Probable	Corn	Canada Goose	10 feet from creek	5
I020627-033[2]	2001	WA	Not specified[3]	Undetermined	Probable	Agricultural area	Dog	Distance not given but paraquat possibly used in two locations	2 killed, others sickened
I021685-002[2]	2009	Not U.S.: Ireland[4]	Paraquat in carcass/meat[3]	Undetermined	Probable	Bait, carcass/meat	Eagle/ Golden Eagle	N/R	1 each
I021848-003[2]	2010	Not U.S.: Ireland[4]	Paraquat and carbofuran laced into pieces of meat and animal carcasses[3]	Undetermined	Possible	Bait, carcass/meat	Eagle	N/R	13
I021848-004[2]	2007 - 2010	Not U.S.: Ireland[4]	Paraquat and carbofuran laced into pieces of meat and animal carcasses[3]	Undetermined	Possible	Unknown	Red Kites	N/R	1-4 killed
I027242-001[2]	2014	Not US: Cayman Islands[4]	Not specified[3]	Undetermined	Possible	Veterinarian determined ingestion of paraquat	Dog	Vicinity	1
Fish									
B0000502-18	1981	VA	Not specified	Undetermined	Possible	Agricultural Area	Sunfish	Adjacent	1 largemouth bass, and 53 sunfish
I009314-005	1997	IN	Gramoxone Extra	Registered Use	Possible	Treated field	Bluegill/ Crappie/	250 feet	Unreported number in a 1-acre pond.

							Bass		The 250-feet distance was reported to be covered by heavy sod which showed no signs of herbicide damage.
I005805-0001	1997	IN	Possibly Gramoxone	Undetermined	Possible	Treated field	Bluegill/ Crappie/ Bass	250 feet	Unreported number in a 1-acre pond. The 250-feet distance was reported to be covered by heavy sod which showed no signs of herbicide damage.
I008768-007	1999	N/R	Gramoxone	Undetermined	Possible	Treated field	Bluegill/ Crappie/ Bass	N/R	200 bass and bluegills in a ¾ acre pond; at least 2 frogs; no mortality to pond catfish
Pollinators									
I029512-00004[2]	2016	N/R	Gramoxone SL 2.0	Undetermined	Possible	Unknown	Honey Bee	Adjacent	2 hives
Plants									
I007334-001	1998	IL	Gramoxone (paraquat) Also involved: Canopy (metribuzin and chlorimuron ethyl) and Dual (s-metolachlor)	Undetermined	Possible	N/R	Corn	Vicinity	18 of 103 acres
I007371-008	1997	PA	Gramoxone (paraquat) Also involved: Bladex 90 DF (Cyanazine)	Misuse (accidental)	Highly Probable	Soybean	Soybean	Vicinity	Not given
I007371-033	1997	PA	Gramoxone (paraquat) Also involved: Bladex 90 DF (Cyanazine)	Misuse (accidental)	Probable	Corn	Grass	Vicinity	Not given
I007371-034	1997	PA	Gramoxone (paraquat) Also involved: Bladex 90 DF (Cyanazine)	Misuse (accidental)	Probable	Corn	Grass	Vicinity	Not given
I009573-009	1999	AL	Gramoxone (paraquat) Also possibly involved: Exceed (prosulfuron and primisulfuron-methul)	Undetermined	Possible	N/R	Corn	Treated directly	75% of 200 Acres
I011838-038	2001	GA	Gramoxone (paraquat) Also involved: Valor (flumioxazin) and Prowl	Undetermined	Possible	Peanut	Peanut	Treated directly	All 25 Acres

			(pendimethalin)						
I011838-055	2001	NC	Gramoxone (paraquat) Also involved: Dual (s-metolachlor) and Frontier (dimethenamid)	Registered Use	Possible	N/R	Peanut	N/R	10 acres
I011838-091	2001	OK	Cyclone (paraquat) Also involved: Valor (flumioxazin) and Prowl (pendimethalin)	Undetermined	Possible	Peanut	Peanut	N/R directly, but from write-up appears to be on site.	80 acres
I012366-023	2000	VA	Gramoxone (paraquat) Also involved: Python (flumetsulam), Bicep (atrazine and s-metolachlor) and Princep (simazine)	Undetermined	Possible	Corn, field	Corn, Field	N/R directly, but from write-up appears to be on site.	120 acres
I012684-010	2001	VA	Gramoxone (paraquat) Also involved: Valor (flumioxazin) and Dual (s-metolachlor)	Registered Use	Possible	Peanut	Peanut	N/R directly, but from write-up appears to be on site.	5 acres
I013554-040	2002	IL	Gramoxone Max	Misuse	Probable	N/R	Corn, Field	On site	1040 acres
I013636-029	1996	OR	Gramoxone (paraquat) Also involved: "other unknown ingredients" in a tank mix	Registered Use	Possible	N/R	Pepperm int	Treated directly	181 acres
I013884-014	1998	WA	Not specified[3]	Undetermined	Possible	Potato?	Apple	Vicinity	Not given
I013884-038[2]	1998	WA	Not specified[3]	Registered Use	Probable	Pea	Orname ntal	Vicinity	Not given Over-spray was noted. State inspector observed "paraquat symptoms"
I014034-009	2003	GA	Gramoxone MAX	Registered Use	Possible	Pasture	Pasture Grass	Treated directly	60 acres
I014409-001[2]	1992	WA	Not specified[3]	Undetermined	Possible	N/R	Radish	Vicinity	Not given Unlicensed application.
I014409-024	1992	WA	Not specified[3]	Misuse	Possible	Wheat	Alfalfa	Vicinity	Not given
I016940-005	2005	CA	Gramoxone	Misuse (intentional)	Probable	Wheat	Wheat	Adjacent	120 of 184 acres
I020459-025[2]	2000	WA	Not specified[3]	Undetermined	Probable	Corn, sweet	Winter Wheat	Adjacent	2.5 acres
I020627-019[2]	2001	WA	Not specified[3]	Undetermined	Probable	Agricultural area	Blueberr y	Adjacent	Not given

I020627-036[2]	2001	WA	Not specified[3]	Undetermined	Probable	Agricultural area	Alfalfa	Drift from field (distance not given)	Not given
I020998-023[2]	2002	WA	Unspecified paraquat product[3] Also involved: unspecified carfentrazone-ethyl product	Misuse	Possible	Hops	Cherry	Drift from field (distance not given)	Number not given
I021276-006[2]	2004	WA	Not specified[3]	Undetermined	Probable	Agricultural area - onion	Corn	Vicinity	Not given
I021457-015[2]	2006	WA	Unspecified paraquat product[3] Also involved: unspecified glyphosate product	Undetermined	Possible	N/R	Ornamental	Adjacent	Many
I023444-012[2]	2011	PA	Gramoxone Inteon[3]	Undetermined	Possible	Corn, field	Corn	On site	100% of 130 acres
I023587-006	2011	CA	Gramoxone Inteon	Undetermined	Possible	Cotton	Vegetable	Vicinity	100% of 25 acres
I028934-00016	2016	CA	GRAMOXONE SL 2.0	Undetermined	Possible	Agricultural area	Onion	Vicinity	145 acres

N/R = not found in report.

[1]An incident from 1989 (I000097-015) involving sparrows, grackles and robins was not included in this table because the certainty was "Unlikely." A summary is included in Appendix H of the Red-Legged Frog assessment (USEPA, 2009a).

[2] Incident was new or not previously summarized. Summary of information about this incident can be found in **Appendix E.**

[3] Incident was listed under PC. Code: 61603 (paraquat cation); all other incidents cited in this table were listed under PC Code: 61601 (paraquat dichloride). Although a search was made for PC Code: 61602 (paraquat bis [methyl sulfate]), no incidents were found associated with that code.

[4] Four incidents are listed here for discussion, even though they occurred outside of the U.S. (in Ireland and the Cayman Islands; I021685-002, I021848-003, I021848-004, and I027242-001).

Table 6-4. Paraquat Aggregate Incidents from the Incident Data System (IDS) for PC Codes 061601 and 061603

Taxa	Number of Incidents[1]
Vertebrate Wildlife (W-B)	4 (061601)
Plant (P-B)	78 (061601)
Non-vertebrate (ONT)	3 (061601) + 1 (061603) = 4

W-B = wildlife incidents; P-B = plant incidents; ONT = other non-target species incidents.

[1] Aggregate incidents are only reported as a count based measure.

The problem formulation document (USEPA, 2011a) contained an August 2011 review of the Ecological Incident Information System (EIIS, version 2.1), the Aggregate Incident Reports (v. 1.0) database, and the Avian Incident Monitoring System (AIMS). These incidents occurred between 1981 and 2005 and included a total of 4 incidents involving paraquat, 26 incidents involving paraquat dichloride, and no incidents involving paraquat bis (methyl sulfate). That analysis of incident reports identified a concern for acute aquatic exposures because of incidents where paraquat was a suggested cause of fish mortality; a discussion of those incidents is found in the problem formulation and also here in **Section 8.2.1**.

The recently updated incident summaries (also see **Appendix E**) only contained one incident that was from a registered use and was of probable likelihood, an incident involving plant damage.

Some of the incidents that were of undermined legality involved mortality of dogs (I020627-033 and I027242-001; I027242-001 occurred outside of the U.S.) and several birds (I021685-002, I021848-003, and I021848-004, all occurred outside of the U.S.); these cannot be attributed to registered use, but do support a line of evidence that paraquat can be toxic to terrestrial vertebrates. One bird incident involving Canada geese (I008168-001) was from a registered use on corn and of probable causality, but also involved other pesticides; however, in this case, even though atrazine, simazine, cyanazine and esfenvalerate were also involved, paraquat was considered to be the pesticide present in the tank mix at an amount representing the highest acute toxicity to birds. A noteworthy incident involving mortalities of several passerines (robins, sparrows, starlings and grackles) was previously described in the problem formulation (USEPA, 2011a); the report indicated that it was certain that carbofuran was responsible for the mortalities and probable that paraquat was responsible (I005750-001, I004169-026 and I000097-015).

One incident (I029512-0004) involved damage to two bee hives and was of possible causality but of undetermined legality. Additionally, many of the ONT (other non-target) aggregate incidents in
Table 6-4 are likely bee incidents and are assumed to be from registered uses unless additional information is provided to show otherwise.

These incidents suggest potential for harm to non-target aquatic and terrestrial animals, but whether this potential extends to registered uses is not clearly substantiated. The potential for damage to non-target plants is supported by at least five incidents associated with paraquat registered use.

Damage to a range of taxa were found in the incident report; absence of reported incidents for other taxa not represented should not be interpreted as an absence of incidents. Incident reports for non-target organisms typically provide information only on mortality events and plant damage. Sublethal effects in organisms such as abnormal behavior, reduced growth and/or impaired reproduction are rarely reported, except for phytotoxic effects in terrestrial plants. In addition, there have been changes in state monitoring efforts due to a lack of resources. However, the incident data that are available suggest that exposure pathways for paraquat are complete for aquatic organisms, and possibly for terrestrial vertebrates and invertebrates and plants, and that exposure levels are sufficient to result in field-observable effects.

7 Analysis Plan

7.1 Overall Process

This assessment uses a weight of evidence approach that relies heavily, but not exclusively, on a risk quotient (RQ) method. RQs are calculated by dividing an estimated environmental concentration (EEC) by a toxicity endpoint *(i.e.,* EEC/toxicity endpoint). This is a way to determine if an estimated concentration is expected to be above or below the concentration associated with the effects endpoint. The RQs are compared to regulatory levels of concern (LOCs). The LOCs for non-listed species are meant to be protective of non-target organisms. For acute and chronic risks to vertebrates, the LOCs are 0.5 and 1.0, respectively, and for plants, the LOC is 1.0. The acute and chronic risk LOCs for bees are 0.4 and 1.0, respectively. In addition to RQs, other available data (*e.g.*, incident data) can be used to help understand the potential risks associated with the use of the pesticide.

Exposure estimates for aquatic and terrestrial organisms were assessed by grouping some use patterns, listed on currently registered labels, that have similar application rates. The registered labels generally contained amount limits on a per crop-cycle basis, that could be used to estimate the annual maximum. Many of the uses registered did not specify the re-application interval. Labels restricting the interval ranged from 5-days to 30-days; where no interval was defined, it was conservatively assumed to be 7-days for modeling based on BEAD (Biological and Economic Analysis Division) recommendations.

For aquatic risk calculations, due to the rapid and strong adsorption to soil/sediment, exposure to bioavailable paraquat through runoff and/or erosion is unlikely within the modeled pond (*i.e.*, the paraquat in runoff and erosion would enter the pond, but not in a bioavailable state and would be unlikely to subsequently detach from the sediment particles and become bioavailable to organisms in the overlying water). However, there is a relatively high certainty of aquatic exposure through spray drift to the same waterbody since spray drift will largely occur under good weather conditions when waters are largely free of any recently introduced suspended sediment. Therefore, only spray drift exposures were modeled.

Since the paraquat introduced into a waterbody through drift, runoff, and erosion would subsequently adsorb rapidly to suspended solids and bottom sediments, chronic exposures in littoral (lemnic zone) and pore waters (benthic zone) are considered unlikely and were not modeled. There is less certainty regarding potential exposure to sediment-ingesting organisms (chiefly epibenthic and infaunal detritivores) since it is unknown to what degree the gut of a detritivore is capable of remobilizing any paraquat attached to sediment particles. However, this route of exposure was modeled by estimating sediment concentrations assuming no sediment burial as well as with sediment burial implemented in the Agency's standard aquatic model.

For terrestrial EEC calculations, only direct application and spray drift were assessed. Runoff was not assessed, consistent with the aquatic exposure assumptions, and also supported by the mode of action (suggesting paraquat will not be present systemically in plants, see **Section 3.1**), and by plant toxicity data (suggesting that direct spray is a more potent route of exposure than runoff exposure, see **Table 6-2**). For spray drift exposure, the highest and lowest single application rates were assessed. For birds and mammals, multiple applications were also assessed for the highest and mid-range application rates. Most uses tended to have the same or similar application rates of 0.5 or 1.01 lb cation/A, while two uses (alfalfa and clover) had a higher rate of 1.5 lb cation/A and a few had slightly different variations of the rates and were grouped with others with similar rates (*e.g.,* peanuts with a 0.938 lb cation/A rate was grouped with others with a 1.01 lb cation/A rate).

7.1.1 Listed Species

In November 2013, the EPA, along with the Services and the United States Department of Agriculture (USDA), released a summary of their joint Interim Approaches for assessing risks to endangered and threatened (listed) species from pesticides. The Interim Approaches were developed jointly by the agencies in response to the National Academy of Sciences' (NAS) recommendations and reflect a common approach to risk assessment shared by the agencies as a way of addressing scientific differences between the EPA and the Services. The NAS report[2] outlines recommendations on specific scientific and technical issues related to the development of pesticide risk assessments that EPA and the Services must conduct in connection with their obligations under the ESA and FIFRA.

EPA received considerable public input on the Interim Approaches through stakeholder workshops and from the Pesticide Program Dialogue Committee (PPDC) and State-FIFRA Issues Research and Evaluation Group (SFIREG) meetings. As part of a phased, iterative process for developing the Interim Approaches, the agencies will also consider public comments on the Interim Approaches in connection with the development of upcoming Registration Review decisions. The details of the joint Interim Approaches are contained in the white paper *Interim Approaches for National-Level Pesticide Endangered Species Act (ESA) Assessments Based on the Recommendations of the National Academy of Sciences April 2013 Report,*[2] dated November 1, 2013.

---

[2] Available at http://www2.epa.gov/endangered-species/assessing-pesticides-under-endangered-species-act#report

Given that the agencies are continuing to develop and work toward implementation of the Interim Approaches to assess the potential risks of pesticides to listed species and their designated critical habitat, this ecological risk assessment for paraquat does not contain a complete ESA analysis that includes effects determinations for specific listed species or designated critical habitat. Although EPA has not yet completed effects determinations for specific species or habitats, this assessment assumed, for all taxa of non-target wildlife and plants, that listed species and designated critical habitats may be present in the vicinity of the application of paraquat. This assessment will allow EPA to focus its future evaluations on the types of species where the potential for effects exists once the scientific methods being developed by the agencies have been fully vetted. Once the agencies have fully developed and implemented the scientific methodology for evaluating risks for listed species and their designated critical habitats, these methods will be applied to subsequent analyses for paraquat as part of completing this registration review.

7.1.2 Endocrine Disruptor Screening Program (EDSP)

As required by FIFRA and the Federal Food, Drug, and Cosmetic Act (FFDCA), EPA reviews numerous studies to assess potential adverse outcomes from exposure to chemicals. Collectively, these studies include acute, subchronic and chronic toxicity, including assessments of carcinogenicity, neurotoxicity, developmental, reproductive, and general or systemic toxicity. These studies include endpoints which may be susceptible to endocrine influence, including effects on endocrine target organ histopathology, organ weights, estrus cyclicity, sexual maturation, fertility, pregnancy rates, reproductive loss, and sex ratios in offspring. For ecological hazard assessments, EPA evaluates acute tests and chronic studies that assess growth, developmental and reproductive effects in different taxonomic groups. As part of the Preliminary Ecological Risk Assessment for Registration Review, EPA reviewed these data and selected the most sensitive endpoints for relevant risk assessment scenarios from the existing hazard database. However, as required by FFDCA section 408(p), paraquat is subject to the endocrine screening part of the Endocrine Disruptor Screening Program (EDSP).

EPA has developed the EDSP to determine whether certain substances (including pesticide active and other ingredients) may have an effect in humans or wildlife similar to an effect produced by a “naturally occurring estrogen, or other such endocrine effects as the Administrator may designate.” The EDSP employs a two-tiered approach to making the statutorily required determinations. Tier 1 consists of a battery of 11 screening assays to identify the potential of a chemical substance to interact with the estrogen, androgen, or thyroid (E, A, or T) hormonal systems. Chemicals that go through Tier 1 screening and are found to have the potential to interact with E, A, or T hormonal systems will proceed to the next stage of the EDSP where EPA will determine which, if any, of the Tier 2 tests are necessary based on the available data. Tier 2 testing is designed to identify any adverse endocrine-related effects caused by the substance, and establish a dose-response relationship between the dose and the E, A, or T effect.

Under FFDCA section 408(p), the Agency must screen all pesticide chemicals. Between October 2009 and February 2010, EPA issued test orders/data call-ins for the first group of 67 chemicals, which contains 58 pesticide active ingredients and 9 inert ingredients. A second list of chemicals identified for EDSP screening was published on June 14, 2013[3] and includes some pesticides scheduled for registration review and chemicals found in water. Neither of these lists should be construed as a list of known or likely endocrine disruptors. Paraquat is not on List 1 or List 2. For further information on the status of the EDSP, the policies and procedures, the lists of chemicals, future lists, the test guidelines and Tier 1 screening battery, please visit our website.[4]

7.2 Modeling

Various models are used to calculate aquatic and terrestrial EECs (see **Table 7-1).** The specific models used in this assessment are discussed further below. The PWC (v. 1.52) was only used to estimate sediment concentrations. Surface water exposure through spray drift alone was calculated using a spreadsheet to avoid the runoff and erosion contributions that PWC would have included. (Paraquat in runoff and erosion is considered to be strongly adsorbed and not bioavailable for limnetic exposures.)

[3] See http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPPT-2009-0477-0074 for the final second list of chemicals.
[4] Available: http://www.epa.gov/endo/

Table 7-1. List of the Models Used to Assess Risk

Environment	Taxa of Concern	Exposure Media	Exposure Pathway	Model(s) or Pathway
Aquatic	Vertebrates/ Invertebrates (including sediment dwelling)	Surface water and sediment	Runoff and spray drift to water and sediment	PRZM-VVWM with PWC version 1.2[1]
	Aquatic Plants (vascular and nonvascular)			
Terrestrial	Vertebrate	Dietary items	Ingestion of residues in/on dietary items as a result of direct foliar application	T-REX version 1.5.2[2]
	Plants	Spray drift	Spray drift to plants	TERRPLANT version 1.2.2
	Bees and other terrestrial invertebrates	Contact dietary items	Spray contact and ingestion of residues in/on dietary items as a result of direct application	BeeREX version 1.0
All Environments	All	Movement through air to aquatic and terrestrial media	Spray drift	AgDRIFT version 2.1.1 (Spray drift)

[1] The Pesticide in Water Calculator (PWC) is a Graphic User Interface (GUI) that estimates pesticide concentration in water using the Pesticide Root Zone Model (PRZM) and the Variable Volume Water Model (VVWM). PRZM-VVWM.
[2] The Terrestrial Residue Exposure (T-REX) Model is used to estimate pesticide concentration on avian and mammalian food items.
[3] The K_{OW} based Aquatic Bioaccumulation Model (KABAM) is used to estimate exposure to terrestrial animals that may consume aquatic organisms when a chemical has the potential to bioconcentrate or bioaccumulate. The general triggers for running this model is that: the pesticide is a non-ionic, organic chemical; the Log K_{OW} value is between 3 and 8; and the pesticide has the potential to reach aquatic habitats.

8 Aquatic Organisms Risk Assessment

8.1 Aquatic Exposure Assessment

8.1.1 Modeling

There are two major uncertainties with paraquat exposure estimates. First, paraquat does not follow the typical soil/sediment adsorption/desorption relationships modeled by the Agency's aquatic exposure models. Upon exposure to water or soil moisture, paraquat dichloride loses the negatively charged chloride ions to become a positively charged cation. In the presence of soil or sediment, the available adsorption data indicates that the paraquat cation preferentially adsorbs to clay to such an extent that levels of paraquat are undetectable in the water phase of the adsorption studies even at high doses. Only at experimental doses many times those expected from the maximum single paraquat application rate and in soils/sediments comprised of little clay do the clay adsorption sites reach saturation with any excess paraquat cations (*i.e.*, paraquat accumulated beyond that needed to reach adsorption site saturation) accumulating in the water phase.

This behavior is demonstrated in a batch equilibrium study (MRID 40762701) in which paraquat adsorption/desorption was studied in four soil types under both normal and greatly exaggerated application rates. To measure adsorption, 200 ml of 0.01 M $CaCl_2$ solution plus standard reference paraquat was added to the samples at 1, 10, 800 and 1000 mg/kg soil in the loam soil, at 1, 10, 300, and 500 mg/kg soil in the silty clay loam soil, at 1, 10, 100 and 150 mg/kg soil in the loamy sand soil, and at 1, 10, 20 and 40 mg/kg soil in the sand soil. The 1 mg/kg soil concentration is approximately equal to 1.8 lbs ai/A, which is higher than the highest current single application rate (1.5 lbs ai/A). Therefore, the 10× to 1000× application rate multipliers in **Table 8-1** are 10 to 1000 times the 1.8 lbs ai/A and therefore, represent the accumulation of hundreds of years of paraquat applications at some of the highest experimental application rates. According to the study, the two much higher application rates for each soil were devised (based on preliminary experiments) to be above the "strong adsorption capacity of the soil", which varies with each soil tested. The term "strong adsorption capacity of the soil" is used to refer to the highest concentration of paraquat in soil at which there is no detectable paraquat in the equilibrium solution of the soil slurry.

Table 8-1. Paraquat Batch Equilibrium Study (MRID 40762701) Summary

Application Rate Mutiplier (unitless)	Aqueous Phase Concentration (µg ai/ml)	Soil Phase Cocentration (µg ai/g)	Kd (ml/g)
Loam Soil (Cation Exchange Capacity = 12.9 meq/100g; Sand = 62%; Silt = 17%; Clay = 21%)			
1×	<0.0075	>0.85	>110
10×	<0.0075	>9.9	>1300
800×	0.016	799.7	50,000
1000×	0.624	999.5	42,000
Silty Clay Loam Soil (Cation Exchange Capacity = 15.2 meq/100g; Sand = 14%; Silt = 57%; Clay = 29%)			
1×	<0.0075	>8.5	>110
10×	<0.0075	>98.5	>1300
300×	0.032	299.4	9400
500×	0.093	498.2	5400
Loamy Sand Soil (Cation Exchange Capacity = 6.6 meq/100g; Sand = 81%; Silt = 11%; Clay = 8%)			
1×	<0.0075	>8.5	>110
10×	<0.0075	>98.5	>1300
100×	<0.0075	>985	>13,000
150×	0.0255	1495	5900
Sand Soil (Cation Exchange Capacity = 1.9 meq/100g; Sand = 94%; Silt = 4%; Clay = 2%)			
1×	<0.0075	>8.5	>110
10×	0.02	9.6	480
20×	0.09	18.2	200
40×	0.455	30.9	68

In the first soil of this table (loam), the 1× and 10× application rate trials do not produce measurable concentrations of paraquat in the equilibrium solution of the soil slurry and therefore, produce Kds that are only known to be larger than Kd value listed for that trial (denoted as “>”). However, at the exaggerated rates of 800× and 1000×, paraquat can be measured in the soil slurry at equilibrium, which produces Kds that are 50,000 and 42,000, respectively. Similar results are produced for the other soils, but with declining high application rate multipliers (because the “strong adsorption capacity of the soil” is decreasing as the cation exchange capacity [CEC] and clay content decline) as well as declining Kd estimates for these soils because the equilibrium slurry concentrations (in the denominator of the Kd equation) are increasing.

For the last soil with CEC of 1.9 meq/100g and clay content of 2%, the 10× and “high” application rate multipliers of 20× and 40× all produce relatively lower Kd estimates compared to the other soils tested. The pattern presented in **Table 8-1** appears to be that Kds are high at low application rate multipliers, but continuously decrease as the application rate multiplier increases relative to the “strong adsorption capacity of the soil”.

Amondham *et al* 2006 assessed paraquat adsorption in eight tropical soils of Yom River Basin, Thailand and fit Freundlich isotherm models to each of the soils studied. These fits provided 1/n values ranging from 0.19 to 0.41. More typical values range from 0.9 to 1.0 with 1.0 indicating the equilibrium distribution between soil and water phases of the batch equilibrium studies are not dependent on concentration (i.e., the concentrations in both water and soil increase proportionally as the amount applied varies). Therefore, the low values observed indicate that the equilibrium distribution varies strongly with the amount of paraquat applied with almost all of the paraquat being absorbed to the soil phase at low levels of application and appreciable water phase concentrations appearing only when large amounts have been applied (Figure 8-1). These isotherm plots show accumulations of paraquat in the soil of 1000 mg/kg (equivalent to 1000 applications at 1.8 lbs ai/A) before the concentration in water begins to appreciably increase for seven of the soils. However, similar to the results of MRID 40762701, the sand soil (soil #6 in Figure 8-1**b**) appears to have its adsorption capacity exceeded after little soil accumulation (i.e., potentially at low numbers of applications).

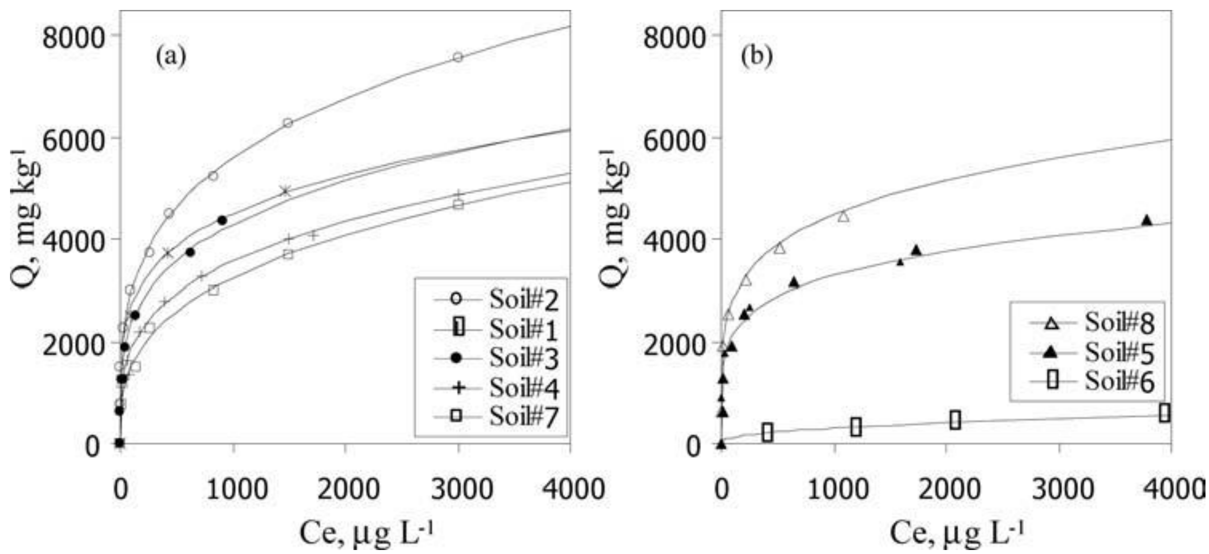


Figure 8-1. Freundlich isotherm plots of paraquat adsorption on two soil groups: (a) high free oxide content soils; (b) low free oxide content soils (reproduced from Amondham et al 2006).

These studies indicate that over a series of paraquat dichloride applications in non-sand soils, the adsorption coefficient (Kd) that would be used as an input to the Agency's aquatic exposure model should be undefined (high soil concentration/zero water concentration) or extremely high (divided by some very small water concentration) until the soil/sediment saturates and then decrease continuously as the paraquat applied exceeds the level needed to saturate the soil/sediment. This variable adsorption coefficient is fundamentally different than the constant adsorption coefficient (Kd) assumed in the Agency's aquatic models.

A second uncertainty concerns whether the excess paraquat would degrade or persist in nonsterile environments. The guideline tests required by the Agency consist of sterile tests in the absence of soil or sediment (*i.e.*, excluding microorganisms in the hydrolysis and aqueous photolysis studies) and nonsterile tests in the presence of soil or sediment (*i.e.*, including microorganisms in the aerobic/anaerobic soil/aquatic metabolism). Therefore, in the Agency's tests, the interpretation of the fate data would be that paraquat's high affinity for adsorption to clay would outcompete any potential metabolism (*i.e.*, paraquat is adsorbed rather than degraded). This results in no degradation occurring in the metabolism tests, not because paraquat is resistant to degradation, but rather that the paraquat is not freely available for degradation by the microorganisms. However, paraquat is the kind of organic molecule that would likely be susceptible to metabolism in that it is not protected from degradation with halogens or has a complex multi-ringed molecular structure. Therefore, once the paraquat exceeds the soil/sediment capacity for adsorption to clay (saturation), it seems likely that any free (not adsorbed) paraquat would be susceptible to metabolism and therefore would not appreciably accumulate (increase in concentration) in the waterbody of the Agency's aquatic exposure model over time. These properties are demonstrated with a registrant-submitted study showing a lack of degradation under the Agency's guideline study and two open literature studies indicating much faster degradation when paraquat occurs in a dissolved (bioavailable) phase.

In a registrant-submitted aerobic soil metabolism study (MRID 41319301), paraquat applied at a rate equivalent to 0.9 lbs ai/A was shown to: 1) adsorb to a sandy loam soil (CEC 10.8 meq/100 g; sand 64%; silt 22%; clay 14%); and 2) not metabolize in that adsorbed state for 180 days. The soil samples were extracted three times with the extracted compounds identified separately for each extract. In the first extraction, the soil samples were shaken with 100-150 ml of methanol for 1 hour. (In MRID 46098802, paraquat's solubility limit was 1000 mg/L in methanol, but less than 11 mg/L in n-hexene, toluene, dichloromethane, acetone, and ethyl acetate.) Despite paraquat's affinity for methanol, <0.2% of the applied paraquat (**Table 8-2**) was released from any of the incubated soil samples even at 180 days indicating again that the paraquat is tightly adsorbed to soils with adequate CEC and clay content.

Table 8-2. Distribution of Radioactivity in Soil Treated with 14c-pyridyl Labelled Paraquat

Portion-Analysed	Radioactivity Recovered as % of Applied (Paraquat as % of Applied)						
	0	**3**	**7**	**30**	**61**	**90**	**180**
1st Extract	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
2nd Extract	95.3 (92.3)	98.6 (93.0)	81.7 (79.8)	83.3 (82.1)	83.6 (81.4)	80.0 (77.3)	73.5 (72.9)
3rd Extract	7.4 (7.2)	3.3	10.5 (9.9)	10.4 (10.2)	12.2 (11.7)	12.0 (11.5)	21.7 (20.5)
$^{14}CO_2$	NA	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Unextracted	4.1	1.9	4.1	1.2	1.4	0.5	0.7
Total Extracted	106.8	103.8	96.3	94.9	97.2	92.5	95.9
Total Paraquat Extracted	99.5	96.3	89.7	92.3	93.1	88.8	93.4

The second extract was for 2-4 hours with 100 or 150 ml of aqueous technical grade (not radiolabeled) paraquat solution (7440 ppm paraquat cation) in order to desorb radiolabeled [^{14}C]paraquat by isotopic exchange. The clear majority of the radiolabeled paraquat was released from the soil by being exchanged with the non-labeled paraquat. To identify the remaining unextracted residues, the soil was further extracted by a 5-6 hour reflux with 6 M HCl (3rd extract), which resulted in the total paraquat extracted being greater than 88% of the applied in every sampling interval. (Note that <0.1% of the applied radioactivity was metabolized to CO2, and the unextracted residues following the 3rd extract were consistently less than 5% of the applied radioactivity, ensuring that little if any degradates could have been produced, but adsorbed and characterized as unextracted residues.) This experiment indicates the paraquat did not metabolize during the experiment when it was tightly adsorbed to soil, with the study authors estimating a half-life in excess of 10 years but provides no indication of the rate of degradation that would occur in any bioavailable (not in an absorbed state) paraquat.

In the open literature studies, the previously described Amondham *et al* study (2006) that assessed paraquat adsorption, degradation, and remobilization in eight tropical soils of Yom River Basin, Thailand, did measure paraquat degradation. In the field portion of this study, first order dissipation rates of 36 days (low application rate) and 46 days (high rate), whereas a half-life 0f 166 days was calculated for the laboratory study. The difference in rates between field and laboratory was attributed to differences in temperature (field being warmer) and soil photolysis. In Ricketts (1999), isolates of soil bacterial were shown to be capable of degrading paraquat with rapid production of CO_2 (approximately 50% of applied radioactivity) with no paraquat remaining in the study at 30 days (half-life could not be calculated). The CADPR (no date) has a more comprehensive review of the scientific literature regarding paraquat environmental fate.

The degradation found in these open literature studies is likely due to the higher application rates of paraquat relative to the amount of soil occurring in the open literature studies with faster rates likely occurring in those experiments where a larger proportion of the paraquat was bioavailable (i.e., in a disolved phase) with:

- No degradation at the typical application rates in the Agency guideline study;
- Faster degradation under the higher application rates (greater bioavailability) in Amondham *et al* (2006); and
- Fastest degradation rates achieved in Ricketts (1999) since the bacteria and paraquat occurred in a soil free (no adsorption) environment.

Therefore, the persistence of paraquat appears to be an artifact of the Agency guideline study design, rather than an actual property of the paraquat molecule. Considering these degradation findings in conjunction with the previously discussed adsorption findings, it appears likely that paraquat only accumulates (persists) in the environment when it is in a non-bioavailable state and degrades rapidly when bioavailable. Because of these unique properties of paraquat, the typical aquatic exposure assessment was modified as described in the following sections.

Acute Water Column Exposure Calculations

For acute aquatic environmental exposures, it would be more likely that the highest concentrations in the water column would occur immediately after spray drift enters the pond. Since spray drift would likely occur under good weather conditions when water column suspended sediment concentrations would often be low (*i.e.*, not during or immediately after a run-off producing storm event), the paraquat entering the pond could remain in solution and impact aquatic organisms. Therefore, paraquat exposure was modeled as spray drift only concentrations which vary with application method (aerial vs. ground) and application rate. This assumes that the spray drift enters the waterbody, causes a brief high concentration, and then quickly dissipates via adsorption to clay in sediment.

Note that this acute exposure is calculated outside of the standard Agency aquatic exposure model (PWC) since PWC would include 50% of the paraquat entering the pond through runoff and erosion as partitioning into the overlying pond water. Therefore, the acute exposure to paraquat (*Peak*) is calculated as:

$$Peak(\mu g/L) = \frac{SprayFrac(unitless) \times AppRate(Kg/ha) \times PondSA(ha) \times CF(\mu g/Kg)}{PondVolume(L)}$$

Where:

SprayFrac is the fraction (0.125 for aerial and 0.062 for ground) of the application rate that falls on the USEPA standard pond;
AppRate is the single application rate to the crop-specific scenario modeled;
PondSA is the surface area of the USEPA standard pond (1 ha);
CF is a conversion factor to convert from kilograms to micrograms (1×10^9 µg/Kg); and
PondVolume is the volume of the USEPA standard pond (2×10^7 L).

Current EFED guidance (USEPA 2017) is to calculate an average 24-hour exposure as the acute exposure. However, there is no dissipation rate available for paraquat from which this average 24-hour exposure can be calculated. Therefore, the instantaneous peak values calculated in **Table 8-3** may over-estimate exposure to aquatic organisms to some unknown extent. This method is equivalent to how PWC calculates spray drift contribution to EECs assuming no degradation occurs on the day of the drift event (also see **Appendix C**).

Table 8-3. Acute Aquatic Exposures to Paraquat Dichloride through Drift Based on Application Type and Application Rate

Application Rate		Application Type (Spray Drift Fraction)	Acute (peak) Exposure (ug cation/L)
(lbs cation/A)	(kg cation/Ha)		
0.5	0.56	Aerial (0.125)	3.5
		Ground (0.062)	1.7
1.01	1.13	Aerial (0.125)	7.1
		Ground (0.062)	3.5
1.5	1.68	Aerial (0.125)	10.5
		Ground (0.062)	5.2

Sediment Exposure Estimates

Based on the assumption that paraquat quickly and strongly adsorbs to sediment (suspended or deposited at the bottom of waterbodies), there would be no meaningful chronic exposure via overlying water or pore water. However, some organisms ingest sediment, and it is unknown if the digestive systems of these organisms would be able to desorb some fraction of the paraquat from the ingested sediment. Therefore, conservative sediment exposure estimates were modeled: 1) using the Agency's aquatic exposure model (PWC); 2) assuming the vast majority of the paraquat entering the standard pond accumulated in the sediment; and 3) assuming all of the paraquat in this sediment was available to these benthic organisms. The PWC modeling parameters appear in **Table 8-4**.

Table 8-4. PRZM-EXAMS Input Parameters

Input Parameter	Value	Reference/Comment
Molecular Weight	257.2 g/mol	http://extoxnet.orst.edu/pips/paraquat.htm
Vapor Pressure	1×10^{-9} torr	http://extoxnet.orst.edu/pips/paraquat.htm
Solubility	700,000 mg/L	http://extoxnet.orst.edu/pips/paraquat.htm

Input Parameter	Value	Reference/Comment
K_d	Uncertain (1000 ml/g based on analysis presented below)	MRID 40762701
Incorporation Depth	0 cm	Foliar Application
Application Rate	1.01 (lb ai/ac) 1.13 (kg ai/ac)	Maximum Application Rate for FIFRA Section 3 Registrations
Number of Applications	4 (MS Cotton) 10 (FL Turf)	Maximum Number Allowed
First Application Date	April 26 (MS Cotton) January 26 (FL Turf)	Minimum Interval = 28 days
Application Efficiency	0.95 (MS Cotton) 0.99 (FL Turf)	Aerial Spray Ground Spray
Spray Drift Fraction	0.125 (MS Cotton) 0.062 (FL Turf)	Aerial Spray Ground Spray
Hydrolysis	Stable (pH 5, 7, 9)	Upton et al., 1985
Aqueous Photolysis Half-life	Stable	MRID 40762701
Water Half-life	Stable	MRID 00055093
Benthic Half-life	Stable	MRID 41319302
Soil Half-life	Stable	MRID 41319301

The two scenarios presented in **Table 8-5** were chosen to provide a range of potential sediment exposure values. Because the value of the soil:water partition coefficient (Kd is assumed since adsorption under paraquat saturation conditions was related to clay content) is uncertain, a range of Kd values was explored to identify a value that would yield conservative sediment EECs. In **Figure 8-2a**, the Mississippi Cotton scenario (typically considered to be a scenario that yields high-end exposure estimates) indicates that the highest total fraction of pesticide applied to the field transported to the pond based on modeled exposure from drift, runoff, and erosion occurs at or near a Kd of 1000. **Figure 8-2b** investigates the Florida turf scenario (typically considered to be a scenario that yields much more moderate exposure estimates due to erosion being attenuated by a two-centimeter-thick thatch layer) which produced much lower total pesticide fraction transported. (Note the y-axis scale change and that attempts to model Kd values higher than 10,000 produced a PWC error.) Based on these results and the Kd constraints imposed by the model, a Kd of 1000 was chosen as a Kd value that should result in high-end (conservative) sediment EECs (*i.e.*, this Kd value likely provides a conservative value because it is high enough to minimize leaching in the field and produce greater erosive transport, while still allowing some runoff to the pond).

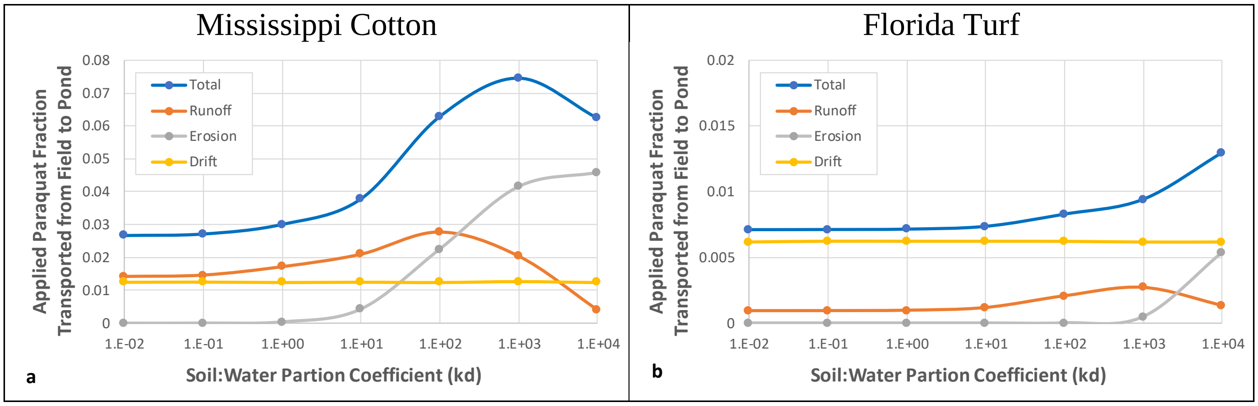


Figure 8-2. Comparison of the Relationship Between Total Pesticide Transport and Soil:Water Partition Coefficient in a Typically High-End Exposure Scenario (a) and More Moderate Exposure Scenario (b)

Based on the Kd selected (1000 ml/g), the PWC bulk sediment EECs are graphically depicted in **Figure 8-3** based on two different modeling options. The blue lines depict the standard estimates assuming no sediment burial, while the red lines depict the same estimates with the sediment burial routine implemented. In the MS cotton scenario, the paraquat accumulates continuously over time without sediment burial, but quickly reaches a much lower steady state concentration when sediment burial is implemented. If we think of the red and blue lines as high and low estimates bracketing some true accumulation trend over time, then this true accumulation trend has a high level of uncertainty for this scenario. In the MS cotton scenario, high amounts of erosion carrying adsorbed paraquat either cause the concentration to build continuously or level off quickly to a low sediment concentration due to continuous burial by the latest eroded soil entering the waterbody. Conversely for the FL turf scenario, the with and without sediment burial bulk sediment EECs plot directly on top of each other, which indicates very little erosion is occurring in this scenario and therefore, no sediment burial.

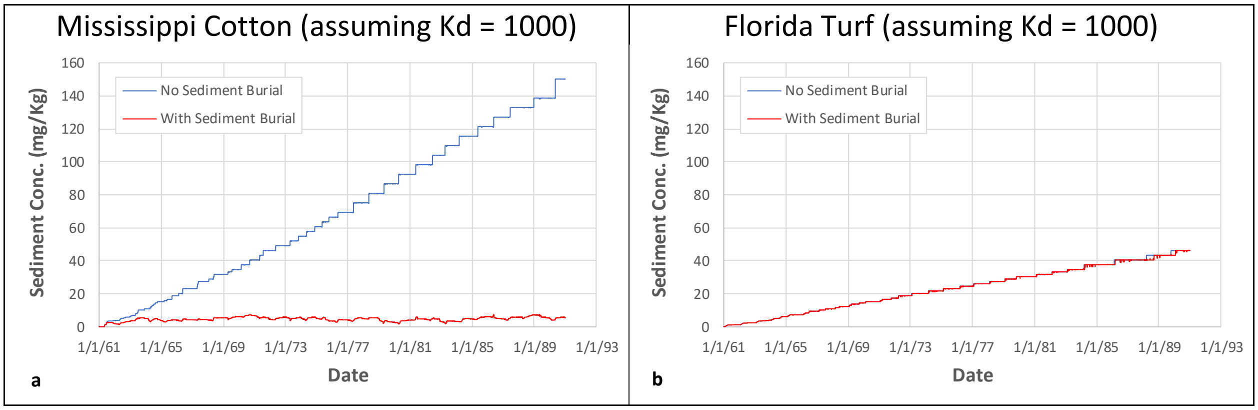


Figure 8-3. Comparison of Sediment Estimated Environmental Concentrations for Two Scenarios with and without Sediment Burial Implemented based on a 1.0 lbs ai/A Application Rate

The EECs estimated from these scenarios are listed in **Table 8-5**. Three of the scenarios (MS cotton without sediment burial and both with and without for FL turf) have continuously accumulating EECs, which are described by their 30-year concentration (*i.e.,* the accumulated concentration that occurs at the end of 30 years). Only one scenario (MS cotton with sediment burial) reaches a steady state EECs, which is described with a 1-in-10-year concentration.

Table 8-5. Estimated Concentrations in Sediment after Thirty Years based on a 1.0 lbs ai/A Application Rate[1]

Scenario	Application Type	Sediment Burial	Water Concentration EEC (µg cation/L)	Sediment Concentration EEC (mg cation/Kg)
MS Cotton	Aerial	Without	150	150
		With	7.18	7.18
FL Turf	Ground	Without	46.3	46.3
		With	46.3	46.3

[1] Pore water and sediment EECs represent the accumulated concentration that occurs at the end of 30 years.

8.1.2 Monitoring

The Water Quality Portal (https://www.waterqualitydata.us/) was searched for paraquat monitoring data. The water samples (from NWIS, STEWARDS, STORET) comprise 1381 results from 64 sites. Among the 1381 water samples, there are only 14 detections by two organizations: California State Water Resources Control Board (CASWRCB) and South Florida Water Management District (SFWMD). Of the 1277 SWFMD samples, only 1 sample had paraquat detected at 1.4 µg/L. However, there is no indication of what type of water sample was collected (total, dissolved fraction, etc.) for any of the SWFMD samples. The other paraquat detections are all from CASWRCB with 13 detections (ranging from 0.24 to 3.6 µg/L) out of 68 water samples collected by this organization. These samples are total water samples indicating that the samples were not filtered and therefore, the paraquat detected may be attached to suspended sediment rather than dissolved in water (i.e., total samples are less indicative that the paraquat detected is bioavailable). The remaining 36 samples had non-detectable levels of paraquat and are from the Chumash Mission Indian tribe (7 samples), National Park Service (1), Pomo Indian tribe (27), and Utah Department of Environmental Quality (1). The U.S. Geological Survey (USGS) which typically provides the majority of samples for pesticides from Water Quality Portal data set, does not monitor for paraquat.

A different compilation of California data (https://www.cdpr.ca.gov/docs/emon/surfwtr/surfdata.htm) from the California Department of Pesticide Regulation (CDPR) contains many of the same samples, but does include five samples that were not incorporated into the Water Quality Portal data set, while also excluding five samples that were in the Water Quality Portal data set. Out of 2099 samples in the CDPR data set, 13 detections were included ranging from 0.1 to 3.6 µg/L. It is difficult to reconcile the two data sets because: 1) many of the 'Agency' names in the CDPR data set appear to fall under the umbrella of the CASWRCB organization name included in the Water Quality Portal data set; 2) many of the non-detects recorded in the CDPR data set are omitted from the Water Quality

Portal data set; and 3) the CDPR data set does not record the water sample type (total, dissolved fraction, etc). The CDPR data summarized by collecting Agency (**Table 8-6**).

Table 8-6. Summary of the Paraquat Data Contained California Department of Pesticide Regulation (CDPR) data set

Collecting Agency	Number of samples	Number Detected	Highest Detected (µg/L)
Buena Vista Coalition*	12	0	NA
E. San Joaquin Water Quality Coalition (RWB5Irrigated Lands Monitoring)*	419	3	1.5
Kaweah River Sub-Watershed*	45	0	NA
Kern River Sub-Watershed*	71	0	NA
Kings River Sub-Watershed*	35	2	1.1
Michael L. Johnson, LLC	445	2	0.68
Pacific Ecorisk	164	1	0.67
S. San Joaquin Water Quality Coalition (RWB5 Irrigated Lands Monitoring)*	94	1	0.01
Sacramento Valley Water Quality Coalition (RWB5 Irrigated Lands Monitoring)*	171	0	NA
San Joaquin County and Delta Water Quality Coalition (RWB5 Irrigated Lands Monitoring)*	330	1	3.6
Tetra Tech, Inc.	60	0	NA
Tule River Sub-Watershed*	47	0	NA
University of California-Aquatic Ecosystems Analysis Laboratory	38	0	NA
Westside San Joaquin Water Quality Coalition (RWB5 Irrigated Lands Monitoring)*	168	3	1.4

* Appear to be subdivisions of the California State Water Resources Control Board (CASWRCB).

These studies were not specifically targeted at paraquat use areas and the frequency of sample collection in all studies was not adequate to ensure the capture of peak concentrations. Monitoring data are useful in that they provide some information on the occurrence of paraquat in the environment under existing usage conditions. However, the measured concentrations should not be interpreted as reflecting the upper end of potential exposures unless they were collected in areas with frequent sampling and where usage was occurring. Absence of detections from non-targeted monitoring cannot be used as a line of evidence to indicate exposure is not likely to occur because it is often collected in areas where the pesticide is not used. Additionally, modeling results are not expected to be similar to monitoring results as monitoring does not reflect the conceptual model and the sampling frequency and duration often does not reflect what is simulated in modeling (*i.e.,* daily concentrations). However, monitoring data is a useful line of evidence to explore whether exposure in the environment is occurring at the levels of the modeled EECs and whether monitoring shows that exposure is occurring at levels that are higher than toxicity endpoints. For non-targeted monitoring data, if exceedances are not occurring this is not evidence that exceedances will not occur with usage; however, if there are exceedances, it confirms that exposure occurred in the environment at levels where effects are expected to occur.

8.2 Aquatic Organism Risk Characterization

8.2.1 Aquatic Vertebrates

Risk estimates showed no acute LOC exceedances for aquatic vertebrates from water column exposure (**Table 8-7**). Chronic RQs could not be calculated due to previously described fate characteristics. However, when chronic toxicity endpoints (based on growth, see **Table 6-1**) were conservatively screened against the acute EECs, the exposure:toxicity ratios were all less than or equal to 0.01, indicating that that estimated exposure concentrations are less than those expected to produce chronic effects.

Table 8-7. Acute and Chronic Vertebrate Risk Quotients for Non-listed Species

Use Pattern	Peak EEC, µg cation/L[1]	Risk Quotient			
		Freshwater		Estuarine/Marine	
		Acute	Chronic	Acute	Chronic
		LC_{50} = 4700 µg cation/L	NOAEC = 740 µg cation/L	LC_{50} = >41,000 µg cation/L	NOAEC = 1800 µg cation/L
Almond and Clover, 1.5 lb cation/A - Aerial	10.5	<0.01	Chronic RQs could not be calculated; however if the chronic endpoint is screened against the acute EECs, the ratio is 0.01 or less for all use patterns.	<0.01	Chronic RQs could not be calculated; however if the chronic endpoint is screened against the acute EECs, the ratio is <0.01 for all use patterns.
- Ground	5.2	<0.01		<0.01	
Multiple Uses – Highest Rate, 1.10 lb cation/A - Aerial	7.1	<0.01		<0.01	
- Ground	3.5	<0.01		<0.01	
Multiple Uses – Lower Rate, 0.5 lb cation/A - Aerial	3.5	<0.01		<0.01	
- Ground	1.7	<0.01		<0.01	

A lack of **Bolded** values shows that no RQs exceed the LOC for acute risk to non-listed species of 0.5 or the chronic risk LOC of 1.0. The endpoints listed in the table are the endpoint used to calculate the RQ.
[1] The EECs used to calculate these RQs are based on the 1-in-10-year peak value from **Table 8-3**; for this assessment, this value is also used to screen for chronic risk; see explanation in **Section 8.1.1**.

As described in **Section 8.1.1**, paraquat is not expected to remain long in the water column. This is consistent with risk estimates.

However, information from the open literature suggests that some species of fish and aquatic-phase amphibians may be as much as an order-of-magnitude more sensitive than the quantitatively usable fish endpoints used here; **Appendix B** cites studies conducted with Red-eyed Treefrogs (*Agalychnis callidryas,* Ghose, *et al*., 2014, E168034) and Gourami Fish (*Trichogaster trichopterus*, Banaee, *et al*., 2013, E172383; references in **Appendix B**) although due to insufficient information in both cases, the study results were not quantitatively useable to calculate risk. These LC_{50} endpoints were approximated between 1,240 and 1,410 µg cation/L, based on the assumption that the reported concentrations are based on paraquat dichloride and are converted to cation (this is unconfirmed for the frog endpoint). If these endpoints are used to estimate risk, they would not change the risk conclusions; for example, if the highest peak EEC (10.5 µg cation/L) is divided by 1240 µg cation/L, the ratio is <0.01, which is below the 0.5 level of concern for non-listed species.

Additionally, six incidents involved aquatic organisms, with paraquat dichloride suspected of being the primary cause in 4, and of these 1 was from a registered use (I009314-005; fish-kill involving bluegill, crappie, and bass) and 3 of undetermined legality (B0000502-18, I005805-0001, and I008468-007; fish-kills involving sunfish, bluegill, crappie, and bass). The incident known to be from a registered use (I009314-005) is the strongest evidence of potential damage to non-target aquatic life. No other pesticides were implicated. The fish kill occurred in a one-acre pond in Madison, IN, approximately 250 feet from the edge of a treated field. The incident was determined to be of unknown cause but of suspected pond turnover. One potential scenario suggests that the pond may have suffered low dissolved oxygen from paraquat damage to aquatic plants, but the report also states that the distance between the treated field and pond was entirely covered by heavy sod which showed no signs of herbicide damage, so the sod plants may have been less sensitive than the aquatic plants involved. The causality is not entirely clear, but does seem to be associated with paraquat registered use.

Similar scenarios were described in two additional incidents, with the exception that legality was undetermined. Incident I005805-001 (Jefferson, IN), also involved a one-acre pond approximately 250 feet from a treated field; no other pesticides were implicated. Bluegill, bass, and crappie were killed and the report suggests that pond turnover was suspected. The distance between treated field and pond was also covered by sod that showed no sign of herbicide damage. In Incident B0000-502-18 (Frederick Co., VA), the report stated that runoff of paraquat from adjacent fields was involved in killing one largemouth bass and 53 sunfish, the theory being that it killed the vegetation in the pond and caused a low D.O. (2.0 ppm at 1200 hours). Also, the reporter stated that the organisms in the stream feeding the pond were destroyed by toxic concentrations of paraquat. Causality was determined to be of possible certainty. No other pesticides were implicated. These incidents are somewhat consistent with three incidents involving direct application of diquat dibromide to waterbodies that likely caused deaths of aquatic animals due to low dissolved oxygen following a large die-off of aquatic plants (see diquat assessment, USEPA, 2015). However, the incident involving runoff (B0000-502-18) challenges the assumption used in this assessment that runoff will be minimal due to very strong binding to clay. One possible explanation is that the exposure pathway cited in the incident report may have been incorrect, and the actual exposure involved spray drift. This would be consistent with several of the other incidents where the pond was approximately 250 feet from treated fields, and the sod between each field and pond showed no signs of herbicide damage, suggesting that although the sod plants, as well as the aquatic plants, were exposed to spray drift, they may have been less sensitive, perhaps by having a sound root structure that was not exposed to the drift.

Another fish-kill incident (I008768-007) involved approximately 200 dead bluegill and bass combined, and at least two frogs, but no deaths to pond catfish in a three-quarter acre pond. This incident was reported by a Conservation Officer and was determined to be of undetermined legality and “possible” certainty; however, this incident involved application of multiple pesticides (also including chlorimuron-ethyl and metribuzin).

These incidents suggest potential for harm to aquatic organisms from paraquat exposure, and one of these incidents was linked to a registered use. The pathway of damage is possibly from oxygen sinks due to plant aquatic die-offs. The available acute toxicity data do not suggest that fish will die from direct exposure; however, estimated environmental concentrations are at or above the effects concentrations for algae and so the scenario of algal die-offs resulting in aquatic animal mortality is supported. The exposure pathway is not entirely clear, due to one incident being attributed to runoff, but fate characteristics suggest that spray drift is a much more likely pathway.

A low number of reported incidents should not be construed as the absence of incidents. Incident reports for non-target animals typically provide information only on mortality events. Sublethal effects in organisms such as abnormal behavior, reduced growth and/or impaired reproduction are rarely reported.

Based on the available data, the risk to fish and aquatic-phase amphibians from the use of paraquat cannot be precluded due to fish-kill incidents and the persistence of adsorbed-phase paraquat.

8.2.2 Aquatic Invertebrates

Risk estimates showed no acute LOC exceedances for aquatic invertebrates from water column exposure (**Table 8-8)**. Chronic RQs could not be calculated due to previously-described fate characteristics. However, when chronic toxicity endpoints (based on growth, reproduction and survival see **Table 6-1**) were conservatively screened against the acute EECs, the exposure:toxicity ratios were all less than one, indicating that that estimated exposure concentrations are less than those expected to produce chronic effects.

Table 8-8. Acute and Chronic Aquatic Invertebrate Risk Quotients

Use Pattern	Peak EEC, µg cation/L[1]	Risk Quotient				
		Freshwater		Estuarine/Marine		
		Acute	Chronic	Acute (Crustaceans)	Acute (Mollusks)	Chronic
		LC_{50} = 1300 µg cation/L	NOAEC = 97 µg cation/L	LC_{50} = 228 µg cation/L	LC_{50} = 22,500 µg cation/L	NOAEC = 38 µg cation/L
Almond and Clover, 1.5 lb cation/A - Aerial	10.5	<0.01	Chronic RQs could not be calculated; however if the chronic endpoint is screened against the acute EECs, the ratio is <1 (0.04-0.11) for all use patterns.	0.046	<0.01	Chronic RQs could not be calculated; however if the chronic endpoint is screened against the acute EECs, the ratio is <1 (0.09-0.28) for all use patterns.
- Ground	5.2	<0.01		0.023	<0.01	
Multiple Uses – Highest Rate, 1.10 lb cation/A - Aerial	7.1	<0.01		0.031	<0.01	
- Ground	3.5	<0.01		0.015	<0.01	
Multiple Uses – Lower Rate, 0.5 lb cation/A - Aerial	3.5	<0.01		0.015	<0.01	
- Ground	1.7	<0.01		<0.01	<0.01	

A lack of **Bolded** values shows that no RQs exceed the LOC for acute risk to non-listed species of 0.5 or the chronic risk LOC of 1.0. The endpoints listed in the table are the endpoint used to calculate the RQ.
[1] The EECs used to calculate these RQs are based on the peak values from **Table 8-3**; for this assessment, these values are also used to screen for chronic risk; see explanation in **Section 8.1.1**.

As described in **Section 8.1.1**, paraquat's strong tendency to adsorb to components of sediment does not fit some of the assumptions usually made for aquatic exposure estimates, necessitating adjustments to the usual calculation of 24-hour and 21-day EECs. Because paraquat is assumed here to increase steadily over time, the acute and 21-day EECs are similar and are represented together as a 21-day estimate; the longer-term estimate is a 30-year estimate (**Table 8-9**) based on 1.01 lb cation/A applications (note that for uses with 1.5 lb cation/A, the exposure and risk estimates would be 50% higher). Due to the non-standard timeframes, actual RQs were not calculated for sediment, but screenings were conducted by calculating the ratios of exposure estimates with sediment toxicity endpoints.

Table 8-9. Aquatic Benthic Invertebrate Risk Quotients for Non-listed Species based on a 1.0 lbs ai/A Application Rate

Use Site	EEC			EEC:Toxicity Ratios Based on Sub-Chronic Toxicity (10-Day Study-Exposure to Dosed Sediment)				
	Bulk Sediment, µg cation/kg-DW[1]		Pore Water Estimate, µg cation/L[2]	Freshwater				Estuarine /Marine
				Crustacean (*Hyalella*)		Insect (*Chironomus*)		Crustacean (*Leptocheirus*)
				NOAEC = 30,000 µg cation/kg-DW[3]		NOAEC = 90,000 µg cation /kg-DW[3]	Pore W. NOAEC = 210 µg cation/ L[4]	NOAEC = 99,000 µg cation/kg-DW[3]
	21-day	30-year	30-year	21-day	30-year			
MS Cotton Aerial - Without Burial	<10,000	150,000	150	<0.5	**5.0**	**1.7**	0.71	**1.5**
- With Burial	<10,000	7,180	7.18	<0.5	0.2	0.08	0.03	0.07
FL Turf Ground - Without Burial	<10,000	46,300	46.3	<0.5	**1.5**	0.51	0.22	0.47
- With Burial	<10,000	46,300	46.3	<0.5	**1.5**	0.51	0.22	0.47

Bolded values show ratios where risk cannot be precluded because the ratios exceed the LOC for acute risk to non-listed species of 0.5 or the chronic risk LOC of 1.0. The endpoints listed in the table are the endpoint used to calculate the ratio.

[1] The bulk sediment EECs are based on chemical-specific assumptions described in **Section 8.1.1**. The acute (short-term) EEC is based on visual inspection of **Figure 8-2** which shows that the sediment concentration does not reach 10 mg/kg during the first two years. The 30-year estimate is from **Table 8-5**.

[2] The sediment pore water EEC estimates are based on chemical-specific assumptions described in **Section 8.1.1** and presented in **Table 8-5**.

[3] Measured bulk sediment concentration.

[4] Measured pore-water concentration.

Although the pore water risk estimate using the midge data (**Table 8-9)** does not show LOC exceedances, screening using the lower *Hyalella* NOAEC pore water estimate of 60 µg cation/L does estimate risk concerns above the LOC for all scenarios except MS Cotton With Burial (see footnote to **Table 6-1** and notes for MRID 49577003 in **Appendix B**). The *Hyalalla* pore water screening estimate is in agreement with the *Hyalella* bulk sediment risk estimate. Pore water estimates are difficult to interpret due to paraquat's strong adsoption (**Sections** 5 and **7.1**).

Calculated risk to benthic organisms is heavily influenced by the length of time available for accumulation to occur, as well as the scenario used for modeling exposure. As described in **Section 8.1.1**, many uncertainties are acknowledged. Despite the uncertainties, using conservative assumptions showed that risk to benthic organisms was low from short-term sediment exposure (including a 21-day time-frame, usually used to designate chronic exposure). However, when paraquat is allowed to accumulate in the sediment over time (30-year exposure estimate), risk to benthic organisms may be a concern based on a 1.01 lb cation/A application rate and would be approximately 50% greater if based on 1.5 lb cation/A.

Although freshwater crustacea were more sensitive than freshwater insects or saltwater crustacea, all categories had LOC exceedances when based on the most conservative EEC estimate (MS Cotton without burial assumed).

Information from the open literature suggests that some crustacean species may be more sensitive than the invertebrate endpoints used here; **Appendix B** cites a study conducted with another daphnid (*Diaphanosoma excisum*, Leboulanger, *et. al.*, 2009, E112408; reference in **Appendix B**); however, due to insufficient information, the study results were not quantitatively useable to calculate risk. This endpoint was approximated at an LC_{50} of 40 µg cation/L if the reported concentration is assumed to be based on paraquat dichloride and is converted to cation (this is unconfirmed). This endpoint is a rough estimate of the LC_{50} based on 40-60% mortality at that treatment level, rather than a calculated value. If this endpoint were used to estimate risk, it would not change the risk conclusions; for example, if the highest peak EEC (10.5 µg cation/L) is divided by 40 µg cation/L, the ratio is 0.26, which is below the 0.5 level of concern for non-listed species.

Based on the available data, the risk to aquatic invertebrates from the use of paraquat is expected to be low from water column exposure, but potentially of concern over time from sediment exposure due to paraquat's persistence when adsorbed to sediment. The potential for epibenthic and infaunal detritivores that ingest sediment to be exposed to toxic amounts of paraquat would depend largely on their ability to desorb paraquat from ingested sediment in the gut. This potential is not quantifiable. However, long-term paraquat accumulation in the sediment may reach amounts sufficient to cause reduced survival for benthic invertebrates. Additionally, the sediment may be resuspended causing lotic, as well as benthic organisms to be exposed. As shown in **Figure 8-4**, the Mississippi Cotton scenario suggests that, without sediment burial, in approximately 15 years sufficient accumulation could be present in amounts that caused 84% mortality to the amphipod (*Hyalella* azteca) in a laboratory study. Relevant amounts of accumulation may take years to occur, but could potentially place benthic organisms at risk.

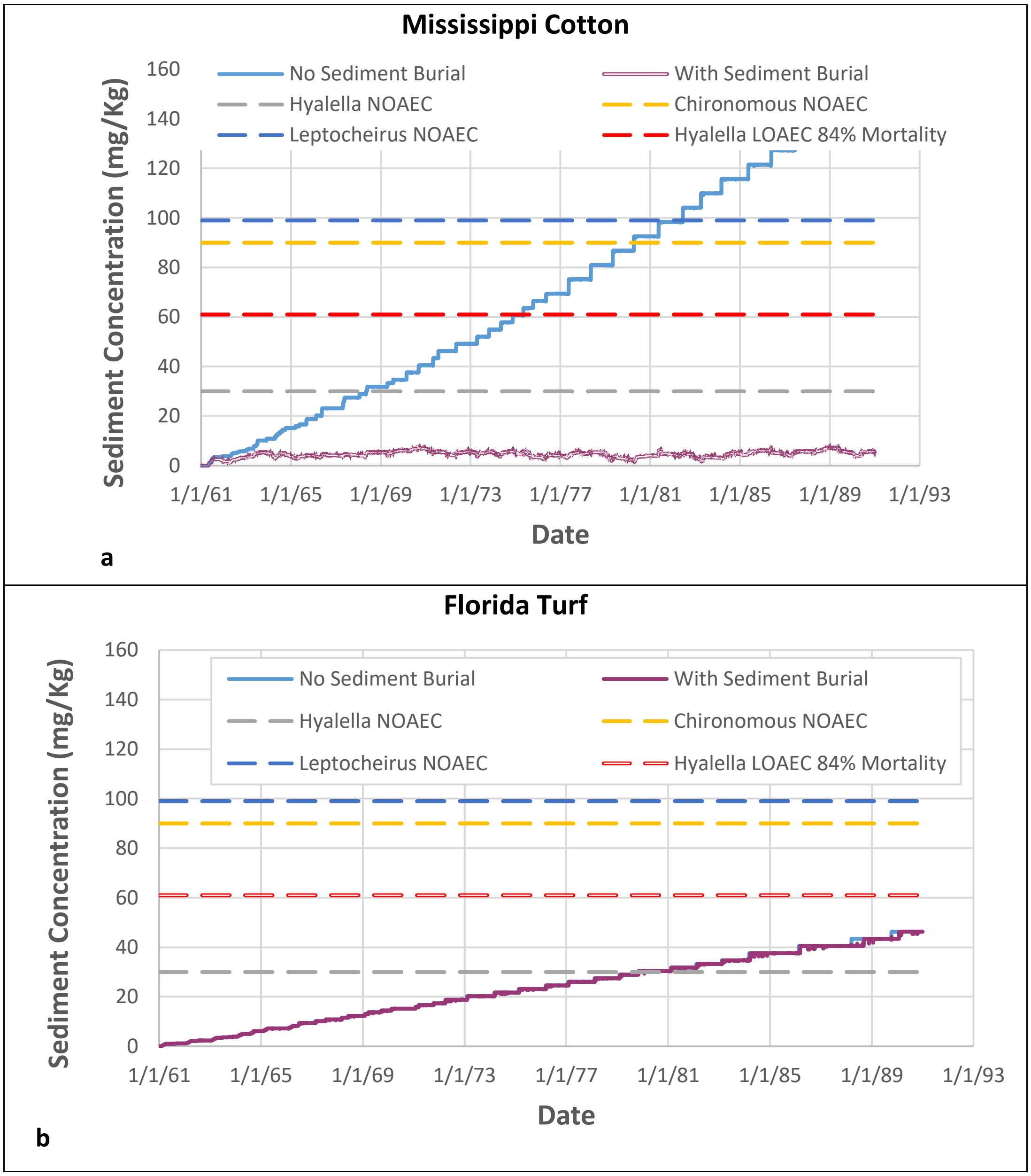


Figure 8-4. Comparison of Sediments Estimated Environmental Concentrations to Chronic Effects Endpoints for Two Scenarios with and without Sediment Burial Implemented based on a 1.0 lbs ai/A Application Rate

8.2.3 Aquatic Plants

Risk estimates showed LOC exceedances (RQs of 4-26) to non-vascular aquatic plants (algae) from all registered uses of paraquat and all application rates. Vascular plants were less sensitive and had no LOC exceedances.

Table 8-10. Aquatic Plant Risk Quotients for Non-Listed Species

Use Sites	Application Method	Peak EEC µg/L	Risk Quotients	
			Vascular	Non-vascular
			IC_{50} = 71 µg cation/L	IC_{50} = 0.40 µg cation/L
Alfalfa and Clover, 1.5 lb cation/A	Aerial	10.5	0.15	**26**
	Ground	5.2	0.07	**13**
Multiple Uses, Higher Application Rate, 1.01 lb cation/A	Aerial	7.1	0.10	**18**
	Ground	3.5	0.05	**8.8**
Multiple Uses, Lower Application Rate, 0.5 lb cation/A	Aerial	3.5	0.05	**8.8**
	Ground	1.7	0.02	**4.3**

Bolded values exceed the LOC for non-listed plants of 1. The endpoints listed in the table are the endpoint used to calculate the RQ.

The low RQs for aquatic vascular plants are somewhat surprising, given that *Lemna* has been studied for use in bioassays for determining the presence of paraquat (Funderburk and Lawrence, 1963, and Kamanakis, 1970), with growth expressed as dry weight of *Lemna*, as a consistent indicator of paraquat.

Further investigation shows that when *Lemna* toxicity endpoints (EC_{50} of 71 µg cation/L; MRID 42601003) are compared with a range of algal toxicity endpoints (ranging from *Navicula* EC_{50} of 0.40 µg cation/L to *Chlorococcum* EC_{50} of 36,000 µg cation/L, MRIDs 42601006 and 40228401), *Lemna* is among the more sensitive aquatic plant species, with two of eight algal species tested having a more sensitive EC_{50} than *Lemna*, the others less sensitive.

The weight of evidence shows that aquatic plants can be affected by paraquat exposure, but the amount of bioavailable paraquat to which they are exposed is difficult to predict. As previously discussed, paraquat's strong adsorption to particles or sediment, likely reduces its bioavailability to aquatic plants. Conversely, paraquat has been reportedly used for aquatic weed control, although this use is not registered in the U.S. (Ogamba, *et al.*, 2011; Zaranyika and Nyoni, 2013). Potential effects likely depend on spray drift, rather than runoff, as discussed earlier for all aquatic exposure. The presence of dissolved or particulate matter may also influence the amount of paraquat that reaches aquatic plant tissue.

Therefore, based on the available data, risk to aquatic plants is expected from the use of paraquat.

9 Terrestrial Vertebrates Risk Assessment

9.1 Terrestrial Vertebrate Exposure Assessment

Terrestrial wildlife exposure estimates are typically calculated for birds and mammals by emphasizing the dietary exposure pathway. Paraquat is applied through aerial and ground application methods, which includes banded and broadcast sprayers, spot-treatment sprays and a tree wound treatment. No seed treatments or granular products are currently registered, and so dietary exposure does not include calculations for treated seeds or granules. Additionally, due to low bioaccumulation potential (see footnotes to **Table 7-1**), dietary exposure does not include calculations for consumption of aquatic organisms. Therefore, potential dietary exposure for terrestrial wildlife in this assessment is based on consumption of paraquat residues on food items following spray (foliar or soil) applications.

9.1.1 Dietary Items on the Treated Field

Potential dietary exposure for terrestrial wildlife in this assessment is based on consumption of paraquat residues on food items following spray (foliar or soil) applications. EECs for birds (also used as a proxy for reptiles and terrestrial-phase amphibians) and mammals from consumption of dietary items on the treated field were calculated using T-REX v.1.5.2 and based on application rates, number of applications, and intervals presented in **Table 3-1**. The default foliar dissipation half-life of 35 days was used here in the absence of chemical-specific foliar dissipation data, and given paraquat's stability, without information showing that at least three foliar dissipation half-lives are greater than 35 days (so that a longer half-life could be used in the calculations), the 35-day default is used here, but some uncertainty is acknowledged (per TREX user guide, USEPA, 2012c). However, because a single application triggered risk concerns for both birds and mammals, additional information would not likely change the risk conclusions.

Upper-bound Kenaga nomogram values are used to derive EECs for paraquat exposures to terrestrial mammals and birds on the field of application based on a 1-year time period, and also for a single application at the lower (0.50 lb cation/A) and higher (1.01 lb cation/A) application rates common for most uses. Consideration is given to different types of feeding strategies for mammals, including herbivores, insectivores and granivores. Dose-based exposures are estimated for three weight classes of birds (20 g, 100 g, and 1,000 g) and three weight classes of mammals (15 g, 35 g, and 1,000 g). EECs on terrestrial food items range from 8 to 242 mg cation/kg-diet for a single application and from 25 to 1620 mg cation/kg-diet for the maximum number of applications, based on upper bound Kenaga values. Dose-based EECs, adjusted for body weight, range from 0.5 to 1840 mg cation/kg-bw for birds and 0.3 to 1540 mg cation/kg-bw for mammals. A summary of EECs is found in **Table 9-1** (also see **Appendix D**).

Table 9-1. Summary of Dietary (mg a.i./kg-diet) and Dose-Based EECs (mg a.i./kg-bw) as Food Residues for Birds, Reptiles, Terrestrial-Phase Amphibians and Mammals from Labeled Uses of Paraquat (T-REX v. 1.5.2, Upper Bound Kenaga)

Food Type	Dietary-Based EEC (mg cation/kg-diet)	Dose-Based EEC (mg cation/kg-body weight)					
		Birds			Mammals		
		Small (20 g)	Medium (100 g)	Large (1000 g)	Small (15 g)	Medium (35 g)	Large (1000 g)
Alfalfa and Clover (1.5 lb cation/acre, 1x per crop cycle, interval not specified; modeled 3x annually with 120-day interval)[1]							
Short grass	397	452	258	115	378	261	60.6
Tall grass	182	207	118	52.9	173	120	27.8
Broadleaf plants/small insects	223	254	145	64.9	213	147	34.1
Fruits/pods/(seeds, dietary only)	24.8	28.2	16.1	7.21	23.6	16.3	3.79
Arthropods	155	177	101	45.2	148	102	23.7
Seeds (granivore)	24.8	6.27	3.58	1.60	5.25	3.63	0.84
Premises/Areas (1.01 lb cation/A, 10x, 7-day interval)[2]							
Short grass	1400	1600	912	408	1340	925	215
Tall grass	644	733	418	187	614	424	98.3
Broadleaf plants/small insects	790	900	513	230	753	521	121
Fruits/pods/(seeds, dietary only)	87.8	100	57.0	25.5	83.7	57.8	13.4
Arthropods	550	626	357	160	524	362	84.0
Seeds (granivore)	87.8	22.2	12.7	5.67	18.6	12.9	2.98
Multiple Ag and Non-Ag Uses (1.01 lb cation/A, 5x, 7-day interval)[3]							
Short grass	936	1070	608	272	893	617	143
Tall grass	429	489	279	125	409	283	65.6
Broadleaf plants/small insects	527	600	342	153	502	347	80.5
Fruits/pods/(seeds, dietary only)	58.5	66.7	38.0	17.0	55.8	38.6	8.94
Arthropods	367	418	238	107	350	242	56.0
Seeds (granivore)	58.5	14.8	8.45	3.78	12.4	8.57	1.99
Single App. Most Common Rate (1.01 lb cation/A)							
Short grass	242	276	157	70.5	231	160	37.0
Tall grass	111	127	72.2	32.3	106	73.2	17.0
Broadleaf plants/small insects	136	155	88.6	39.7	130	89.9	20.8
Fruits/pods/(seeds, dietary only)	15.2	17.3	9.84	4.41	14.4	9.98	2.31
Arthropods	94.9	108	61.7	27.6	90.5	62.6	14.5
Seeds (granivore)	15.2	3.83	2.19	0.98	3.21	2.22	0.51

Food Type	Dietary-Based EEC (mg cation/kg-diet)	Dose-Based EEC (mg cation/kg-body weight)					
		Birds			Mammals		
		Small (20 g)	Medium (100 g)	Large (1000 g)	Small (15 g)	Medium (35 g)	Large (1000 g)
Single App. Lowest Rate (0.50 lb cation/A)[4]							
Short grass	120	137	77.9	34.9	114	79.1	18.3
Tall grass	55.0	62.6	35.7	16.0	52.4	36.2	8.40
Broadleaf plants/small insects	67.5	76.9	43.8	19.6	64.4	44.5	10.3
Fruits/pods/(seeds, dietary only)	7.50	8.54	4.87	2.18	7.15	4.94	1.15
Arthropods	47.0	53.5	30.5	13.7	44.8	31.0	7.18
Seeds (granivore)	7.50	1.90	1.08	0.48	1.59	1.10	0.25

[1]Alfalfa has a 1.5 lb a.e./acre max with 1 app. per crop cycle, and specifies 3 applications per year, but also has a 2 lb a.e./acre annual max, so although this screening for alfalfa and clover is represented here using 3 apps, the annual amount is over-estimated for alfalfa. The clover use does not currently specify the annual number of applications or the annual maximum amount.

[2]Premises/Areas included outdoor occupational, manufacturing, processing or industrial areas using a ground sprayer. These did not specify the intervals or any type of seasonal limits so a 7-day application interval was conservatively assumed. They specify a max. single app. rate of 1.01 lb a.e./A and a max. of 10 apps annually.

[3]Many agricultural and forestry uses have a maximum single app. rate of 1.01 lb a.e./A and specify either 1, 2, 3, 4, or 5 apps annually—5 apps are used here for screening, with the exception that a single app. is also modeled. Like the premises/areas use, these uses did not specify the intervals or any type of seasonal limits so a 7-day interval was assumed (based on recommendations from BEAD). Uses with a max. of 5 apps include: acerola, almond, apple, avocado, banana, bushberries, caneberries, citrus, cocoa, coffee, figs, grapes, papaya, passion fruit, pear, persimmon, pistachio, prune, tree nuts, and various non-food trees.

[4] The 0.5 lb cation/A application rate applies to beans, guar, hops, lentils, peas, strawberries, tuberous and corm vegetables and pastureland/rangeland uses. One use, for macadamia nuts, actually has a slightly lower application rate (0.475 lb cation/A), but this was not modeled.

9.2 Terrestrial Vertebrate Risk Characterization

RQ values are generated based on the upper bound EECs discussed above and toxicity values contained in **Table 6-2**.

For acute dose-based exposure for birds and mammals, RQ values range from 0.01 to 57 (**Table 9-2** and **Table 9-3,** also see **Appendix D**). For birds, RQs exceed the LOC for most feeding groups of non-listed birds for all uses, with the exception that for granivores, only the smallest size class have LOC exceedances, and only with multiple applications with a 7-day re-application interval. For mammals, acute RQs exceed the LOC for groups of non-listed mammals feeding on grasses, broadleaf plants and arthropods for all uses. Considering specifically a single application at the most common maximum application rate for most agricultural and non-agricultural uses (1.01 lb cation/A), most feeding groups of birds have exceedances, but only mammals feeding on grasses and broadleaf plants exceed the LOC. For the lower single application rate of 0.5 lb cation/A, only birds feeding on grasses, broadleaf plants, and arthropods had exceedances, and only the smallest size class of mammals feeding on short grasses had exceedances.

For acute dietary-based exposures for birds, RQs range from 0.01 to 2.0 (**Table 9-2**) based on upper bound values. For all uses, birds feeding on short grass had exceedances; for multiple applications modeled using a 7-day re-application interval (premises/areas and multiple agricultural and non-agricultural uses), birds feeding on grasses, broadleaf plants, and arthropods also had LOC exceedances.

For chronic exposures for birds, dietary based RQs (**Table 9-2**) were based on significant ($p<0.05$) reductions in reproduction and food consumption (mallard reductions of 59.0 % in eggs laid, 24.7% in viable embryos/egg set, 33.1% in live embryos/egg set, and 8.5% in mean food consumption, MRID 00110455). RQs ranging from 0.26 to 48 based on upper bound values exceed the LOC in all feeding groups and for all uses, except that no exceedances were found for granivores and fruits/pods/seeds consumers with a single application, or for granivores with the longer (120-day) re-application interval (applying to alfalfa and clover).

For chronic exposures for mammals, dietary-based RQs (**Table 9-4)** were based on no measurable effects in rat reproductive or offspring body weight at the highest treatment level tested (7.5 mg cation/kg-bw, 108 kg cation/kg-diet, MRID 43685001). RQs ranged from 0.04 to 81 and show that RQs do not exceed the LOC from a single application for granivores (all uses except premises/areas use and smallest size class), and fruit/pod/seed consumers. For bolded values, these show that risk cannot be precluded for all size classes feeding on grasses, broadleaf plants and arthropods, from both dose-based and most dietary-based estimates.

Table 9-2. Acute and Chronic RQs for Birds, Reptiles, and Terrestrial-Phase Amphibians from Labeled Uses of Paraquat (T-REX v. 1.5.2, Upper Bound Kenaga)

Food Type	Acute Dose-Based RQ LD_{50} = 26.5 mg cation/kg-bw			Acute Dietary-Based RQ LC_{50} = 698 mg cation/kg-diet	Chronic Dietary RQ NOAEC = 29.4 mg cation/kg-diet
	Small (20 g)	Medium (100 g)	Large (1000 g)		
Alfalfa and Clover (1.5 lb cation/acre, 3x, 120-day interval)[1]					
Herbivores/Insectivores					
Short grass	**16.2**	**7.26**	**2.30**	**0.57**	**13.5**
Tall grass	**7.43**	**3.33**	**1.05**	0.26	**6.18**
Broadleaf plants	**9.12**	**4.08**	**1.29**	0.32	**7.59**
Fruits/pods	**1.01**	0.45	0.14	0.04	**0.84**
Arthropods	**6.35**	**2.84**	**0.90**	0.22	**5.28**
Granivores					
Seeds	0.23	0.10	0.03	0.04	0.84
Premises/Areas (1.01 lb cation/A, 10x, 7-day interval)					
Herbivores/Insectivores					
Short grass	**57.4**	**25.7**	**8.15**	**2.01**	**47.8**
Tall grass	**26.3**	**11.8**	**3.73**	**0.92**	**21.9**
Broadleaf plants	**32.3**	**14.5**	**4.58**	**1.13**	**26.9**
Fruits/pods/seeds	**3.59**	**1.61**	**0.51**	0.13	**2.99**
Arthropods	**22.5**	**10.1**	**3.19**	**0.79**	**18.7**
Granivores					
Seeds	**0.80**	0.36	0.11	0.13	**2.99**
Multiple Ag and Non-Ag Uses (1.01 lb cation/A, 5x, 7-day interval)					
Herbivores/Insectivores					
Short grass	**38.3**	**17.1**	**5.43**	**1.34**	**31.9**
Tall grass	**17.5**	**7.86**	**2.49**	**0.61**	**14.6**
Broadleaf plants	**21.5**	**9.64**	**3.06**	**0.75**	**17.9**
Fruits/pods/seeds	**2.39**	**1.07**	0.34	0.08	**1.99**
Arthropods	**15.0**	**6.71**	**2.13**	**0.53**	**12.5**
Granivores					
Seeds	**0.53**	0.24	0.08	0.08	**1.99**
Single App. (1.01 lb cation/A)					
Herbivores/Insectivores					
Short grass	**9.91**	**4.44**	**1.41**	0.35	**8.24**
Tall grass	**4.54**	**2.03**	**0.64**	0.16	**3.78**
Broadleaf plants	**5.57**	**2.50**	**0.79**	0.20	**4.64**
Fruits/pods/seeds	**0.62**	0.28	0.09	0.02	0.52
Arthropods	**3.88**	**1.74**	**0.55**	0.14	**3.23**
Granivores					
Seeds	0.14	0.06	0.02	0.02	0.52
Single App. Lower Rate (0.50 lb cation/A)					
Herbivores/Insectivores					
Short grass	**4.90**	**2.20**	**0.70**	0.17	**4.08**
Tall grass	**2.25**	**1.01**	0.32	0.08	**1.87**

Food Type	Acute Dose-Based RQ LD_{50} = 26.5 mg cation/kg-bw			Acute Dietary-Based RQ LC_{50} = 698 mg cation/kg-diet	Chronic Dietary RQ NOAEC = 29.4 mg cation/kg-diet
	Small (20 g)	Medium (100 g)	Large (1000 g)		
Broadleaf plants	**2.76**	**1.24**	0.39	0.10	**2.30**
Fruits/pods/seeds	0.31	0.14	0.04	0.01	0.26
Arthropods	**1.92**	**0.86**	0.27	0.07	**1.60**
Granivores					
Seeds	0.07	0.03	0.01	0.01	0.26

Bolded values exceed the LOC for acute risk to non-listed species of 0.5 or the chronic risk LOC of 1.0. The endpoints listed in the table are the endpoint used to calculate the RQ.
Toxicity endpoints used in RQ calculations: Zebra Finch LD_{50} (MRID 49349901, bird weight of 14.3g used in T-REX); Japanese Quail LC_{50} (MRID 00022923, bird weight of 43g used in T-REX) and Mallard Duck NOAEC (MRID 00110455) based on significant ($p<0.05$) reductions in reproduction and food consumption (59.0 % in eggs laid, 24.7% in viable embryos/egg set, 33.1% in live embryos/egg set, and 8.5% in mean food consumption).
[1]Alfalfa has a 1.5 lb a.e./A max with 1 app. per crop cycle, and specifies 3 apps per year, but also has a 2 lb a.e./A annual max, so although this screening for alfalfa and clover is represented here using 3 apps, the ann. amount is over-estimated for alfalfa. The clover use does not currently specify the ann. no. of apps or the ann. max. amount.

Table 9-3. Acute RQs for Mammals from Labeled Uses of Paraquat (T-REX v. 1.5.2, Upper Bound Kenaga)

Food Type	Acute Dose-Based RQ LD_{50} = 93 mg cation/kg-bw			Acute Dietary-Based RQ Data Unavailable
	Small (15 g)	Medium (35 g)	Large (1000 g)	
Alfalfa and Clover (1.5 lb cation/acre, 3x, 120-day interval)[1]				
Herbivores/Insectivores				
Short grass	**1.85**	**1.58**	**0.85**	--
Tall grass	**0.85**	**0.72**	0.39	--
Broadleaf plants	**1.04**	**0.89**	0.48	--
Fruits/pods/seeds	0.12	0.10	0.05	--
Arthropods	**0.72**	**0.62**	0.33	--
Granivores				
Seeds	0.03	0.02	0.01	--
Premises/Areas (1.01 lb cation/A, 10x, 7-day interval)				
Herbivores/Insectivores				
Short grass	**6.55**	**5.60**	**3.00**	--
Tall grass	**3.00**	**2.56**	**1.37**	--
Broadleaf plants	**3.68**	**3.15**	**1.69**	--
Fruits/pods/seeds	**0.41**	0.35	0.19	--
Arthropods	**2.57**	**2.19**	**1.17**	--
Granivores				
Seeds	0.09	0.08	0.04	--
Multiple Ag and Non-Ag Uses (1.01 lb cation/A, 5x, 7-day interval)				
Herbivores/Insectivores				
Short grass	**4.37**	**3.73**	**2.00**	--
Tall grass	**2.00**	**1.71**	**0.92**	--
Broadleaf plants	**2.46**	**2.10**	**1.12**	--
Fruits/pods/seeds	0.27	0.23	0.12	--

Food Type	Acute Dose-Based RQ LD_{50} = 93 mg cation/kg-bw			Acute Dietary-Based RQ Data Unavailable
	Small (15 g)	Medium (35 g)	Large (1000 g)	
Arthropods	**1.71**	**1.46**	**0.78**	--
Granivores				
Seeds	0.06	0.05	0.03	--
Single App. (1.01 lb cation/A)				
Herbivores/Insectivores				
Short grass	**1.13**	**0.97**	**0.52**	--
Tall grass	**0.52**	0.44	0.24	--
Broadleaf plants	**0.64**	**0.54**	0.29	--
Fruits/pods/seeds	0.07	0.06	0.03	--
Arthropods	0.44	0.38	0.20	--
Granivores				
Seeds	0.02	0.01	0.01	--
Single App. Lower Rate (0.50 lb cation/A)				
Herbivores/Insectivores				
Short grass	**0.56**	0.48	0.26	--
Tall grass	0.26	0.22	0.12	--
Broadleaf plants	0.31	0.27	0.14	--
Fruits/pods/seeds	0.03	0.03	0.02	--
Arthropods	0.22	0.19	0.10	--
Granivores				
Seeds	0.01	0.01	<0.01	--

Bolded values exceed the LOC for acute risk to non-listed species of 0.5. The endpoints listed in the table are the endpoint used to calculate the RQ.

Toxicity endpoint used in RQ calculations: Rat LD_{50} (MRID 43685001).

[1]Alfalfa has a 1.5 lb a.e./A max with 1 app. per crop cycle, and specifies 3 apps per year, but also has a 2 lb a.e./A annual max, so although this screening for alfalfa and clover is represented here using 3 apps, the ann. amount is over-estimated for alfalfa. The clover use does not currently specify the ann. no. of apps or the ann. max. amount.

Table 9-4. Chronic RQs for Mammals from Labeled Uses of Paraquat (T-REX v. 1.5.2, Upper Bound Kenaga)

Food Type	RQs Based on Multi-Gen. Rat Study				Additional Line-of-Evidence Exposure:Effect Ratios (RQ Estimates) Based on Pre-Natal Data NOAEL = 1 mg cation/kg-bw[1]		
	Chronic Dose-Based RQ NOAEL = 7.5 mg cation/kg-bw[1]			Chronic Dietary RQ NOAEC = 108 mg cation/kg-diet[1]			
	Small (15 g)	Medium (35 g)	Large (1000 g)		Small (15 g)	Medium (35 g)	Large (1000 g)
Alfalfa and Clover (1.5 lb cation/acre, 3x, 120-day interval)[2]							
Herbivores/Insectivores							
Short grass	**22.9**	**19.6**	**10.5**	**3.67**	**172**	**147**	**78.8**
Tall grass	**10.5**	**8.98**	**4.81**	**1.68**	**78.8**	**67.4**	**36.1**
Broadleaf plants	**12.9**	**11.0**	**5.91**	**2.07**	**96.8**	**82.7**	**44.3**
Fruits/pods/seeds	**1.43**	**1.22**	0.66	0.23	**10.8**	**9.18**	**4.92**
Arthropods	**8.98**	**7.67**	**4.11**	**1.44**	**67.4**	**57.6**	**30.9**
Granivores							
Seeds	0.32	0.27	0.15	0.23	**2.39**	**2.04**	**1.09**
Premises/Areas (1.01 lb cation/A, 10x, 7-day interval)							
Herbivores/Insectivores							
Short grass	**81.2**	**69.4**	**37.2**	**13.0**	**609**	**520**	**279**
Tall grass	**37.2**	**31.8**	**17.1**	**5.96**	**279**	**239**	**128**
Broadleaf plants	**45.7**	**39.0**	**20.9**	**7.31**	**343**	**293**	**157**
Fruits/pods/seeds	**5.08**	**4.34**	**2.32**	0.81	**38.1**	**32.5**	**17.4**
Arthropods	**31.8**	**27.2**	**14.6**	**5.09**	**239**	**204**	**109**
Granivores							
Seeds	**1.13**	0.96	0.52	0.81	**8.46**	**7.23**	**3.87**
Multiple Ag and Non-Ag Uses (1.01 lb cation/A, 5x, 7-day interval)							
Herbivores/Insectivores							
Short grass	**54.2**	**46.3**	**24.8**	**8.67**	**406**	**347**	**186**
Tall grass	**24.8**	**21.2**	**11.4**	**3.97**	**186**	**159**	**85.2**
Broadleaf plants	**30.5**	**26.0**	**14.0**	**4.88**	**228**	**195**	**105**
Fruits/pods/seeds	**3.38**	**2.89**	**1.55**	0.54	**25.4**	**21.7**	**11.6**
Arthropods	**21.2**	**18.1**	**9.71**	**3.40**	**159**	**136**	**72.8**
Granivores							
Seeds	0.75	0.64	0.34	0.54	**5.64**	**4.82**	**2.58**
Single App. (1.01 lb cation/A)							
Herbivores/Insectivores							
Short grass	**14.0**	**12.0**	**6.42**	**2.24**	**105**	**89.8**	**48.2**
Tall grass	**6.43**	**5.49**	**2.94**	**1.03**	**48.2**	**41.2**	**22.1**
Broadleaf plants	**7.89**	**6.74**	**3.61**	**1.26**	**59.2**	**50.5**	**27.1**
Fruits/pods/seeds	0.88	0.75	0.40	0.14	**6.57**	**5.61**	**3.01**
Arthropods	**5.49**	**4.69**	**2.51**	0.88	**41.2**	**35.2**	**18.9**
Granivores							
Seeds	0.19	0.17	0.09	0.14	**1.46**	**1.25**	0.67

Single App. Lower Rate (0.50 lb cation/A)							
Herbivores/Insectivores							
Short grass	**6.94**	**5.93**	**3.18**	**1.11**	**18.4**	**15.8**	**8.44**
Tall grass	**3.18**	**2.72**	**1.46**	0.51	**7.81**	**6.67**	**3.58**
Broadleaf plants	**3.90**	**3.33**	**1.79**	0.63	**9.76**	**8.34**	**4.47**
Fruits/pods/seeds	0.43	0.37	0.20	0.07	**1.52**	**1.30**	0.70
Arthropods	**2.72**	**2.32**	**1.24**	0.44	**14.1**	**12.0**	**6.46**
Granivores							
Seeds	0.10	0.08	0.04	0.07	0.34	0.29	0.15

Bolded values exceed the chronic risk LOC of 1.0. The endpoints listed in the table are the endpoint used to calculate the RQ.
[1]The toxicity endpoint used in RQ calculations, Rat LD_{50} (MRID 43685001), had no measurable effects in reproductive or offspring body weight at the highest treatment level of 7.5 mg cation/kg-bw (108 mg cation/kg-diet). Due to the non-definitive LOAEC.and additional line-of-evidence was added by estimating risk using a growth endpoint from a prenatal developmental study.
[2]Alfalfa has a 1.5 lb a.e./A max with 1 app. per crop cycle, and specifies 3 apps per year, but also has a 2 lb a.e./A annual max, so although this screening for alfalfa and clover is represented here using 3 apps, the ann. amount is over-estimated for alfalfa. The clover use does not currently specify the ann. no. of apps or the ann. max. amount.

In characterizing terrestrial vertebrate risk, consideration is given here to available options, chiefly the effect on risk conclusions if mean Kenaga residues are considered, rather than upper Kenaga residues, and if avian LOAEC, rather than NOAEC, is considered.

For mammals, dietary based RQs (**Table 9-4)** were based on no measurable effects in rat reproductive or offspring weight at the highest treatment level tested (as mentioned above). This was approximately the same dietary level that caused chronic effects to reproduction and food consumption in birds (108 kg cation/kg-diet for rats vs. 101 mg cation/kg-diet for birds, MRIDs 43685001 and 00110455). Many of the chronic RQs calculated here are above 1 because the highest dose tested was below the highest predicted exposure level. The RQs can definitively show cases where risk does not exceed the LOC; this mainly applies to granivores, but also to fruit/pod/seed consumers from a single application. The LOC exceedances show where risk cannot be precluded but do not confirm risk; this applies to all size classes feeding on grasses, broadleaf plants and arthropods, from both dose-based and most dietary-based estimates. Therefore, the specific chronic-exposure risk to mammals from the use of paraquat is uncertain.

For mammals, use of mean, rather than upper bound Kenaga only produced LOC exceedances for chronic dose-based risk and because the chronic study was non-definitive, the results are not presented here, but the information can be found in **Appendix D**. However, using the mean Kenega exposure estimates with the rat prenatal growth endpoint, the lowest single application rate (0.5 lb cation/A) had LOC exceedances for all feeding groups except granivores (RQs ranged from 0.15 to 18). Further analyses may be done at the request of risk managers if deemed to be helpful.

The bird data is more conducive to this type of characterization. If risk calculations are based on mean Kenaga, rather than upper Kenaga, a single application at the lowest application rate of 0.50 lb cation/A will still cause LOC (0.5) exceedances for small and medium birds feeding on short grass and small birds feeding on tall grass, broadleaf plants and arthropods from dose-based toxicity data. From dietary-based toxicity data, the lowest application rate does not cause acute LOC exceedances, but does cause chronic LOC (1) exceedances for birds feeding on short grass and arthropods (**Table 9-5**, also see **Appendix D** for the output showing EECs and additional information). Therefore, even using the lowest single application rate and mean, rather than upper, Kenaga exposure estimates, acute risk is still identified for some feeding groups of small and medium birds, and possibly chronic risk for all sizes.

Table 9-5. Acute and Chronic RQs for Birds, Reptiles, and Terrestrial-Phase Amphibians from Lowest Single Application of Paraquat Using Mean Kenaga Values

Food Type	Acute Dose-Based RQ LD_{50} = 26.5 mg cation/kg-bw			Acute Dietary-Based RQ LC_{50} = 698 mg cation/kg-diet	Chronic Dietary RQ NOAEC = 29.4 mg cation/kg-diet
	Small (20 g)	Medium (100 g)	Large (1000 g)		
Single App. Lower Rate (0.50 lb cation/A)					
Herbivores/Insectivores					
Short grass	**1.74**	**0.78**	0.25	0.06	**1.45**
Tall grass	**0.74**	0.33	0.10	0.03	0.61
Broadleaf plants	**0.92**	0.41	0.13	0.03	0.77
Fruits/pods	0.14	0.06	0.02	0.01	0.12
Arthropods	**1.33**	**0.59**	0.19	0.05	**1.11**
Granivores					
Seeds	0.03	0.01	<0.01	0.01	0.12

Bolded values exceed the LOC for acute risk to non-listed species of 0.5 or the chronic risk LOC of 1.0. The endpoints listed in the table are the endpoint used to calculate the RQ.
Toxicity endpoints used in RQ calculations: Zebra Finch LD_{50} (MRID 49349901); Japanese Quail LC_{50} (MRID 00022923) and Mallard Duck NOAEC (MRID 00110455).

For birds, the chronic study was definitive and so, the mallard LOAEC could be used to further characterize risk from paraquat use. For mammals, this comparison was not made here because the chronic study was non-definitive. The mallard LOAEC (see **Table 6-2**) was based on significant ($p<0.05$) reductions of 59.0 % in eggs laid, 24.7% in viable embryos/egg set, 33.1% in live embryos/egg set, and 8.5% in mean food consumption (MRID 00110455). This analysis shows that the estimated exposure (EECs) are at risk of exceeding the LOAEC by 2-14X for some feeding groups of birds, where effects would be expected to occur, from the highest multiple application rate (1.01 lb cation/A at 10 applications with 7-day intervals, **Table 9-6**). A single application at the highest and lowest rate (1.01 and 0.5 lb cation/A) would be expected to exceed the LOAEC for some feeding groups if upper Kenega values are considered, but not if only mean Kenaga values are considered.

Table 9-6. Chronic RQs for Birds from Highest Multiple and Highest and Lowest Single Application of Paraquat Based on Mallard LOAEC Using Both Upper and Mean Kenaga Values

Food Type	Chronic Dietary RQ based on Mallard LOAEC = 101 mg cation/kg-diet			
	Highest Multiple App. Rate (1.01 lb cation/A, 10x, 7-day interval))		Single App. Highest/Lowest Rates (1.01/0.50 lb cation/A)	
	Mean Kenaga EECs	Upper Kenaga EECs	Mean Kenaga EECs	Upper Kenaga EECs
Herbivores/Insectivores				
Short grass	**4.92**	**13.9**	0.85/0.42	**2.40/1.19**
Tall grass	**2.09**	**6.37**	0.36/0.18	**1.10**/0.54
Broadleaf plants	**2.61**	**7.82**	0.45/0.22	**1.35**/0.67
Fruits/pods	0.41	0.87	0.07/0.03	0.15/0.07
Arthropods	**3.77**	**5.45**	0.65/0.32	0.94/0.47
Granivores				
Seeds	0.41	0.87	0.07/0.03	0.15/0.07

Bolded values exceed the LOC for acute risk to non-listed species of 0.5 or the chronic risk LOC of 1.0. The endpoints listed in the table are the endpoint used to calculate the RQ.
Toxicity endpoints used in RQ calculations: Zebra Finch LD_{50} (MRID 49349901); Japanese Quail LC_{50} (MRID 00022923) and Mallard Duck NOAEC (MRID 00110455).

Although the above analysis shows that multiple applications of paraquat are likely to exceed the mallard LOAEC by up to 14X, some uncertainty is acknowledged over whether chronic risk would be likely due to rapid plant death. For animals feeding on living plants, rapid plant death from paraquat exposure may make plants unpalatable and so chronic exposure may be unlikely. This uncertainty is limited to plant-eaters and would not apply to consumers of fruits, grains, seeds, or arthropods.

For acute effects, however, the analysis described above strongly suggests that effects are likely to occur, in that even a single application at the lowest application rate (0.5 lb cation/A), and based on mean, rather than upper, Kenaga values, still exceeds the LOC for most feeding groups of small-sized birds and two feeding groups of medium-sized birds (**Table 9-5**).

In two non-guideline studies, a formulated product containing paraquat dichloride was sprayed onto the eggs of pheasant (MRID 43942605) and mallard ducks (MRID 43942604). In the pheasant study, a decrease in the number of eggs hatched and the number of 28-d old survivors was observed at 1.0 lb cation/A, resulting in a study NOAEC of 0.5 lb cation/A. In the mallard study, an application rate of 2.0 lb cation/A increased the number of embryonic deaths (at days 13 and 19) as well as the number of dead embryos in the shell at day 31. At this concentration, the number of hatchlings and number of chicks surviving to 28 d were also decreased. The resulting NOAEC was 1.0 lb cation/A. This suggests that application timing may be important in preventing reproduction effects to birds and other egg-laying animals, and likely also to live-bearing animals.

Incidents reviewed above in **Section 6.3**, suggest potential for harm to non-target terrestrial animals from exposure to paraquat. For birds, three bird-kill incidents were found in the database that actually occurred outside the U.S. (I021685-002, I021848-003, and I021848-004) and so cannot be attributed to registered use, but do support a line of evidence that paraquat can be toxic to birds. One domestic bird incident involving the deaths of five Canada geese (I008168-001) was from a registered use on corn and of probable causality, but also involved other pesticides; however, as previously mentioned, paraquat was considered to be the pesticide present in the tank mix at an amount representing the highest acute toxicity to birds. Another incident with a causality of probable for paraquat involved the deaths two unknown species (four individuals) of birds (I007344-001), but the legality of use was undetermined.

Similarly, incidents that were of undetermined legality involved mortality of dogs (I020627-033 and I027242-001; I027242-001 occurred outside of the U.S.) and cannot be attributed to registered use, but do support a line of evidence that paraquat can be toxic to mammals.

These incidents, along with multiple LOC exceedances for birds and mammals strongly support risk to terrestrial vertebrates. In some cases, however, the level of risk is uncertain due to either uncertainty in effects or exposure. The chief effects uncertainty is limited to mammalian chronic risk, as described above, where the highest dose tested in the rat reproduction study was below the highest predicted exposure level, and, therefore, the specific risk to mammals from the use of paraquat is uncertain. In the absence of data definitive LOAEC, where the RQ was greater than 1, risks to mammal species are assumed. The added value of obtaining a definitive LOAEC, however, would not greatly affect the risk conclusions even if many of the feeding groups dropped below the chronic LOC because acute LOCs were also exceeded for most feeding groups and registered use application rates.

There was uncertainty in the exposure estimates pertaining to repeated applications, partly because the labels did not specify a re-application interval for many labeled uses. As a result, a 7-day interval was conservatively assumed. Also, the foliar dissipation half-life for paraquat was uncertain. No foliar dissipation study was available for use and, due to the persistence of paraquat (years), the 35-day T-REX default half-life was used because theoretically, the food items on which paraquat would be present would not remain in the environment for the longevity of the chemical, or would be expected to be washed off by rain. EPA policy (USEPA, 2012c) is to use the default half-life unless at least three chemical-specific foliar dissipation half-lives are readily available, and values are >35 days. Further information on the length of time paraquat can reasonably be expected to remain on food items, such as leaf surfaces, is sometimes obtained from magnitude of residue studies used in tolerance determinations (USEPA, 1995). Half-lives were not calculated from the original studies at this time because LOC exceedances were found with a single application, even at the lowest application rate (0.5 lb cation/A). Refined information on the foliar dissipation half-life either from residue or foliar dissipation studies might reduce uncertainty; however, this additional information would not likely change the risk conclusions because a single application triggered risk concerns for both birds and mammals.

Based on the available data, risks to birds and mammals from the use of paraquat are expected with acute RQs as high as 57 for birds and 7 for mammals. Although the RQs are lower for single applications, the acute dose-based RQ is still 10 times the LOC for small birds feeding on short grass. Chronic risk to birds is also high with RQs as high as 48, based on significant effects to mallard reproduction and food consumption. For mammals, the chronic risk was less certain with RQs as high as 81, based on a no-effect level from a rat 3-generation study. However, an additional line-of-evidence was used by estimating risk using rat prenatal growth data, which showed LOC exceedances for all uses. Chronic risk to mammals was identified for all uses, with the exception of some feeding groups from a single application. More information on chronic mammalian reproduction effects would not greatly affect the risk conclusions due to the acute risk picture and results of risk estimates using rat prenatal growth data. Incident data were available for both birds and mammals that show the potential for mortality from paraquat exposure, though the association with registered uses was not clear.

A further point to consider in characterizing chronic dietary risk to terrestrial vertebrates is whether the food items sprayed with paraquat would be palatable on a chronic exposure basis. Because paraquat is a desiccant, animals consuming grasses and broadleaf plants might be more at risk from acute exposure than chronic exposure because the palatability of the plants would likely decrease as the plant food items desiccate. However, the desiccating action is not sufficiently rapid to eliminate the exposure pathway. Rapid wilting and desiccation begin within hours of application in full sunlight when paraquat produces superoxide radicals that disrupt the plasma membrane and the cell contents leak out. The leaves go from soft and turgid to dry and desiccated in a matter of days, with complete foliar necrosis occurring in 1 to 3 days and, for some plant species, leaves fall off in the final stages (2014, Shaner; BEAD, personal communication[5]). The net result could be similar to non-chemical control methods that involve plowing-under and mowing (BEAD, personal communication[5]). It’s possible that, in some cases, the lower plant weight due to desiccation may result in more plants being consumed by the animal and, where food alternatives are limited, the exposure may be increased. In the case of nuts, seeds, and arthropods (and possibly fruits) palatability would not likely be altered by desiccation in the same way as that described for foliage. Therefore, for food items in the treated area, the chronic risk to grass and broadleaf consuming mammals, birds, and reptiles

---

[5] BEAD. 2019. Personal communication between Bill Chism, Senior Biologist, Biological and Economic Analysis Division and Marianne Mannix, Chemical Review Manager, Pesticide Re-registration Division, Office of Pesticide Programs, U.S. Environmental Protection Agency, April 29 and May 1, 2019.

may be lessened by the reduced palatability, but risk to consumers of seeds, nuts, arthropods, and possibly fruits, are not expected to be affected by the desiccating action.

10 Terrestrial Invertebrate Risk Assessment

10.1 Terrestrial Invertebrate Exposure Assessment

Terrestrial invertebrate framework assumes honey bees are a surrogate for all terrestrial invertebrates (USEPA *et al.*, 2014). The list of crops to which paraquat is applied is summarized in **Table 10-1** (USDA, 2017) along with the USDA pollinator attractive data to identify which crops may have exposure to pollinators on the field. Off-field assessments are conducted for foliar sprays regardless of whether the crop is attractive or not (also see **Appendix F** for more information). Bees may be exposed on and off the field to a wide range of crops. Not all registered uses were included in the database in the form they are listed in the use table (**Table 3-1**) and some notations are made in **Table 10-1**, but the conclusion is that multiple uses have the potential to attract pollinators. Because paraquat is used as a desiccant, the likelihood that it would be applied directly to crops during blooming periods seems low for most crops, but it is not unfathomable. For example, paraquat might be applied between rows of blooming fruit trees, which, though not directly on the crops, might be in close proximity.

Table 10-1. Summary of Information on the Attractiveness of Registered Use Patterns for Paraquat to Bees

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive?[1, 2]	Solitary Bee Attractive?[1, 2]
Sunflower	Y (pollen[2] & nectar[2])	Yes[2]	Yes[2]
Apricot Beans, Dried-Type Legume Vegetables Peanuts	Y (pollen[2] & nectar[2])	Yes[2]	Yes[1]
Cabbages and Other Brassica Vegetables Turnips and Tyfon Citrus Clover	Y (pollen[2] & nectar[2])	Yes[1]	Yes[1 or 2]
Acerola, Mazzard, Sweet Cherries Almond Apple	Y (pollen[2] & nectar[1])	Yes[1 or 2]	Yes[1 or 2]
Alfalfa	Y (pollen[1] & nectar[2])	Yes[1]	Yes[2]
Bushberries Caneberries	Y (pollen[1] & nectar[1])	Yes[2]	Yes[1]
Artichoke Carrot Clary Cucurbit Vegetables Garlic Guar	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1]

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive?[1, 2]	Solitary Bee Attractive?[1, 2]
Kiwi Fruit Lentils Lettuce Melons Okra Peaches/ Nectarines Pear Peas Persimmon Plums/Prunes Soybeans Strawberry			
Onion Asparagus Avocado Safflower Macadamia Nut	Y (pollen[1] & nectar[1])	No or Unknown	Yes[1] or Unknown
Corn Tobacco Pepper	Y (pollen[1])	Yes[1 or 2]	Yes[1]
Coffee Sorghum	Y (pollen[1])	Unknown	Yes[1]
Grapes Grass/Turf Hops Olives	Y (pollen[1])	No or Unknown	No or Unknown
Cotton	Y (nectar[1])	Yes[1]	Yes[1]
Banana	Y (nectar[1])	No	No
Potato, Yams, and Taro Tomato Sugar Beet	N	Yes[1]	Yes[1] or Unknown
Eggplant	N	Yes[2]	Yes[1]
Barley Fig Manioc (Cassava) Pistachio Rhubarb Rice Sugarcane Wheat	N	No	No
Cocoa Coniferous/Evergreen/Softwood (Non-Food) Deciduous/Broadleaf/Hardwood (Non-Food) Fallow Land Flowering Plants Fruiting Vegetables Guava Leafy Vegetables Mint Papaya Passion Fruit	Not Available, Grouping not in Database, or Uncertainty	Not Available, Grouping not in Database, or Uncertainty	Not Available, Grouping not in Database, or Uncertainty

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive? [1, 2]	Solitary Bee Attractive? [1, 2]
Pastureland/Rangeland Pineapple Premises/Areas Root and Tuber Vegetables Subtropical/Tropical Fruit Tree Nuts Trees (Non-Food) Tuberous and Corm Vegetables Vegetables (Unspecified) Ginger Sage			

[1] Use pattern is opportunistically attractive to bees.
[2] Use pattern is attractive in all cases.

10.2 Tier I Exposure Estimates

Contact and dietary exposure are estimated separately using different approaches specific for different application methods. The Bee-REX model (Version 1.0) calculates default EECs for contact and dietary routes of exposure for foliar and soil treatment applications.

In cases where the Tier I RQs exceed the level of concern (LOC, discussed below), estimates of exposure may be refined using measured pesticide concentrations in pollen and nectar of treated crops, and further calculated for other castes of bees using their food consumption rates as summarized in the White Paper to support the Scientific Advisory Panel (SAP) on the pollinator risk assessment process (USEPA, 2012d).

10.3 Terrestrial Invertebrate Risk Characterization (Tier I)

Toxicity endpoints are currently only available for adult acute contact and oral exposures. These acute endpoints (LD_{50} of 52 and 22 µg cation/bee, respectively for contact and oral exposures) are considered practically non-toxic. Therefore, the following section will briefly describe the potential for risk to pollinators that could be evaluated using available data; however, chronic toxicity data for adults and toxicity data for larvae were not available.

10.3.1 Tier I Risk Estimation (Contact Exposure)

On-Field Risk

Since the exposure potential for bees has been identified for multiple crops both on and off the treated field, the next step in the risk assessment process is to conduct a Tier 1 risk assessment. By design, the Tier 1 assessment begins with (high-end) estimates of exposure via contact and oral routes. For contact exposure, only the adult (forager and drones) life stage is considered since this is the relevant life stage for honey bees. Furthermore, toxicity protocols have only been developed for acute exposures. Effects are defined by laboratory exposures to groups of individual bees.

Based on acute contact toxicity, the highest maximum application rate (1.5 lb cation/A for alfalfa and clover) did not exceed the LOC (0.4) for pollinators (**Table 10-2**, also see **Appendix D**).

Table 10-2. Default Tier 1 Adult, Acute Contact Risk for Honey Bees Foraging on Paraquat-Treated Plants

Use Pattern	Bee Attractiveness	Max. Single Application Rate	Dose (μg cation/bee per 1 lb cation/A)[1]	Paraquat Contact Dose (μg cation/bee)	Acute RQ[2]
Alfalfa and Clover	Y (pollen & nectar) Attractive in all cases, except for alfalfa pollen which has is opportunistically attractive	1.5 lb cation/A	4.1 (165 mg cation/kg)	52	0.08

No values are bolded; **Bolded** RQ value exceeds (or potentially exceeds) the acute risk LOC of 0.4. No exceedances.
[1] Source: USEPA 2014. Guidance for Assessing Pesticide Risks to Bees
[2] Based on a 48-h acute contact LD_{50} of 52μg cation/bee for paraquat (MRID 43942603).

10.3.2 Tier I Risk Estimation (Oral Exposure)

On-Field Risk

For oral exposure, the Tier 1 assessment considers just the caste of bees with the greatest oral exposure (foraging adults). If risks are identified, then other factors are considered for refining the Tier 1 risk estimates. These factors include other castes of bees and available information on residues in pollen and nectar which is deemed applicable to the crops of interest.

Based on acute oral toxicity, six out of eight castes of adult bees had LOC exceedances at the highest single application rate (1.5 lb cation/A) for alfalfa and clover **(Table 10-3**, also see **Appendix D**). For the highest and lowest single application rates (1.01 and 0.5 lb cation/A, respectively) for all other uses (a few had rates between these highest and lowest rates), two castes had LOC exceedances, workers foraging for nectar and drones. Worker nurse bees tending brood and queen also had LOC exceedance with the higher rate (1.01 lb cation/A).

Table 10-3. Tier 1 (Default) Oral Risk Quotients for Adult Nectar Forager and Worker Honey Bees

Use Pattern	Max. Single Appl. Rate	Bee Caste/Task	Unit Dose (μg a.i./bee per 1 lb a.i./A)[1]	Oral Dose (μg a.i./bee)	Acute Oral RQ[2,3,4]
Alfalfa and Clover	1.5 lb cation/A	Worker (cell cleaning and capping)	4.1	11.0	**0.50**
		Worker (brood and queen tending, nurse bees)		25	**1.1**
		Worker (comb building, cleaning and food handling)		10	**0.46**
		Worker (foraging for pollen)		7.2	0.33
		Worker (foraging for nectar)		48	**2.2**
		Worker (maintenance of hive in winter)		5.1	0.23
		Drone		39	**1.8**
		Queen (laying 1500 eggs/day)		0.87	0.04
		Worker (cell cleaning and capping)		11	**0.50**
Multiple Uses – Highest Single Application Rate	1.01 lb cation/A	Worker (cell cleaning and capping)	2.7	7.4	0.34
		Worker (brood and queen tending, nurse bees)		17	**0.76**
		Worker (comb building, cleaning and food handling)		6.9	0.31
		Worker (foraging for pollen)		4.8	0.22
		Worker (foraging for nectar)		32	**1.5**
		Worker (maintenance of hive in winter)		3.4	0.16
		Drone		26	**1.2**
		Queen (laying 1500 eggs/day)		0.58	0.027
Multiple Uses – Lower Rate	0.5 lb cation/A	Worker (cell cleaning and capping)	1.4	3.7	0.17
		Worker (brood and queen tending, nurse bees)		8.2	0.37
		Worker (comb building, cleaning and food handling)		3.4	0.15
		Worker (foraging for pollen)		2.4	0.11
		Worker (foraging for nectar)		16	**0.73**
		Worker (maintenance of		1.7	0.078

Use Pattern	Max. Single Appl. Rate	Bee Caste/Task	Unit Dose (μg a.i./bee per 1 lb a.i./A)[1]	Oral Dose (μg a.i./bee)	Acute Oral RQ[2,3,4]
		hive in winter)			
		Drone		13	**0.59**
		Queen (laying 1500 eggs/day)		0.29	0.013

[1] Source: USEPA 2014. Guidance for Assessing Pesticide Risks to Bees.
[2] Based on a 48-h acute oral LD_{50} of 22 μg cation/bee for adults (MRID 43942603).
[3] **Bolded** RQ value exceeds (or potentially exceeds) the acute risk LOC of 0.4 or chronic LOC of 1.0
[4] Information on chronic effects not available.

As mentioned in **Section 10.1**, although multiple crops for which paraquat is registered are attractive to pollinators, the use pattern does not suggest that paraquat would be applied directly to crops in blooming phase. Paraquat is used primarily as a burn down product before crops are planted in the spring (corn, cotton, soybeans, peanuts, etc.). Small winter and spring annual weeds (broadleaf and grass species) could be present and flowering when those applications are made and would be targeted by the paraquat application. If sprayed. those plants and their flowers would likely show symptoms within a few hours and be dead within 1 to 3 days. Paraquat is also used as a desiccant just prior to harvest on crops like potato to get rid of the vines. In those cases, there may be some large flowering plants in the field where pollinator exposure could occur. If the plant is large enough, some flowers might escape direct contact with paraquat and survive for a few more days until the whole plant wilts and dies. In that case, pollinators would not be expected to be exposed (BEAD, personal communication[6]). If applied between rows while crops are blooming, however, this would potentially be a route of exposure for pollinators.

Off-Field Risk

In addition to bees foraging on the treated field, bees may also be foraging in fields adjacent to the treated fields. AgDrift analysis showed that distances needed to remove the presumption of risk for the bee caste at highest risk (workers foraging for nectar) were:

- 4 to 46 feet for the highest application rate (1.5 lb cation/A) for alfalfa and clover;
- 4 to 20 feet at the highest application rate for most uses (1.01 lb cation/A); and
- <1 to 7 feet at the lowest application rate for most uses (0.5 lb cation/A).

[6] Personal communication between Bill Chism, Senior Biologist, Biological and Economic Analysis Division and Marianne Mannix, Chemical Review Manager, Pesticide Re-registration Division, Office of Pesticide Programs, U.S. Environmental Protection Agency, April 29 and May 1, 2019.

Coarse droplet size (and low boom for ground applications) roughly halved the distance applying to fine droplets (and high boom) and similarly, aerial applications of the highest application rates required approximately twice the distance. As a clarification, even though BeeRex calculated LOC exceedance at the lower rate (0.5 lb cation/A), the aerial calculations from the AgDrift model were slightly different and were already below the fraction to remove the presumption of risk at the edge of the field (**Table 10-4**, also see **Appendix D**).

Table 10-4. AgDrift Tier 1 Distances to Remove the Presumption of Oral Risk to Adult Nectar Forager and Worker Honey Bees

Use, Single Application Rate	Fraction of Application Rate That Would Remove the Presumption of Risk[1]	For Aerial Application: Estimated Distance from Edge of Field to Approximate Fraction, feet		For Ground Application: Estimated Distance from Edge of Field, feet	
		Fine Droplet Size[2]	Coarse Droplet Size[3]	Fine Droplet Size[2] / High Boom	Coarse Droplet Size[3] / Low Boom
Based on Worker Foraging for Nectar					
Alfalfa and Clover, 1.5 lb cation/A	0.18	46	20	17	4
Multiple Uses, 1.01 lb cation/A	0.27	20	14	10	4
Multiple Uses, 0.5 lb cation/A	0.55	<1	<1	7	4

[1]This is the fraction of the highest calculated caste RQ from BeeRex (**Table 10-3**) that would equal the LOC of 0.4 for pollinators.
[2]Based on a tier 1 aerial-spray and ground-spray scenarios with high boom application (for ground), ASAE very fine to fine drop spectrum (fine to medium for aerial/fine to very fine for ground) and 90th percentile exposure.
[3] Based on a tier 1 aerial-spray and ground-spray scenarios with low boom application (for ground), ASAE medium/coarse drop spectrum (course to very coarse for aerial/fine to medium/coarse for ground) and 90th percentile exposure.

10.4 Terrestrial Invertebrate Risk Characterization – Additional Lines of Evidence

Some risk to bees was found based on oral toxicity data, but not on contact data. The oral risk applied to six out of eight castes of adult bees at the highest single application rate (1.5 lb cation/A) for alfalfa and clover. At the lowest application rate applying to many uses (0.5 lb cation/A), only two castes were found to be at risk: drones and workers foraging for nectar. However, the exposure pathway for nectar is not clear because paraquat is not systemic, but locosystemic. Nonetheless, based on modeling estimates, distances of up to 46 feet, lower application rates, coarse droplets, ground vs. aerial, and low boom for ground applications all were effective in removing the presumption of risk for the caste with the highest RQs.

An additional consideration is that paraquat is often used as a preplant (site preparation) treatment, rather than a direct foliar spray. For paraquat applied directly to soil, crop attractiveness would not be a factor in bee exposure. However, if target plants are sprayed while flowering or if blooming plants are adjacent to the treated area, spray drift may expose foraging bees. Exposure to bees depends heavily on timing of application and proximity to blooming plants.

One bee incident (I029512-0004) involved damage to two bee hives and was of possible causality but of undetermined legality. This incident suggests potential for harm to pollinators. Additionally, as mentioned above, many of the ONT aggregate incidents in **Table** 6-4 are likely bee incidents. The scarcity of reported incidents should not be construed as the absence of incidents. Incident reports for non-target animals typically provide information only on mortality events. Sublethal effects in organisms such as abnormal behavior, reduced growth and/or impaired reproduction are rarely reported.

With the locosystemic nature of paraquat, the potential may exist for its presence in parts of plants that may be consumed. Due to rapid plant death, it seems unlikely that it would be taken up by the target plant and transported to pollen; it would more likely only be available in off-field non-target plants or pollen as a result of spray drift. Due to its longevity, potential for paraquat presence in pollen and honey may be a concern. The Tier 1 analysis showed concern for adults based on acute oral toxicity to some castes of bees, and those risks could be reduced to below the levels of concern. Risk to larvae and chronic risk to adult bees were not determined due to lack of data.

Because paraquat is a desiccant and not likely applied directly to blooming crops, pollinator exposure is likely greater off-field than on-field. However, if paraquat is applied between rows of blooming crops, then on-field exposure may also be likely.

11 Terrestrial Plant Risk Assessment

11.1 Terrestrial Plant Exposure Assessment

EECs for terrestrial plants are calculated using TERRPLANT v.1.2.2. Exposure is estimated for a single application evaluating exposure via spray drift. Runoff was not considered due to fate characteristics previously discussed. For spray drift, exposure is estimated approximately 200 feet from the edge of the treated field. Exposures from spray drift are then compared to measures of survival and growth (*e.g.,* effects to vegetative vigor) to develop RQ values. Resulting upper bound exposure estimates are in **Table 11-1** (also see **Appendix D**). EECs are based on the maximum single application rate for terrestrial uses and spray drift fraction. The EECs represent residues from off-site exposure via spray drift to non-target plants found near application sites.

Table 11-1. TerrPlant Calculated EECs for Terrestrial and Semi-Aquatic Plants near Paraquat Terrestrial Use Areas

Use Site	Single Max. Application Rate (lb cation/A)	EECs (lb a.i./A)[1]	
		Ground[2] Spray Drift	Aerial[3] Spray Drift
Alfalfa and Clover	1.5	0.015	0.075
Multiple Ag and Non-Ag Uses – High Rate	1.01	0.0101	0.0505
Multiple Ag and Non-Ag Uses – Low Rate	0.50	0.0050	0.025

[1] Based on a solubility limit of 336,000 mg cation/L (464,000 mg paraquat dichloride/L * 0.724294 = 336,000; MRID 46098802).
[2] Based on a drift fraction of 1% (*i.e.*, 0.01).
[3] Based on a drift fraction of 5% (*i.e.*, 0.05).

11.2 Terrestrial Plant Risk Characterization

Monocots and dicots are similarly sensitive to paraquat toxicity. The seedling emergence endpoints (EC_{25}) used to calculate non-listed species risk, were based on 25% reductions in oat and cocklebur survival and emergence (**Table 6-2** and **Appendix B**). Oats also had significant ($p<0.05$) 21% reduction in survival and emergence at 0.57 lb cation/A, just below the EC_{25} of 0.64 lb cation/A; although the NOAEL/LOAEL endpoints were not used in these calculations (they typically are only used for the listed-species calculations which were not done here), they provide support of effects at this exposure level. Similarly, the cocklebur had measured 21% reduction in emergence at 0.34 lb cation/A, compared to the calculated EC_{25} of 0.67, which was based on emergence data. The vegetative vigor endpoints used in the spray drift calculations were more sensitive than the seedling emergence endpoints. This is consistent with the mode of action where paraquat is expected to be absorbed into plant tissue and cause rapid damage, resulting in more localized effects than systemic uptake. Exposure in the vegetative vigor study was from direct spray to green parts of the plant, while exposure in the seedling emergence study was from treated soil.

These EC_{25}s of 0.021 and 0.022 lb cation/A for ryegrass and soybeans were based on 25% effects in growth (dry weight and height). Ryegrass also had significant ($p<0.05$) 60% reduction in dry weight at 0.033 lb cation/A, and soybeans had significant ($p<0.05$) 20% reduction in height at 0.018 lb cation/A, which were close to the EC_{25} estimates, and provide support that effects may be seen at these exposure levels.

Based on these endpoints and the EECs calculated using TerrPlant (**Table 11-1**), the LOCs are exceeded for non-target plants exposed to spray drift (based on vegetative vigor endpoints as described above) had exceedances for all application rates from aerial spray (RQs from 1.2-3.6) but not from ground spray (**Table 11-2**). Distances to remove the presumption of risk range from <1 foot to 17 feet, depending in part on droplet size.

Table 11-2. Terrestrial Plant Risk Quotients and AdDrift Distances to Remove the Presumption of Risk

Type of Plant	Ground spray RQs from Spray Drift[1]	Aerial Spray RQs from Spray Drift		
		RQ/ Fraction of Applied to Remove Presumption of Risk	Distance to Fraction of Applied	
			Fine to Medium Droplets	Coarse Droplets
Alfalfa and Clover (1.5 lb cation/A)				
Monocot	0.72	**3.61**/0.277	17	14
Dicot	0.69	**3.46**/0.289	17	10
Multiple Ag and Non-Ag Uses – High Rate (1.01 lb cation/A)				
Monocot	0.49	**2.43**/0.412	7	7
Dicot	0.47	**2.33**/0.429	7	4
Multiple Ag and Non-Ag Uses – Low Rate (0.5 lb cation/A)				
Monocot	0.24	**1.20**/0.833	<1[1]	<1[1]
Dicot	0.23	**1.15**/0.870	<1[1]	<1[1]

Bolded RQ values exceed the LOC of 1.0.
[1]Even though this is a herbicide, the TerrPlant estimate is for the edge of the field so that for ground application, the model estimates 1% drift and for aerial application 5% drift. As a result, the ground spray RQs are below the LOC. Similarly, for AgDrift, the model estimates that some of the distances to remove the presumption of risk are <1 foot.

Twenty-seven plant incidents were found, with paraquat as probable or highly probable cause in ten; of these, one was from a registered use (I013884-038) involved damage to ornamental plants from paraquat use on peas. Four additional plant incidents attributed to registered uses of paraquat on peanuts, pastureland, and non-specified uses were determined to be *possibly* caused by paraquat (I011838-005, I012684-010, I013636-029, and I014034-009); these involved damage to peanut, peppermint and pasture grass in areas ranging from 5 to 181 acres, suggesting potential for harm to plants from registered use. Fifteen incidents of undetermined legality were reported, involving damage to corn, peanuts, apples, radishes, winter wheat, blueberries, alfalfa, onions, non-specified vegetables and ornamentals; of these, four were determined to have probable causality and eleven to have possible causality for paraquat. These incidents support the suggestion that a potential for harm to plants is established from registered use of paraquat.

Therefore, based on the available data, plants exposed to spray drift from aerial applications are at risk at all registered application rates, which is consistent with paraquat being an herbicide. Given paraquat's registrations as an herbicide along with many plant damage incidents linked to paraquat use, plants in areas exposed to paraquat application are expected to be at risk.

12 Conclusions

Given the uses of paraquat and the chemical's environmental fate properties, there is a likelihood of exposure of paraquat residues of concern to non-target terrestrial and/or aquatic organisms. When used in accordance with the label, such exposure may result in adverse effects upon the survival, growth, and reproduction of non-target terrestrial and aquatic organisms. Consistent with previous risk assessments (USEPA, 2011a, USEPA, 2014a), all registered uses of paraquat pose a potential for direct adverse effects to birds, mammals, terrestrial-phase amphibians, reptiles, terrestrial plants, and aquatic plants, and to a lesser degree, to pollinators, fish, and benthic invertebrates. Application timing may be important in preventing reproduction effects to terrestrial vertebrates and also to avoid pollinator effects if applied onto or near blooming plants. Paraquat is very persistent in the environment. A more in-depth summary of the risk conclusions is available in the Executive Summary **Section** 1.

13 Literature Cited

Amondham, W., P. Parkpian, C. Polprasert, R.D. DeLaune, and A. Jugsujinda. 2006. "Paraquat Adsorption, Degradation, and Remobilization in Tropical Soils of Thailand." Journal of Environmental Science and Health -Part B 41 (5): 485–507. doi: 10.1080/03601230600701635.

CADPR. No date. Environmental fate and ecotoxicology of paraquat: a California perspective. Department of Pesticide Regulation, California Environmental Protection Agency, Sacramento, California, USA. Available at https://www.cdpr.ca.gov/docs/emon/pubs/fatememo/paraquat_final.pdf

CADPR. 2018. Surface Water Protection Program Database. Available at http://www.cdpr.ca.gov/docs/emon/surfwtr/surfdata.htm.

Damanakis, M. 1970. A Bioassay for the Determination of Low Concentrations of Paraquat. *Weed Research* (1970)10:77-80.

Funderburk, H.H. and J.M. Lawrence. 1963. A sensitive Method for Determination of Low Concentrations of Diquat and Paraquat. *Nature* (07 September 1963)199:1011-1012.

Ogamba, E.N., I.R. Inyang and I.K. Azuma. 2011. Effect of Paraquat Dichloride on Some Metabolic and Enzyme Parameters of *Claris gariepinus*. *Current Research Journal of Biological Sciences* 3(3):186-190 (E160909).

Ricketts, D.C. The microbial biodegradation of paraquat in soil. Pestici. Sci. 1999, 55, 596–598.Shaner, D.L. 2014. *Herbicide Handbook. 10th Edition,* Weed Science Society of America, Lawrence, 513 p.

State Water Resources Control Board. 2015. California Environmental Data Exchange Network. California State Water Resources Control Board. Available at http://www.ceden.org/.

USDA. 2017 *Attractiveness of Agricultural Crops to Pollinating Bees for the Collection of Nectar and/or Pollen*. U.S. Department of Agriculture. Available at http://www.ree.usda.gov/ree/news/Attractiveness_of_Agriculture_crops_to_pollinating_bees_Report-FINAL.pdf.

USEPA. 1993 *Wildlife Exposure Factors Handbook*. EPA/600/R-13/187a. Office of Research and Development. U.S. Environmental Protection Agency. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2799.

USEPA. 1995 *Paraquat Dichloride. (061601) Product Chemistry Chapter and Residue Chemistry Chapter for the Reregistration Eligibility Document: DP Barcode 217262: CBRS No. 15906; No MRID No.; Rereg. Case No. 0262.* U.S. Environmental Protection Agency.

USEPA. 2004 *Government Printing Office. Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs*. January 23, 2004. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency. Available at https://www.epa.gov/sites/production/files/2014-11/documents/ecorisk-overview.pdf.

USEPA. 2009a *Risks of Paraquat Use to Federally Threatened California Red-legged Frog (Rana aurora draytonii): Pesticide Effects Determination,* June 10, 2009. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency.

USEPA. 2009b *Guidance for Selecting Input Parameters in Modeling the Environmental Fate and Transport of Pesticides, Version 2.1*. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency. Available at hhttps://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/guidance-selecting-input-parameters-modeling.

USEPA. 2010a *Guidance for Reporting on the Environmental Fate and Transport of the Stressors of Concern in the Problem Formulation for Registration Review, Registration Review Risk Assessments, Listed Species Litigation Assessments, New Chemical Risk Assessments, and Other Relevant Risk Assessments*. January 25, 2010. Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. Available at http://www.epa.gov/pesticides/science/efed/policy_guidance/team_authors/endangered_species_reregistration_workgroup/esa_reporting_fate.htm.

USEPA. 2011a. *EFED Registration Review: Preliminary Problem Formulation for Paraquat Dichloride.* December 12, 2011. DP Barcode: 392076. Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency.

USEPA. 2011b. *Guidance for Using Non-Definitive Endpoints in Evaluating Risks to Listed and Non-listed Animal Species*. Memorandum From D. J. Brady to E. F. a. E. Division. May 10, 2011. Environmental Fate and Effects Division. Office of Chemical Safety and Pollution

Prevention. U.S. Environmental Protection Agency. Available at http://www.epa.gov/pesticides/science/efed/policy_guidance/team_authors/endangered_species_reregistration_workgroup/esa_non_definitive_endpoints.htm.

USEPA. 2012a Review of Jar Test Results for Drinking Water Assessment Purpose. January 10, 2012. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency. DP Barcode: D396402.

USEPA. 2012b *Standard Operating Procedure for Using the NAFTA Guidance to Calculate Representative Half-life Values and Characterizing Pesticide Degradation*. November 30, 2012. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency. Available at http://www.epa.gov/oppefed1/ecorisk_ders/degradation_kinetics/NAFTA_Degradation_Kinetics.htm.

USEPA. 2012c *User's Guide: T-REX Version 1.5 (Terrestrial Residue EXposure model).* March 22, 2012. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency.

USEPA. 2012d *White Paper in Support of the Proposed Risk Assessment Process for Bees*. September 11-14, 2012. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency. Available at https://www.regulations.gov/document?D=EPA-HQ-OPP-2012-0543-0004.

USEPA. 2013b *Guidance on Modeling Offsite Deposition of Pesticides Via Spray Drift for Ecological and Drinking Water Assessment*. Environmental Fate and Effects Division. Office of Pesticide Programs. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. Available at http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2013-0676.

USEPA. 2014a *Ecological Risk Assessent for the Proposed Section 3 use of Paraquat Dichloride on Tuberous and Corm Vegetables (Corp Subgroup 1C)*. June 5, 2014. DP Barcode 415769. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency.

USEPA. 2014b. *Guidance for Addressing Unextracted Residues in Laboratory Studies*. Memorandum From to E. F. a. E. Division. September 12, 2014. Environmental Fate and Effects Division. Office of Pesticide Programs. Office of Chemical Safety and Pollution Prevention. Available at http://www.epa.gov/pesticides/science/efed/policy_guidance/team_authors/environmental_fate_tech_team/Unextracted_Residues_in_Lab_Studies.htm.

USEPA. 2014c. *Response to Data Waiver Request for an Avian Acute Inhalation Study for Paraquat Dichloride.* Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. DP Barcode: 421901. October 2, 2014.USEPA. 2015. Preliminary Ecological Risk Assessment for the Registration Review of Diquat Dibromide. Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. DP Barcode: 427095. August 18, 2015.

USEPA. 2016. Screening Level Usage Analysis (SLUA) for Paraquat. Biological and Economic Assessment Division (BEAD). Office of Pesticide Programs. U.S. Environmental Protection Agency. September 19, 2016

USEPA. 2017 *Guidance for Using Daily Average Aquatic Concentrations in Ecological and Drinking Water Assessments*. June 27, 2017. Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency.

USEPA, Health Canada PMRA, & California Department of Pesticide Regulation. 2014 *Guidance for Assessing Pesticide Risks to Bees*. June 23, 2014. U.S. Environmental Protection Agency. Health Canada Pest Management Regulatory Agency. California Department of Pesticide Regulation. Available at http://www2.epa.gov/pollinator-protection/pollinator-risk-assessment-guidance.

USEPA. 2018. Pesticide Label Use Summary (PLUS) Report for Paraquat. Biological and Economic Assessment Division (BEAD). Office of Pesticide Programs. U.S. Environmental Protection Agency. May 31, 2018

USEPA, USGS, & NWQMC. 2018. Water Quality Portal. United States Environmental Protection Agency. United States Geological Survey. National Water Quality Monitoring Council. Available at https://www.waterqualitydata.us/.

Zaranyika, M.F. and S. Nyoni. 2013. Degradation of Paraquat in the Aquatic Environment: A Proposed Enzymatic Kinetic Model that takes into Account Adsorption/Desorption of the Herbicide by Colloidal and Sediment Particles. *International Journal of Research in Chemistry and Environment* 3(3, July 2013): 26-35.

14 Referenced MRIDs

14.1.1 Environmental Fate Studies:

161-1 Hydrolysis

MRID	Citation Reference
67161	Funderburk, H.H., Jr.; Negi, N.S.; Lawrence, J.M. (1966) Photo- chemical decomposition of diquat and paraquat. Weeds 14:240- 243. (Also In unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231432-L)
85678	Harned, W.H.; Lengen, M.R. (1981) The Photolysis of Harvade in Aqueous and Soil Environments: Project No. 8031. (Unpublished study received Aug 19, 1981 under 1F2560; submitted by Uniroyal Chemical, Bethany, Conn.; CDL:070240-E)
114412	Slade, P. (1965) Photochemical degradation of paraquat. Nature 207 (4996):515-516. (Also In unpublished submission received on unknown date under 5G0440; submitted by California Chemical Co., Richmond, CA; CDL:092728-A)

161-2 Photodegradation-water

MRID	Citation Reference
40562301	Parker, S.; Leahey, J. (1988) Paraquat Aqueous Photolysis at pH 7: Laboratory Project ID R0633B. Unpublished study prepared by ICI Plant Protection Division. 51 p.

161-3 Photodegradation-soil

MRID	Citation Reference
17934	Hance, R.J. (1967) Decomposition of herbicides in the soil by non- biological chemical processes. J. Sci. Fd Agric. 18(?/Nov):544- 547. (Also In unpublished submission received Aug 20, 1976 under 39445-1; submitted by American Carbonyl, Inc., Tenafly, N.J.; CDL:228229-AX)
67161	Funderburk, H.H., Jr.; Negi, N.S.; Lawrence, J.M. (1966) Photo- chemical

	decomposition of diquat and paraquat. Weeds 14:240- 243. (Also In unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231432-L)
85678	Harned, W.H.; Lengen, M.R. (1981) The Photolysis of Harvade in Aqueous and Soil Environments: Project No. 8031. (Unpublished study received Aug 19, 1981 under 1F2560; submitted by Uniroyal Chemical, Bethany, Conn.; CDL:070240-E)
108334	Corbin, F. (1967) Influence of pH on the Detoxication of Herbicides in Soil. Abstracted from: Weeds 15(4):370-377. (Unpublished study received Nov 4, 1971 under 1F1042; prepared by North Carolina State Univ., Dept. of Crop Science, submitted by Stauffer Chemical Co., Richmond, CA; CDL:091932-L)
140344	Tucker, B.V.; Pack, D.E. (1965) Paraquat Metabolic Fate--Status Re- port. (Unpublished study received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180001-C)
140345	Baldwin, B.C.; Slade, P. (1968) The Fate of Carbon-14 Labelled Paraquat in Soil under Field Conditions: AR 2220 B. (Unpublished study received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180001-D)
140346	Chevron Chemical Company (1970) The Fate of Carbon 14 Labelled Paraquat in Soil under Field Conditions. (Unpublished study received Apr 7, 1971 under unknown admin. no.; CD:180001-E)
140350	Tucker, B.V.; Pack, D.E. (1966) The Metabolism 4-Carboxy-1- methylpyridinium Ion in Soil. (Unpublished study received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180001-M)
146806	Day, S.; Hemingway, R. (1981) [Carbon-14] Paraquat: Degradation on a Sandy Soil Surface in Sunlight: Report Series RJ 0168B. Unpublished study prepared by ICI Plant Protection Division. 40 p.
146807	Pack, D. (1982) Long Term Exposure of [Carbon 14] Paraquat on a Sandy Soil to California Sunlight. Unpublished study prepared by Chevron Chemical Company. 16 p.

162-1 Aerobic soil metabolism

MRID	Citation Reference
55092	Burns, R.G.; Audus, L.J. (1970) Distribution and breakdown of Paraquat in soil.

	Weed Research 10:49-58. (Also In unpublished submission received Apr 7, 1971 under unknown admin. no.; sub- mitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-H)
91369	Chevron Chemical Company (19??) The Fate of Paraquat in Soils. (Unpublished study received Mar 2, 1966 under 6F0483; CDL: 090543-F)
114414	Chevron Chemical Co. (1967) Name, Chemical Identity and Composition of the Pesticide Chemical: (Paraquat). (Compilation; unpublished study received Apr 3, 1967 under 7F0592; CDL:092880-A)
140345	Baldwin, B.C.; Slade, P. (1968) The Fate of Carbon-14 Labelled Paraquat in Soil under Field Conditions: AR 2220 B. (Unpublished study received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180001-D)
140346	Chevron Chemical Company (1970) The Fate of Carbon 14 Labelled Paraquat in Soil under Field Conditions. (Unpublished study received Apr 7, 1971 under unknown admin. no.; CD:180001-E)
140350	Tucker, B.V.; Pack, D.E. (1966) The Metabolism 4-Carboxy-1- methylpyridinium Ion in Soil. (Unpublished study received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180001-M)
140355	Anderson, J.R.; Drew, E.A.; Tomlinson, T.E. (1971) Distribution of *Lipomyces starkey* in Some Soils and Its Ability to Degrade Paraquat in Soil or Clay Associations: Report No. AR 2236 A. (Unpublished study received Apr 7, 1971 under unknown admin. no.; prepared by Imperial Chemical Industries, Ltd., submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180001-R)
140356	Anderson, J.R.; Drew, E.A.; Tomlinson, T.E. (1971) Growth Characteristics of, and Paraquat Degradation by, a Species of *Lipomyces*: Report No. AR 2238 A. (Unpublished study received Apr 7, 1971 under unknown admin. no.; prepared by Imperial Chemical Industries, Ltd., submitted by Chevron Chemical Co., Richmond, Calif.; CDL:18001-S)
41319301	Vickers, J.; Hurt, A.; Bewick, D. (1989) Paraquat: Degradation in Aerobic Soil: Lab Project Number: 88JH386. Unpublished study prepared by ICI Agrochemicals. 33 p.

162-2 Anaerobic soil metabolism

MRID	Citation Reference

41319302	Vickers, J.; Hurt, A.; Bewick, D. (1989) Paraquat: Degradation in Anaerobic Soil: Lab Project Number: 88JH386. Unpublished study prepared by ICI Agrochemicals. 34 p.

163-1 Leach/adsorp/desorption

MRID	Citation Reference
17934	Hance, R.J. (1967) Decomposition of herbicides in the soil by non-biological chemical processes. J. Sci. Fd Agric. 18(?/Nov):544- 547. (Also In unpublished submission received Aug 20, 1976 under 39445-1; submitted by American Carbonyl, Inc., Tenafly, N.J.; CDL:228229-AX)
22802	Warnock, R.E.; Leary, J.B. (1978) Paraquat, Atrazine and Bladex- Dissipation in Soils. (Unpublished study received Jul 30, 1979 under 201-279; prepared by Chevron Chemical Co., submitted by Shell Chemical Co., Washington, D.C.; CDL:238889-G)
25063	Shell Chemical Company (1975) Dissipation of Bladex^(R)I Herbicide and Paraquat in Soil following Application of Bladex, Paraquat, or a Tank Mix of Bladex and Paraquat: TIR-24-135-74. (Unpublished study received Apr 22, 1976 under 201-279; CDL:224461-F)
29088	Mangels, G.D. (1979) CL 222,705: Determination of Mobility by Soil Thin-Layer Chromatography: Project No. 0414. (Unpublished study received Apr 22, 1980 under 241-259; submitted by American Cyanamid Co., Princeton, N.J.; CDL:099383-E)
32006	Weissler, M.S.; Prashad, S.; Hill, I.R. (1979) Paraquat: Strong Ad- sorption Capacities, Measured by Wheat Bioassay, of Seven Sandy Soils from West Germany: Report Series RJ 0097 B. (Unpublished study received May 2, 1980 under 239-2186; prepared by ICI, sub- mitted by Chevron Chemical Co., Richmond, Calif.; CDL:242382-B)
32045	Reichert, B.L.; Knoll, B.A. (1979) CL 217,300: Determination of Mobility in Soil: Project No. 0420. (Unpublished study received Jun 11, 1980 under 241-260; submitted by American Cyanamid Co., Princeton, N.J.; CDL:099457-C)
33449	Clinch, R.C.; Middleton, M.R.; Winchester, J.N. (1962) Bipyridylium Herbicides: Adsorption of Diquat and Paraquat Salts and Formulations by Soils: Experimental Report No. PP/E/178. (Unpublished study received Jun 10, 1963 under 239-1994; prepared by Imperial Chemical Industries, Ltd. in cooperation with Plant Protection, Ltd., submitted by Chevron Chemical Co., Richmond,

Calif.; CDL: 001407-B)

33837 California Chemical Company (1964) Bio-assay of Extracts from Para- quat-Treated Soils with *Lemna minor*. (Unpublished study received Oct 14, 1965 under 239-1994; submitted by Chevron Chemi- cal Co., Richmond, Calif.; CDL:001432-C)

52390 Gowman, M.A.; Riley, D.; Newby, S.E. (1980) Paraquat and Diquat: Long-Term High-Rate Trial, Frensham, UK. 2. Persistence and Movement in Soil, and Glasshouse Bioassays: Report Series RJ 0014 B. (Unpublished study received Jun 4, 1980 under 239-2186; prepared by ICI, submitted by Chevron Chemical Co., Richmond, Calif.; CDL:242577-B)

55086 Coats, G.E.; Funderburk, H.H., Jr.; Lawrence, J.M.; et al. (1966) Factors affecting persistence and inactivation of Diquat and Paraquat. Weed Research 6(1):58-66. (Also In unpublished sub- mission received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-B)

55087 Knight, B.A.G.; Denny, P.J. (1970) The interaction of Paraquat with soil: Adsorption by an expanding lattice clay mineral. Weed Research 10:40-48. (Also In unpublished submission received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-C)

55088 Knight, B.A.G.; Tomlinson, T.E. (1967) The interaction of Paraquat (1:1'-Dimethyl 4:4'-dipyridylium dichloride) with mineral soils. Journal of Soil Science 18(2):233-243. (Also In unpublished submission received Apr 7, 1971 under unknown admin. no.; sub- mitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-D)

55089 Tomlinson, T.E.; Knight, B.A.G.; Bastow, A.W.; et al. (1968) Structural factors affecting the adsorption of bipyridylium cations by clay minerals. Pages 317-333, In Physico-Chemical and Biophysical Factors Affecting the Activity of Pesticides. By ? London, England: Soc. of Chem. Ind. (S.C.I. monograph no. 29; also In unpublished submission received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-E)

55090 Weber, J.B.; Perry, P.W.; Upchurch, R.P. (1965) The influence of temperature and time on the adsorption of Paraquat, Diquat, 2,4-D and Prometone by clays, charcoal, and an anion-exchange resin. Soil Science Society of America Proceedings 29:678-688. (Also In unpublished submission received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-F)

55092 Burns, R.G.; Audus, L.J. (1970) Distribution and breakdown of Paraquat in soil. Weed Research 10:49-58. (Also In unpublished submission received Apr 7, 1971 under unknown admin. no.; sub- mitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-H)

55093 Coats, G.E.; Funderburk, H.H., Jr.; Lawrence, J.H.; et al. (1964) Persistence of Diquat and Paraquat in pools and ponds. Proceedings, Southern Weed Control Conference 17:308-320. (Also In unpublished submission received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 180000-I)

55097 Austin, W.G.L.; Calderbank, A. (1964) Diquat and Paraquat: Residues in Water and Toxicity to Fish and Other Aquatic Fauna: Experimental Report No. PP/E/303. (Unpublished study received Apr 7, 1971 under unknown admin. no.; prepared by Plant Protection, Ltd., submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-M)

56053 Tucker, B.V. (19??) Lack of Effect of a Polar Hydroxy triazine Com- pound on Paraquat Leaching in Soil. (Unpublished study received Jun 19, 1973 under 1F1014; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:091760-C)

64796 Pack, D.E. (1980) Mobility of Naled and Dichlorvos in Soil As Determined by Soil Thin-layer Chromatography: File No. 722.2. (Unpublished study received Oct 20, 1980 under 239-1633; submit- ted by Chevron Chemical Co., Richmond, Calif.; CDL:243547-A)

65606 Baldwin, B.C.; Knight, B.A.G. (1967) The Fate of Diquat in Soils: Survey of Present Knowledge: TMJ 224. (Unpublished study received Aug 22, 1977 under 239-1663; prepared by Imperial Chemical Industries Ltd., England, submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-F)

65609 Gamar, Y.; Mustafa, M.A. (1975) Adsorption and desorption of di- quat^2tI and paraquat^2tI on arid-zone soils. Soil Science 119(4):290-295. (Also In unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-I)

65610 Haque, R.; Lilley, S.; Coshow, W.R. (1970) Mechanism of adsorption of diquat and paraquat on Montmorillonite surface. Journal of Colloid and Interface Science 33(1):185-188. (Also In unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-J)

65611 Hayes, M.H.B.; Pick, M.E.; Toms, B.A. (1972) Application of micro- calorimetry to the study of interactions between organic chemicals and soil constituents.

Science Tools 19:9-12. (Also In unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 231430-K)

65613 Khan, S.U. (1974) Adsorption of bipyridylium herbicides by humic acid. Journal of Environmental Quality 3(3):202-206. (Also In unpublished submission received Aug 22, 1977 under 239- 1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-M)

65614 Khan, S.U. (1973) Interaction of bipyridylium herbicides with or- gano-clay complex. Journal of Soil Science 24(2):244-248. (Also In unpublished submission received Aug 22, 1977 under 239- 1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-N)

65615 Philen, O.D., Jr.; Weed, S.B.; Weber, J.B. (1970) Estimation of surface charge density of mica and vermiculite by competitive adsorption of Diquat^{2+} vs. Paraquat^{2+}. Soil Science Society of America Proceedings 34:527-531. (Also In unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-O)

65618 Tucker, B.V.; Pack, D.E.; Ospenson, J.N. (1967) Adsorption of bipyridylium herbicides in soil. Journal of Agricultural and Food Chemistry 15(6):1005-1008. (Also In unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemi- cal Co., Richmond, Calif.; CDL:231430-S)

65619 Weber, J.B.; Weed, S.B. (1968) Adsorption and desorption of diquat, paraquat, and prometone by montomorillanitic and kaolinitic clay minerals. Soil Science Society of America Proceedings 32:485- 487. (Also In unpublished submission received Aug 22, 1977 un- der 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-T)

65621 Weber, J.B.; Perry, P.W.; Upchurch, R.P. (1965) The influence of temperature and time on the adsorption of paraquat, diquat, 2,4-D and prometone by clays, charcoal, and an anion-exchange resin. Soil Science Society of America Proceedings 29(6):678- 688. (Also In unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-V)

65622 Weed, S.B.; Weber, J.B. (1969) The effect of cation exchange capacity on the retention of Diquat 2I+I and Paraquat21+I by three-layer type clay minerals: I. Adsorption and release. Soil Science Society of America Proceedings 33(3):379-382. (Also in unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-W)

65623 Weed, S.B.; Weber, J.B. (1968) The effect of adsorbent charge on the competitive adsorption of divalent organic cations by layer- silicate minerals. American Mineralogist 53(Mar-Apr):478-490. (Also In unpublished submission received Aug 22, 1977 under 239- 1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 231430-X)

65624 Best, J.A.; Weber, J.B.; Weed, S.B. (1972) Competitive adsorption of Diquat®, Paraquat®, and Ca^{2+} on organic matter and exchange resins. Soil Science 114(6)444-450. (Also In unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-Y)

68226 Coats, G.E.; Funderburk, H.H., Jr.; Lawrence, J.M.; et al. (1964) Persistence of diquat and paraquat in pools and ponds. Proceedings of the Southern Weed Control Conference 17:308-320. (Also In unpublished submission received Aug 22, 1977 under 239- 1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 231431-J)

70873 Pack, D.E. (1980) Paraquat, Atrazine and Terbutryn--Dissipation in Soils Alone and in Combination: File No. 721.7/R-127. (Unpublished study received Mar 24, 1981 under 239-2186; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:244725-A)

82259 Spinks, C.A.; Hendley, P.; Arnold, D.J. (1976) PP796--Degradation in Soil under Laboratory Conditions: Report Series TMJ 1419 B. (Unpublished study received Apr 13, 1977 under PP0796; prepared by Imperial Chemical Industries, Ltd., England, submitted by Chevron Chemical Co., Richmond, Calif.; CDL:098315-G)

90396 California Chemical Company (1964) Paraquat Residues in Soil. (Compilation; unpublished study received Feb 25, 1965 under 5G0440; CDL:090479-B)

91369 Chevron Chemical Company (19??) The Fate of Paraquat in Soils. (Unpublished study received Mar 2, 1966 under 6F0483; CDL: 090543-F)

91370 Chevron Chemical Company (1965?) Adsorption of Bipyridylium Herbicides in Soil. (Unpublished study received Mar 2, 1966 under 6F0483; CDL:090543-G)

96972 Pack, D.E. (1977) Soil Mobility of Captan, Folpet and Captafol As Determined by Soil Thin-layer Chromatography: File No. 722.0. (Unpublished study received May 30, 1978 under 239-2211; sub- mitted by Chevron Chemical Co., Richmond, Calif.; CDL:234046-N)

105942 Leake, C.; Lines, D.; Tiffen, K. (1981) The Leaching of NC 21 314 in Four Soil Types Using Soil TLC: METAB/81/40. (Unpublished study received Jul 1, 1982 under 45639-EX-7; prepared by FBC Ltd., Eng., submitted by BFC Chemicals, Inc., Wilmington, DE; CDL:070966-E)

111528 McCall, H.; Bovey, R.; McCully, M; et al. (1972) Adsorption and desorption of picloram, trifluralin, and paraquat by ionic and nonionic exchange resins. Weed Science 20(3):250-255. (Also In unpublished submission received Sep 26, 1974 under 464-323; submitted by Dow Chemical U.S.A., Midland, MI; CDL:120317-U)

113707 Clinch, R.; Middleton, M.; Winchester, J. (1962) Bipyridylium Herbicides: Adsorption of Diquat and Paraquat Salts and Formulations by Soils: Report No. PP/E/178. (Unpublished study received Aug 1, 1962 under unknown admin. no.; submitted by Imperial Chemical Industries Ltd., London, Eng.; CDL:121729-A)

114299 Leake, C.; Somerville, L.; Lines, D.; et al. (1982) The Leaching of Amitraz in Four Soil Types Using Soil T.L.C.: METAB/82/16. (Un- published study received Sep 8, 1982 under 45639-49; prepared by FBC, Ltd., Eng., submitted by BFC Chemicals, Inc., Wilmington, DE; CDL:248318-B)

116619 Kinne, L.; Reynolds, J.; Froelich, L.; et al. (1982) Soil Mobility of FMC 57020: M-4862. (Unpublished study received Oct 1, 1982 under 279-EX-93; submitted by FMC Corp., Philadelphia, PA; CDL: 248476-C)

121311 Hayes, M.; Pick, M.; Toms, B. (1972) Application of microcalorimetry to the study of interactions between organic chemicals and soil constituents. LKB Instrument Journal 19:9-12. (Also In unpublished submission received Dec 21, 1982 under 239-2247; submitted by Chevron Chemical Co., Richmond, CA; CDL:249102-K)

121313 Philen, O.; Weed, S.; Weber, J. (1970) Estimation of surface charge density of mica and vermiculite by competitive adsorption of di- quat vs. paraquat. Soil Science Society of America Proceedings 34:527-531. (Also In unpublished submission received Dec 21, 1982 under 239-2247; submitted by Chevron Chemical Co., Richmond, CA; CDL:249102-O)

121317 Weber, J.; Weed, S. (1968) Adsorption and Desorption of diquat, paraquat, and prometone by montmorillonitic and kaolinitic clay minerals. Soil Science Society of America Proceedings 32:485- 487. (Also In unpublished submission received Dec 21, 1982 under 239-2247; submitted by Chevron Chemical Co., Richmond, CA; CDL:249102-T)

121318 Weed, S.; Weber, J. (1968) The effect of adsorbent charge on the competitive adsorption of divalent organic cations by layer-silicate minerals. American

	Mineralogist 53(Mar-Apr):478-490. (Also in unpublished submission received Dec 21, 1982 under 239-2247; submitted by Chevron Chemical Co., Richmond, CA; CDL: 249102-X)
128974	LaFleur, K. (1979) Sorption of pesticides by model soils and agronomic soils: Rates and equilibria. Soil Science 127(2):94-101. (Also In unpublished submission received Jun 16, 1983 under 464-502; submitted by Dow Chemical U.S.A., Midland, MI; CDL: 250517AE)
135717	Chevron Chemical Co. (1970) Diquat: Residue Tolerance Petition: The Results of Tests on the Amount of Residue Remaining, Including a Description of the Analytical Methods Used: Water, Aquatic Life and Soil. (Compilation; unpublished study received Dec 12, 1970 under 1F1101; CDL:090861-A)
140075	Chevron Chemical Company (1965) Leaching of Paraquat in Soil. (Un- published study received Apr 7, 1971 under unknown admin. no.; CDL:180001-AH)
140076	Chevron Chemical Company (1971) Effect of Massive Paraquat Soil Treatment on Soil Leaching. (Unpublished study received Apr 7, 1971 under unknown admin. no.; CDL:180001-AI)
140346	Chevron Chemical Company (1970) The Fate of Carbon 14 Labelled Paraquat in Soil under Field Conditions. (Unpublished study received Apr 7, 1971 under unknown admin. no.; CD:180001-E)
140358	Tucker, B.V. (1969) Paraquat Stability in Soil. (Unpublished study received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180001-V)
5016652	Helling, C.S. (1971) Pesticide mobility in soils: II Applications of soil thin-layer chromatography. Proceedings of the Soil Science Society of America 35(5):737-743.

164-1 Terrestrial field dissipation

MRID	Citation Reference
23515	Ballantine, L.G.; Herman, M.M.; Coan, R.M.; et al. (1979) Bicep® plus Roundup® or Paraquat and Dual®/Princep® plus Roundup or Paraquat Tank Mix Soil Dissipation Studies: Report No. ABR-79101. (Unpublished study received Dec 10, 1979 under 100-583; prepared in cooperation with Chevron Chemical Co. and others, submitted by Ciba-Geigy Corp., Greens- boro, N.C.; CDL:241649-A)

27021 Chevron Chemical Company (1976) Residue Data Sheet: Soil: Test Number T-4088 (AG-A 4084 I-IV). (Unpublished study received Dec 10, 1979 under 100-583; submitted by Ciba-Geigy Corp., Greens- boro, N.C.; CDL:241649-F)

27022 Chevron Chemical Company (1976) Residue Data Sheet: Soil: Test Number T-4089 (AG-A 4085 I-IV). (Unpublished study received Dec 10, 1979 under 100-583; submitted by Ciba-Geigy Corp., Greens- boro, N.C.; CDL:241649-G)

27023 Chevron Chemical Company (1978) Residue Data Sheet: Soil: Test Number T-4834 (AG-A 6061). (Unpublished study received Dec 10, 1979 under 100-583; submitted by Ciba-Geigy Corp., Greensboro, N.C.; CDL:241649-H)

33836 Chevron Chemical Company (1957) Paraquat Residues in Soil. (Unpublished study received Oct 14, 1965 under 239-1994; CDL:001432-B)

52390 Gowman, M.A.; Riley, D.; Newby, S.E. (1980) Paraquat and Diquat: Long-Term High-Rate Trial, Frensham, UK. 2. Persistence and Movement in Soil, and Glasshouse Bioassays: Report Series RJ 0014 B. (Unpublished study received Jun 4, 1980 under 239-2186; prepared by ICI, submitted by Chevron Chemical Co., Richmond, Calif.; CDL:242577-B)

52394 Tucker, B.V.; Agbakoba, C.S.O. (1978) Paraquat Soil Residue Studies. (Unpublished study received Jun 4, 1980 under 239-2186; submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 242577-G)

55091 O'Toole, M.A. (1965) Residual effects of Paraquat on peat soil. Irish Journal of Agricultural Research 4(2):231-233. (Also In unpublished submission received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-G)

55093 Coats, G.E.; Funderburk, H.H., Jr.; Lawrence, J.H.; et al. (1964) Persistence of Diquat and Paraquat in pools and ponds. Proceedings, Southern Weed Control Conference 17:308-320. (Also In unpublished submission received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 180000-I)

55109 Geoghegan, M.J.; Newman, J.F.; Wilkinson, W. (1966) Bipyridylium Herbicides--Paraquat, Preliminary Observations on the Effects on Soil Organisms: Central File No. A.126,393. (Unpublished study received Apr 7, 1971 under unknown admin. no.; prepared by Imperial Chemical Industries, Ltd., submitted by Chevron Chemi- cal Co., Richmond, Calif.; CDL:180000-AB)

65606 Baldwin, B.C.; Knight, B.A.G. (1967) The Fate of Diquat in Soils: Survey of Present Knowledge: TMJ 224. (Unpublished study received Aug 22, 1977 under

239-1663; prepared by Imperial Chemical Industries Ltd., England, submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231430-F)

73770 Frank, P.A.; Comes, R.D. (19??) Herbicidal residues in pond water and hydrosoil. Weeds 15(Jul):210-213. (Also In unpublished submission received Aug 29, 1979 under 2217-624; submitted by PBI-Gordon Corp., Kansas City, Kans.; CDL:240872-P)

90396 California Chemical Company (1964) Paraquat Residues in Soil. (Compilation; unpublished study received Feb 25, 1965 under 5G0440; CDL:090479-B)

113724 Thompson-Hayward Chemical Co. (1967) Proposed Irrigation Study with Water Treated with Dichlobenil. (Compilation; unpublished study received Jan 12, 1968 under 148-673; CDL:000651-A)

114414 Chevron Chemical Co. (1967) Name, Chemical Identity and Composition of the Pesticide Chemical: (Paraquat). (Compilation; unpublished study received Apr 3, 1967 under 7F0592; CDL:092880-A)

114443 Whipp, A.; Thompson, R. (1962) Progress Report: Diquat and Paraquat Soil Residue Studies. (Unpublished study received Sep 4, 1962 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, CA; CDL:120436-A)

118549 Amchem Products, Inc. (1971) Fenac Residue Data--Total Water Treatment. (Compilation; unpublished study received Jul 7, 1972 under 2F1213; CDL:091039-T)

122696 Newman, J. (1976) Diquat: Biological Effects and Residues in Soil and Crops in a High Rate Field Trial on a Loamy Sand: TMJ 1225A. (Unpublished study received Dec 21, 1982 under 239-2247; pre- pared by Plant Protection, Ltd., Eng., submitted by Chevron Chemical Co., Richmond, CA; CDL:249103-E)

122704 Coats, G.; Funderburk, H.; Lawrence, J.; et al. (1963) Persistence of Diquat and Paraquat in Pools and Ponds. (Unpublished study received Dec 21, 1982 under 239-2247; prepared by Auburn Univ., Agricultural Experiment Station, submitted by Chevron Chemical Co., Richmond, CA; CDL:249104-I)

140345 Baldwin, B.C.; Slade, P. (1968) The Fate of Carbon-14 Labelled Paraquat in Soil under Field Conditions: AR 2220 B. (Unpublished study received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180001-D)

140346 Chevron Chemical Company (1970) The Fate of Carbon 14 Labelled Paraquat in Soil under Field Conditions. (Unpublished study received Apr 7, 1971 under unknown admin. no.; CD:180001-E)

140359 Baldwin, B.C.; Slade, P. (1970) Bipyridylium Herbicides: Residues of Paraquat in Soil following Field Application of Gramoxone: Report No. AR 2219 B. (Unpublished study received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180001-W)

140361 Gratton, R.P. (1970) The Significance of Paraquat Residues from the South African Trial PE/G/20 (b): Report Series TMJ 588 B. (Un- published study received Apr 7, 1971 under unknown admin. no.; prepared by Plant Protection, Ltd., submitted by Chevron Chemi- cal Co., Richmond, Calif.; CDL:18001-Y)

5013351 Doughty, C.C. (1978) Terbacil phytotoxicity and quackgrass (*Agropyron repens*) control in highbush blueberries (*Vaccinium corymbosum*). Weed Science 26(5):448-492.

41293201 Earl, M.; Anderson, L.; Muir, G. (1989) Paraquat: Field Soil Dissipation under In-use Conditions in the USA (Champaign, Illinois) during 1987-89--Analytical Report: Lab Project Nos. PP148BD05; RJ0781B; TMR0089B. Unpublished study prepared by ICI Agrochemicals, Jealott's Hill Research Station in cooperation with ICI Western Research Center. 93 p.

41293202 Anderson, E.; Muir, G. (1989) Paraquat Short Term Field Soil Dissipation under In-use Conditions in the USA (Sussex County, Delaware) during 1987-89: Analytical Report: Lab Project Numbers PP148BD04; RJ0776B; TMR0068B. Unpublished study prepared by ICI Agrochemicals, Jealott's Hill Research Station in cooperation with ICI Americas Western Research Center. 85 p.

41319303 Anderson, L.; Emburay, G.; Hoag, R.; et al. (1989) Paraquat: Field Soil Dissipation Under In-use Conditions in the USA (Leland, Mississippi) During 1987-1988: Lab Project Number: PP148BD05. Unpublished study prepared by ICI Agrochemicals. 122 p.

41319304 Anderson, L.; Muir, G.; Hoag, R. (1989) Paraquat: Field Dissipation under In-use Conditions in the USA (Visalia, California) during 1987-89: Lab Project Number: PP148BD05. Unpublished study prepared by ICI Agrochemicals. 129 p.

41352101 Anderson, L.; Embury, G.; Hoag, R.; et al. (1989) Paraquat: Short Term Field Soil Dissipation Under In-use Conditions in the USA (Pullman, Washington) during 1987-1989: Lab Project Number: PP148BD04: Report No. RJ0797B. Unpublished study prepared by ICI Agrochemicals. 102 p.

41352102 Anderson, L.; Embury, G.; Hoag, R. et al. (1989) Paraquat: Short Term Field Soil Dissipation under In-use Conditions in the USA (Clermont, Florida) During 1987-1989: Lab Project Number: PP148- BD04: Report No. RJ0794B. Unpublished study prepared by ICI Agrochemicals. 91 p.

164-2 Aquatic field dissipation

MRID	Citation Reference
31833	Yeo, R.R. (19??) Dissipation of Diquat and Paraquat and effects on aquatic weeds and fish. Weeds (?):42-46. (Also In unpublished submission received Sep 15, 1972 under 1F1101; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:090862-D)
31853	Austin, W.G.L.; Calderbank, A. (1964) Diquat and Paraquat: Residues in Water and Toxicity to Fish and Other Aquatic Fauna: Experimental Report No. PP/E/303. (Unpublished study received Sep 15, 1972 under 1F1101; prepared by Imperial Chemical Industries, Ltd., submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 090862-AC)
55093	Coats, G.E.; Funderburk, H.H., Jr.; Lawrence, J.H.; et al. (1964) Persistence of Diquat and Paraquat in pools and ponds. Proceedings, Southern Weed Control Conference 17:308-320. (Also In unpublished submission received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 180000-I)
55097	Austin, W.G.L.; Calderbank, A. (1964) Diquat and Paraquat: Residues in Water and Toxicity to Fish and Other Aquatic Fauna: Experimental Report No. PP/E/303. (Unpublished study received Apr 7, 1971 under unknown admin. no.; prepared by Plant Protection, Ltd., submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-M)
55100	Grzenda, A.R.; Nicholson, H.P.; Cox, W.S. (1966) Persistence of four herbicides in pond water. Journal of the American Water Works Association 58(Mar):326-332. (Also~In~unpublished sub- mission received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-P)
68226	Coats, G.E.; Funderburk, H.H., Jr.; Lawrence, J.M.; et al. (1964) Persistence of diquat and paraquat in pools and ponds. Proceedings of the Southern Weed Control Conference 17:308-320. (Also In unpublished submission received Aug 22, 1977 under 239- 1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 231431-J)
68232	Yeo, R.R. (1967) Dissipation of diquat and paraquat and effects on aquatic weeds and fish. Weeds 15:42-46. (Also In unpublished submission received Aug 22, 1977 under 239-1663; submitted by Chevron Chemical Co., Richmond, Calif.; CDL:231431-R)

73770 Frank, P.A.; Comes, R.D. (19??) Herbicidal residues in pond water and hydrosoil. Weeds 15(Jul):210-213. (Also In unpublished submission received Aug 29, 1979 under 2217-624; submitted by PBI-Gordon Corp., Kansas City, Kans.; CDL:240872-P)

113724 Thompson-Hayward Chemical Co. (1967) Proposed Irrigation Study with Water Treated with Dichlobenil. (Compilation; unpublished study received Jan 12, 1968 under 148-673; CDL:000651-A)

113733 Thompson-Hayward Chemical Co. (1967) Disappearance of Dichlobenil and 2,6-Dichlorobenzoic Acid in Water: Report R-649. (Compilation; unpublished study received Feb 23, 1967 under 148-673; CDL:000655-A)

116737 3M Co. (1970) Residue Analyses of 3MCAP-D and Other Chemicals in Various Products|. (Compilation; unpublished study received on unknown date under 10556-EX-1; CDL:127733-A)

118549 Amchem Products, Inc. (1971) Fenac Residue Data--Total Water Treatment. (Compilation; unpublished study received Jul 7, 1972 under 2F1213; CDL:091039-T)

122704 Coats, G.; Funderburk, H.; Lawrence, J.; et al. (1963) Persistence of Diquat and Paraquat in Pools and Ponds. (Unpublished study received Dec 21, 1982 under 239-2247; prepared by Auburn Univ., Agricultural Experiment Station, submitted by Chevron Chemical Co., Richmond, CA; CDL:249104-I)

135717 Chevron Chemical Co. (1970) Diquat: Residue Tolerance Petition: The Results of Tests on the Amount of Residue Remaining, Including a Description of the Analytical Methods Used: Water, Aquatic Life and Soil|. (Compilation; unpublished study received Dec 12, 1970 under 1F1101; CDL:090861-A)

164-5 Long term soil dissipation

MRID	Citation Reference
146803	Abell, J. (1984) High Rate Paraquat Soil Residue Trial: Mt. Holly New Jersey. Unpublished study prepared by Chevron Chemical Company. 12 p.
146804	Abell, J. (1984) High Rate Paraquat Soil Residue Trial: Fresno California. Unpublished study prepared by Chevron Chemical Company. 13 p.
146805	Riley, D.; Abell, J. (19??) Long Term Fate and Biological Activity of Bound Paraquat Residues in Soil. Unpublished study prepared by Jealotts Hill Research

Station and Chevron Chemical Co. 16 p.

42738701 Anderson, L.; Hoag, R.; Anders, C. et al. (1992) Paraquat: Field Soil Dissipation under In-Use Conditions in the USA During 1987-91 (Visalia, California): Lab Project Number: PP148BD05: RJ1191B. Unpublished study prepared by ICI Agrochemicals. 132 p.

42738702 Anderson, L.; Hoag, R.; Anders, C. et al. (1992) Paraquat: Field Soil Dissipation under In-Use Conditions in the USA During 1987-89 (Leland, Mississippi): Lab Project Number: PP148BD05: RJ1206B. Unpublished study prepared by ICI Agrochemicals. 98 p.

42802101 Anderson, L.; Hoag, R.; Safford, J. et al. (1992) Paraquat: Field Soil Dissipation under In-Use Conditions in the USA During 1987-91 (Champaign, Ill.): Lab Project Number: PP148BD05: RJ1187B. Unpublished study prepared by ICI Agrochemicals, Jealott's Hill. 127 p.

42802102 Anderson, L.; Hoag, R.; Anders, C. et al. (1992) Paraquat: Field Soil Dissipation under In-Use Conditions in the USA During 1987-91 (Goldsboro, NC): Lab Project Number: PP148BD05: RJ1146B. Unpublished study prepared by ICI Agrochemicals, Jealott's Hill. 116 p.

14.1.2 Ecological Effects Studies:

PC Codes: 061601 and 061602.

850.2100 Avian Single Dose Oral Toxicity

MRID	Citation Reference
29001	Fink, R.; Beavers, J.B.; Grimes, J.; et al. (1979) Acute Oral LDI50^--Bobwhite Quail: Paraquat dichloride Technical Salt (SX- 1142): Project No. 162-121. Final Rept. (Unpublished study received Feb 21, 1980 under 239-2422; prepared by Wildlife International, Ltd., submitted by Chevron Chemical Co., Rich- mond, Calif.; CDL:241819-A)
0160000	Hudson, R.; Tucker, R.; Haegele, M. (1984) Handbook of toxicity of pesticides to wildlife: Second edition. US Fish and Wildlife Service: Resource Publication 153. 91 p. Mallard study
49349901	Hubbard, P., Martin, K., and Beavers, J. 2014. Paraquat Dichloride — An Acute Oral

Toxicity Study with the Zebra Finch Using a Sequential Testing Procedure. Final Report. Wildlife International, Easton, MD. Report Number 528-416. Study sponsored by Syngenta Crop Protection, LLC, Greensboro, NC. Study initiated on December 30, 2013 and completed on March 20, 1998.

49378001 Johnson, A. 1998. Paraquat - Acute Oral LD_{50} to the Mallard Duck. Final Report. Study performed by Huntingdon Life Sciences Ltd., Cambridgeshire, England. Report Number ISN399/963860. Study sponsored by Zeneca Agrochemicals, Jealotts Hill Research Station, Berkshire, England and sponsored by Syngenta Crop Protection, LLC, Greensboro, North Carolina. Study initiated on December 18, 1996 and completed on March 20, 1998.

850.2200 Avian Dietary Toxicity

MRID	Citation Reference
55103	Ives, M. (1965) Report to Imperial Chemical Industries, Limited: Toxicity Studies on Pheasants and Wild Mallard Ducks: Paraquat Formulation. (Unpublished study received Apr 7, 1971 under unknown admin. no.; prepared by Industrial Bio-Test Labora- tories, Inc., submitted by Chevron Chemical Co., Richmond, Calif.; CDL:180000-S)
90975	Ives, M. (1965) Report to Imperial Chemical Industries Limited: Toxicity Studies on Pheasants and Wild Mallard Ducks, Paraquat Formulation. (Unpublished study received May 6, 1966 under 6F0483; prepared by Industrial Bio-Test Laboratories, Inc.; sub- mitted by Chevron Chemical Co., Richmond, Calif.; CDL:090542-W)
00022923	Hill, E.F.; Heath, R.G.; Spann, J.W.; et al. (1975) Lethal Dietary Toxicities of Environmental Pollutants to Birds: Special Scientific Report--Wildlife No. 191. Mallard, Japanese quail, Ring-necked pheasant, and bobwhite quail

850.2300 Avian Reproduction

MRID	Citation Reference
110454	Fink, R.; Beavers, J.; Joiner, G.; et al. (1982) One-generation Reproduction--Bobwhite Quail: Paraquat Technical (SX-1305): Project No. 162-142. Final rept. (Unpublished study received Aug 18, 1982 under 239-2186; prepared by Wildlife International Ltd., submitted by Chevron Chemical Co., Richmond, CA; CDL: 248133-C) LOEC=215 PPM
110455	Fink, R.; Beavers, J.; Joiner, G.; et al. (1982) One-generation Reproduction--Mallard

Duck: Paraquat Technical (SX-1305): Project No. 162-145. Final rept. (Unpublished study received Aug 18, 1982 under 239-2186; prepared by Wildlife International Ltd., submitted by Chevron Chemical Co., Richmond, CA; CDL: 248133-D) LOEC= 100 PPM

43942604 Hakin, B.; Chanter, D. (1988) The Effect of Paraquat on the Hatchability of Fertile Mallard Duck Eggs: Lab Project Number: ISN 170/881711: ISN/170. Unpublished study prepared by Huntingdon Research Centre, Ltd. 128 p.

43942605 Roberts, N.; Hakin, B.; Chanter, D. (1989) The Effect of Paraquat on the Hatchability of Fertile Pheasant Eggs: Amended Report: Lab Project Number: ISN 171/881712: ISN/171. Unpublished study prepared by Huntingdon Research Centre, Ltd. 134 p.

00025808 Dunachie, J.F.; Fletcher, W.W. (1967) Effect of some herbicides on the hatching rate of hen's eggs. Nature 215(?/Sep):1406-1407. (Also~In~unpublished submission received Jan 2, 1980 under 2217- 485; submitted by PBI-Gordon Corp., Kansas City, Kans.; CDL: 241581-K)

00055110 Fletcher, K. (1967) Production and Viability of eggs from hens treated with Paraquat. Nature 215(Sep 23):1407-1408. (Also~In~ unpublished submission received Apr 7, 1971 under unknown admin. no.; submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 180000-AC)

110453 Fink, R.; Beavers, J.; Joiner, G.; et al. (1981) Subacute Feeding-- Reproduction Screening Bioassay (Bobwhite Quail): Paraquat Technical (SX-1305): Project No. 162-138; S-1994. Final rept. (Unpublished study received Aug 18, 1982 under 239-2186; pre- pared by Wildlife International Ltd., submitted by Chevron Chemical Co., Richmond, CA; CDL:248133-B)

110452 Leary, J.; Tucker, B. (1981) Assessment of Diet Homogeneity and Stability of Paraquat Technical (SX-1305) in Game Bird Ration (Wildlife International Ltd. Project 162-136): Chevron File No. 721.11/S-1951. (Unpublished study received Aug 18, 1982 under 239-2186; submitted by Chevron Chemical Co., Richmond, CA; CDL:248133-A)

850.1075 Acute Toxicity to Freshwater Fish

MRID Citation Reference

31860 Beasley, P. (1965) Effects of Diquat and Paraquat on Channel Cat- fish Eggs and Fry. (Unpublished study received Sep 15, 1972 un- der 1F1101; prepared by Auburn Univ., Fisheries Dept., submitted by Chevron Chemical Co., Richmond, Calif.; CDL:090862-AJ)

113705 McCann, J. (1969) Ortho Paraquat CL: Bluegill|. (U.S. Agricul- tural Research Service,

Animal Biology Laboratory; unpublished study; CDL:103609-A)

118540 Lawrence, J. (1962) Observed Fish Mortality in Plastic Pools Treated with Herbicides during 1962. (Unpublished study received Jul 7, 1972 under 2F1213; prepared by Auburn Univ., Agr. Exp. Station, submitted by Amchem Products, Inc., Ambler, PA; CDL: 091039-I)

129075 Lorz, H.; Glenn, S.; Williams, R.; et al. (1979) Effects of Selected Herbicides on Smolting of Coho Salmon. By Oregon, Dept. of Fish and Wildlife, Research and Development Section and U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station. Corvallis, OR: US EPA. (EPA-600/3-79-071; Grant #R- 804283; pages i,iv-x,1,6-14,40-50,83-85,92 only; also In unpublished submission received Jun 24, 1983 under 464-502; submitted by Dow Chemical U.S.A., Midland, MI; CDL:250605-N)

134846 Calmbacher, C. (1978) The Acute Toxicity of Banvel 4 + Aatrex 80WP + Princip WP + Paraquat 2EC to the Bluegill Sunfish ...: UCES Proj. No. 11506-03-38. (Unpublished study received 1978 under 876-EX-33; prepared by Union Carbide Corp., submitted by Velsicol Chemical Corp., Chicago, IL; CDL:234452-B)

140031 Funderburk, H.H. (1963) Distribution of C14 Labeled Herbicides in Bluegills and Shellcrackers. Annual rept. 1963. (Unpublished study received Apr 19, 1968 under 264-EX-30G; prepared by Auburn Univ., Dept. of Botany and Plant Pathology, submitted by Union Carbide Agricultural Products Co., Inc., Ambler, Pa.; CDL: 123220-D)

139543 or 40094602 Johnson, W.; Finley, M. (1980) Handbook of Acute Toxicity of Chemi- cals to Fish and Aquatic Invertebrates. Washington, DC: U.S. Fish and Wildlife Service. (Resource publication 137; also In unpublished submission received Dec 15, 1983 under 239-2460; submitted by Chevron Chemical Co., Richmond, CA; CDL:252083-B)

162736 Palmateer, S. (1980) Biological Report of Analysis: [Toxicity Test of Paraquat on Rainbow Trout]. Unpublished study prepared by U.S. Environmental Protection Agency, Terrestrial & Aquatic Biology Laboratory. 1 p.

162737 Palmateer, S. (1979) Biological Report of Analysis: [Toxicity Test of Paraquat on Bluegills]. Unpublished study prepared by U.S. Environmental Protection Agency, Terrestrial & Aquatic Biology Laboratory. 1 p.

162738 McCann, J. (1977) Biological Report of Analysis: [Toxicity Test of Ortho Paraquat CL Concentrate on Rainbow trout]. Unpublished study prepared by U.S. Environmental Protection Agency, Animal Biology Laboratory. 1 p.

40098001 Mayer, F.; Ellersieck, M. (1986) Manual of Acute Toxicity: Inter- pretation and Data Base for 410 Chemicals and 66 Species of Freshwater Animals. US Fish & Wildlife Service, Resource Pub- lication 160. 579 p.
Rainbow trout, channel cat, bluegill,

850.1010 Acute Toxicity to Freshwater Invertebrates

MRID	**Citation Reference**
113694	Sanders, H.; Cope, O. (1966) Toxicities of several pesticides to two species of cladocerans. Trans**. Amer. Fish Soc. 95:165-169.** (Also In unpublished submission received Jun 13, 1979 under 239-2186; submitted by Chevron Chemical Co., Richmond, CA; CDL:098334-B)
114473	Wheeler, R. (1978) 48 Hour Acute Static Toxicity of Paraquat Dichloride Salt (SX957) to 1st Stage Nymph Water Fleas (Daphnia magna Straus). (Unpublished study received Sep 15, 1978 under 239-2422; submitted by Chevron Chemical Co., Richmond, CA; CDL:235419-A)
162752	Tompkins, J. (1979) Biological Report of Analysis: [Toxicity of Ortho Paraquat to Daphnia magna]. Unpublished study prepared by U.S. Environmental Protection Agency, Terrestrial & Aquatic Bio- logy Unit Laboratory. 1 p.
40098001	Mayer, F.; Ellersieck, M. (1986) Manual of Acute Toxicity: Inter- pretation and Data Base for 410 Chemicals and 66 Species of Freshwater Animals. US Fish & Wildlife Service, Resource Pub- lication 160. 579 p. - Daphnia, stonefly nymph and Gammarus faciatus

850.1075/850.1025/850.1035 Acute Exposures to Estuarine/Marine Organisms

40228401	Mayer, F.L. USEPA Gulfbreeze Estuarine Toxicity tests - marine algaes, brown shrimp, oyster, longnose killifish
49320301	Claude, MB, KH Martin, SP Gallagher. (2014) Paraquat Dichloride – A 96-Hour Shell Deposition Test with the Eastern Oyster (Crassostrea virginica). Study performed by Wildlife International, Easton, Maryland, USA. Laboratory report ID: 528A-259. Study sponsored by Syngenta Crop Protection, LLC. Greensboro, North Carolina, USA. Study completed: January 21, 2014.
49320302	Claude, MB, KH Martin, SP Gallagher. (2014) Paraquat Dichloride – A 96-Hour Flow-Through Acute Toxicity Test with the Saltwater Mysid (*Americamysis bahia*). Study performed by Wildlife International, Easton, Maryland, USA. Laboratory

	report ID: 528A-257. Study sponsored by Syngenta Crop Protection, LLC. Greensboro, North Carolina, USA. Study completed: January 30, 2014.
49320303	Claude, M.B., K.H. Martin, and S.P. Gallagher. 2014. Paraquat Dichloride – A 96-Hour Flow-Through Acute Toxicity Test with the Fathead Minnow (*Pimephales promelas*). Study conducted by Wildlife International, Easton, Maryland, USA. Laboratory Project ID: 528A-258. Study sponsored by Syngenta Crop Protection, LLC, Greensboro, North Carolina, USA. Study initiated on September 3, 2013 and completed January 23, 2014.
49320304	Claude, M.B., K.H. Martin, and S.P. Gallagher. Paraquat Dichloride – A 96-Hour Flow-Through Toxicity Test with the Sheepshead Minnow (*Cyprinodon variegatus*). Study conducted by Wildlife International, Easton, Maryland, USA. Laboratory Project ID: 528A-264. Study sponsored by Syngenta Crop Protection, LLC, Greensboro, North Carolina, USA. Study initiated on September 24, 2013 and completed January 24, 2014.

850.1300/850.1350/850.1400 Fish Early Life Stage/Aquatic Invertebrate Life Cycle Study

MRID	Citation Reference
31853 or 55097	Austin, W.G.L.; Calderbank, A. (1964) Diquat and Paraquat: Residues in Water and Toxicity to Fish and Other Aquatic Fauna: Experimental Report No. PP/E/303. (Unpublished study received Sep 15, 1972 under 1F1101; prepared by Imperial Chemical Industries, Ltd., submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 090862-AC)
55714	Silvo, O.E.J. (1967) Alustavia Tutkimuksia Eraiden Herbisidien Myrkyllisyydesta Nuorille Karpin Poikasille (~Cyprinus carpio~ L~.). N.P. (Suomen Kalatalous 32 Finlands Fiskerier; incom- plete; also~In~unpublished submission received Jul 11, 1961 un- der 1E1046; submitted by U.S. Dept. of the Army, Washington, D.C.; CDL:093359-X)
49320305	Claude, M.B., K.H. Martin, and S.P. Gallagher. 2014. Paraquat Dichloride – A Flow-Through Life-Cycle Toxicity Test with the Cladoceran (*Daphnia magna)*. Unpublished study performed by Wildlife International Easton, Maryland, USA. Laboratory Study No. 528A-260. Study sponsored by Syngenta Crop Protection, LLC, Greensboro, North Carolina, USA. Study initiated September 6, 2013 and completed February 14, 2014.
49320306	Claude, M.B., K.H. Martin, S.P. Gallagher, E.S. Bodle, and H.O. Krueger. 2014. Paraquat Dichloride – A Flow-Through Life-Cycle Toxicity Test with the Saltwater

	Mysid (*Americamysis bahia*). Unpublished study performed by Wildlife International Easton, Maryland, USA. Laboratory Study No. 528A-261. Study sponsored by Syngenta Crop Protection, LLC, Greensboro, North Carolina, USA. Study completed February 14, 2014.
49320307	Claude, M. *et al*. 2014. Paraquat Dichloride: An Early Life-Stage Toxicity Test with the Fathead Minnow (*Pimephales promelas*). Unpublished study performed by Wildlife International, Easton, Maryland. Laboratory Study No. 528A-262. Study sponsored by Syngenta Crop Protection, LLC, Greensboro, NC. Study initiated October 10, 2013 and completed February 14, 2014.
49320308	Claude, M. *et al*. 2014. Paraquat Dichloride-An Early Life-Stage Toxicity Test with the Sheepshead Minnow (*Cyprinodon variegatus*). Unpublished study performed by Wildlife International, Easton, Maryland, USA. Laboratory Study No. 528A-263. Study sponsored by Syngenta Crop Protection, LLC, Greensboro, North Carolina, USA. Study initiated October 29, 2013 and completed February 14, 2014.

850.1735/850.1740/ Non-Guideline Sediment Toxicity Studies

MRID	Citation Reference
36935	Atkins, E.L.; Greywood, E.A.; Macdonald, R.L. (1975) Toxicity of Pesticides and Other Agricultural Chemicals to Honey Bees: Labo- ratory Studies. By University of California, Dept. of Entomolo- gy. ?: UC, Cooperative Extension. (Leaflet 2287; published study.)
48877201	Hamer, M.J. 1998. Paraquat – Sediment Toxicity Test with *Chironomous riparius*. Study performed by Zeneca Agrochemicals. Laboratory report ID: RJ2649B. Study sponsored by Syngenta Crop Protection, LLC. Study completed: July 30, 1998. OECD Guideline 218.
48877202	Algal study with dosed sediment; listed under 850.4500.
49577001	Bradley, M.J. 2015. 10-Day Toxicity Test Exposing Midge (*Chironomus dilutus*) to Paraquat Dichloride Applied to Sediment Under Static-Renewal Conditions Following OCSPP Draft Guideline 850.1735. Unpublished study performed by Smithers Viscient, Wareham, MA, USA. Laboratory Study No. 1781.7016. Study sponsored by Syngenta Crop Protection, LLC, Greensboro, North Carolina, USA. Study completed February 13, 2015 (Final Report Amendment 1).
49577002	Bradley, M.J. 2015. 10-Day Toxicity Test Exposing Estuarine Amphipods (*Leptocheirus plumulosus*) to Paraquat Dichloride Applied to Sediment under

	Static Conditions Following OCSPP Draft Guideline 850.1740. Unpublished study performed by Smithers Viscient, Wareham, MA, USA. Laboratory Study No. 1781.7018. Study sponsored by Syngenta Crop Protection, LLC, Greensboro, North Carolina, USA. Study completed February 13, 2015.
49577003	Bradley, M.J. 2015. 10-Day Toxicity Test Exposing Amphipods (Hyalella azteca) to Paraquat Dichloride Applied to Sediment Under Static-Renewal Conditions Following OCSPP Draft Guideline 850.1735. Unpublished study performed by Smithers Viscient, Wareham, MA, USA. Laboratory Study No. 1781.7017. Study sponsored by Syngenta Crop Protection, LLC, Greensboro, North Carolina, USA. Study completed February 13, 2015.

850.4400 Aquatic plant growth– Vascular Plants

MRID	Citation Reference
40165104	Blackburn, R.; Weldon, L. (1965) The Sensitivity of Duckweeds (Le- mnaceae) and Azolla to Diquat and Paraquat: Laboratory Project ID: #87022-C and #87025-C. Unpublished study prepared by US Agricultural Research Service, Fort Lauderdale, Florida. 5 p.

850.4500 Aquatic plant growth- Algae

MRID	Citation Reference
42601002	Smyth, D.; Sankey, S.; Penwell, A. (1992) Paraquat Dichloride: Toxicity to the Green Alga Selenastrum capricornutum: Lab Project Number: BL4578/B: T168/G (FT11/92). Unpublished study prepared by Imperial Chemical Industries PLC. 23 p.
42601003	Smyth, D.; Sankey, S.; Cornish, S.; et al (1992) Paraquat Dichloride: Toxicity to the Duckweed Lemna Gibba: Lab Project Number: BL4493/B: T168/E (FT10/92). Unpublished study prepared by Imperial Chemical Industries PLC. 24 p.
42601004	Smyth, D.; Sankey, S.; Penwell, A. (1992) Paraquat Dichloride: Toxicity to the Marine Alga Skeletonema costatum: Lab Project Number: BL4580/B: T168/C (FT08/92). Unpublished study prepared by Imperial Chemical Industries PLC. 22 p.
42601005	Smyth, D.; Sankey, S.; Cornish, S. (1992) Paraquat Dichloride: Toxicity to the Blue-green Alga Anabaena flos-aquae: Lab Project Number: BL4579/B: T168/B (FT07/92). Unpublished study prepared by Imperial Chemical Industries PLC. 26 p.
42601006	Smyth, D.; Sankey, S.; Cornish, S. (1992) Paraquat Dichloride: Toxicity to the Freshwater diatom Navicula pelliculosa: Lab Project Number: BL4464/B: T168/D (FT09/92). Unpublished study prepared by Imperial Chemical Industries PLC. 22 p.
48877202	Shillabeer, N. 2000. Paraquat Dichloride: Toxicity to the Freshwater diatom

Navicula pelliculosa: Lab Project Number:AG0463B. Brixham Laboratories, Devon UK. Sponsor- Syngenta.

850.4100 Seed Emergence

42639601 Canning, L. and J.S. White. 1992. Paraquat: A Glasshouse Study to Evaluate the Effects on Seedling Emergence of a 300 g ai litre^{-1} (2.5 lb ai US gal^{-1}) Soluble Concentrate Formulation on Terrestrial Non-target Plants. Laboratory Project ID No. 92JH089. Conducted by ICI Agrochemicals, Jealotts Hill Research Station, Bracknell, Berkshire, UK. Submitted by ICI Americas Inc., Wilmington, DE. EPA MRID No. 426396-01.

49320310 Martin, J. Paraquat Dichloride (A7813Q) – Seedling Emergence Test. Final Report. Unpublished study performed by Smithers Viscient, Wareham, MA. Study Number: 1781.6948. Study sponsored by Syngenta Crop Protection, LLC. Study completed January 23, 2014.

850.4150 Vegetative Vigor

42601001 Canning, L. and J.S. White. 1992. Paraquat: A Glasshouse Study to Evaluate the Effects on Vegetative Vigour of a 300 g ai litre^{-1} (2.5 lb ai US gal^{-1}) Soluble Concentrate Formulation on Terrestrial Non-target Plants. Laboratory Project ID No. 92JH088. Conducted by ICI Agrochemicals, Jealotts Hill Research Station, Bracknell, Berkshire, UK. Submitted by ICI Americas, Inc., Wilmington, DE. EPA MRID No. 426010-01.

49320309 Martin, J.A. Paraquat Dichloride (A7813Q) – Vegetative Vigor Test. Final Report. Unpublished study performed by Smithers Viscient, Wareham, MA. Project No.: 1781.6947. Study sponsored by Syngenta Crop Protection, LLC. Study completed January 23, 2014.

850.3020 Honey bee acute contact

MRID	**Citation Reference**
43942603	Bull, J.; Wilkinson, W. (1987) Paraquat: Acute 5-Day Contact and Oral Toxicity to Honey Bees (Apis mellifera): Lab Project Number: RJ0578B: PP148CM008. Unpublished study prepared by ICI Plant Protection Division. 27 p.
00036935	Atkins, E.L.; Greywood, E.A.; Macdonald, R.L. (1975) Toxicity of Pesticides and Other Agricultural Chemicals to Honey Bees: Labo- ratory Studies. By University of California, Dept. of Entomolo- gy. ?: UC, Cooperative Extension. (Leaflet 2287; published study.)
00111488	Moffett, J.; Morton, H.; MacDonald, R. (1972) Toxicity of some herbicidal sprays

to honey bees. Journal of Economic Entomology 65(1):32-36. (Also In unpublished submission received Sep 26, 1974 under 464-323; submitted by Dow Chemical U.S.A., Midland, MI; CDL:120345-H) - reviewed by A. Vaughan

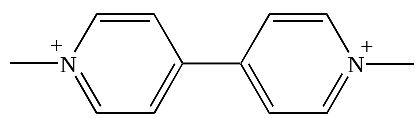
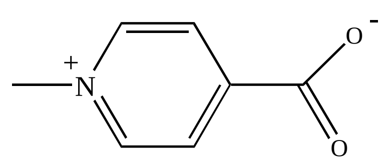
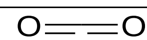
05001991 Stevenson, J.H. (1978) The acute toxicity of unformulated pesticides to worker honey bees (?~Apis mellifera~L_). Plant Pathology 27(1):38-40.

Simulated or Actual Field Testing

MRID	Citation Reference
23951	Larsen, H.H.; Hartman, R.F.; Cooper, R.F.; et al. (1976) Aquazine ^(R)I: As an Exposed Bottom Treatment for Fish Hatchery, Fish Rearing and Other Ponds with Draining Capabilities. (Unpub- lished study received Aug 26, 1977 under 100-437; prepared in cooperation with U.S. Fish and Wildlife Service, National Fish Hatchery and others, submitted by Ciba-Geigy Corp., Greensboro, N.C.; CDL:231410-A)
31847	Lawrence, J.M. (1965) Effects of Single and Repeated Applications of Diquat and Paraquat on Fathead Minnow and Channel Catfish Production in Plastic Pools. (Unpublished study received Sep 15, 1972 under 1F1101; prepared by Auburn Univ., Fisheries Dept., submitted by Chevron Chemical Co., Richmond, Calif.; CDL: 090862-U)
111488	Moffett, J.; Morton, H.; MacDonald, R. (1972) Toxicity of some herbicidal sprays to honey bees. Journal of Economic Entomology 65(1):32-36. (Also In unpublished submission received Sep 26, 1974 under 464-323; submitted by Dow Chemical U.S.A., Midland, MI; CDL:120345-H)

Appendix A. ROCKs table

Table B1. Chemical Names and Structures of Paraquat and its Transformation Products

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (day)
PARENT						
Paraquat Cation	1,1'-dimethyl-4,4'-bipyridinium CAS No.: 4685-14-7 Formula: $C_{12}H_{14}N_2$ MW: 186.25 g/mol SMILES: C[n+]1ccc(cc1)c2cc[n+](C)cc2		Hydrolysis – all pH	00148506		100% (30 @ 25°C) 100% (30 @ 40°C)
			Aqueous photolysis in pH 7 buffer	40562301		100% (37)
			Soil photolysis	00146807		100% (?)
			Aerobic Soil	41319301		93% (180)
			Anaerobic Soil	41319302		94.2% (90)
			Aerobic Aquatic	00055093		100% (?)
			Anaerobic Aquatic	No study		NA
MAJOR (>10%) TRANSFORMATION PRODUCTS						
			None			
MINOR (<10%) TRANSFORMATION PRODUCTS						
4-carboxy-1-methylpyridinium	(RS)-2’-(4,6-dimethoxypyrimidin-2-yl)hydroxymethyl-6’-methoxymethyl-1,1-difluoromethanesulfonamide CAS No.: 221205-90-9 Formula: C16H19F2N3O6S MW: 419.40 g/mol SMILES: c1(COC)c(NS(=O)(=O)C(F)F)c(C(O)c2nc(OC)cc(OC)n2)ccc1		This compound was identified in a literature study as a minor photodegradate and is the subject of a leaching study (MRID 00114414-B).	Literature study	NA	NA
Carbon dioxide	Carbon dioxide		Aerobic Soil	41319301	<0.1% (180)	<0.1% (180)

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (day)
	Formula: CO_2 MW: 44.1 g/mol SMILES: O=C=O		Anaerobic Soil	41319302	<0.1% (180)	<0.1% (90)
			Aerobic Aquatic	00055093	?	?
Unextracted residues	(not applicable)	(not applicable)	Aerobic Soil	41319301	4.1% (0)	0.7% (180)
			Anaerobic Soil	41319302	4.1% (0)	0.75% (90)
			Aerobic Aquatic	00055093	?	?

AR means “applied radioactivity”. MW means “molecular weight”.

Appendix B. Paraquat Toxicity Data

The purpose of this appendix is to update the comprehensive toxicity list to include toxicity studies newly submitted or amended since the problem formulation (USEPA, 2011; note: references cited in this appendix are listed at the end of the appendix). Several plant and avian toxicity studies were amended at the time of the problem formulation and those changes already captured in that document. Since that time, one plant study was amended and additional submitted studies reviewed—newly reviewed studies include: two aquatic invertebrate acute studies, three benthic invertebrate (sediment toxicity) acute studies, one benthic invertebrate (sediment toxicity) emergence study, one algal (non-guideline alteration for sediment exposure) study, two aquatic invertebrate chronic studies, two fish acute studies, two fish early life-stage studies, two avian acute oral studies, three avian reproduction studies, and two terrestrial plant studies. Data from these studies are included in the following tables (identified as "NEW") and endpoints that were determined to be the most sensitive/defensible ones for risk calculation are also included in the body of this document (**Table 6-1** and **Table 6-2**). These studies fulfill the data gaps, with the exception of some pollinator studies, which were requested after the problem formulation (and possibly a need for chronic sediment toxicity data with the amphipod, *Hyalella*--see note on the chronic midge study below).

The data presented in this appendix are from studies submitted by registrants or from the public literature, identified using ECOTOX (USEPA, 2007); an ECOTOX run from December, 2008 was checked during for the problem formulation (USEPA, 2011) and the on-line database rechecked in June, 2018. In the recheck, public literature was searched for studies with more sensitive endpoints, but none were identified for further review.

As described in the problem formulation (USEPA, 2011, see especially **Section 4.3 Environmental Fate and Transport, Degradation section**, and **Section 4.5 Nature of Stressor**), paraquat dichloride is generally applied as a flowable solution, already dissociated into its cation, paraquat, and paraquat is stable in the environment, with no major degradates of concern. Although only the paraquat dichloride form is currently registered (PC code 061601), toxicity data are also considered for paraquat (PC code 061603), and paraquat bis (methyl sulfate) (PC code 061602). All toxicity values, consistent with the problem formulation and the response to comments (USEPA, 2012), were converted (as needed) from paraquat dichloride (molecular weight: 257.158 g/mol) to the paraquat cation (molecular weight: 186.258 g/mol) by using a conversion factor of 0.724294.

Toxicity to Aquatic Organisms

A comprehensive list of available toxicity data for aquatic invertebrates and fish is found in **Table B-1**. A summary of data from most of the studies is found in the problem formulation (USEPA, 2011) and the red-legged frog assessment (USEPA, 2009); the new data reviewed since the problem formulation are noted as "NEW" in the MRID/Classification column.

Table B-1. Summary of Aquatic Toxicity Data for Paraquat Expressed as Paraquat Cation.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Freshwater Invertebrates Acute Toxicity 850.1010 (or equivalent §72-2) Unless Noted:				
Water Flea *Daphnia magna*	TGAI: (92.3% paraquat dichloride) 66.8% cation	48-hr EC_{50} = 1.3 (1.0-1.5) Slope: 4.4	00114473 Supplemental (quantitatively usable)	**Most sensitive/defensible aquatic invertebrate acute endpoint:** EC_{50} = 1.3 mg cation/L based on immobility. Static test with measured concentrations. The endpoint may be used quantitatively. Some uncertainty is associated with the EC_{50} value because the test did not include any treatment levels where no mortality was observed (three levels total).
Water Flea *D. magna*	Formulation	48-hr EC_{50} = 1.7	162752 Supplemental	
Water Flea *D. magna*	Formulation: 21.2%	48-hr EC_{50} = 3.6 (2.7-4.7) Slope: 4.8	40098001 Supplemental	From collection of Mayer & Ellersieck, 1986.
Water Flea *D. magna*	Formulation: 21.2%	48-hr EC_{50} = 3.8 (2.8-5.2) Slope: 3.6	40098001 Supplemental	From collection of Mayer & Ellersieck, 1986.
Water Flea *D. magna*	Formulation Paraquat dichloride (1,1'-dimethyl-4,4'bipyridinium chloride): 29.1%	48-hr EC_{50} = 8.0 (3.4-18.7) mg formulation/L (approx. 2.3 mg cation/L)	00162752 Supplemental	

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Stonefly *Pteronarcys californica*	Formulation: 21.2%	96-hr EC_{50} >10	40098001 Supplemental	From collection of Mayer & Ellersieck, 1986
Scud *Gammarus fasciatus*	Formulation: 21.2%	96-hr EC_{50} = 12 (6.2-15) Slope: 4.1	40098001 Supplemental	From collection of Mayer & Ellersieck, 1986.
Water Flea *Diaphanosoma excisum*	TGAI: (Purity Unknown)	48-hr (roughly LC_{50} at the LOAEC) NOAEC/ LOAEC approximately 0.004/ 0.04 (0.0058/ 0.0577 mg a.i./L in paper)	E112408 (Leboulanger, *et. al.*, 2009) Supplemental (qualitatively usable) NEW	Effect was 40-60% mortality in 24-hours and 60-80% mortality at 48-hours. In the same study, another species, *Moina micrura,* had a 48-hr LC_{50} between *0.04 and 0.40 mg cation/L (0.0577 and 0.577 mg a.i./L reported), with 100% mortality at 0.40 mg cation/L.* Insufficient information is available from the open literature publication for the endpoint to be quantitatively usable to calculate risk, but does suggest that some crustacea may be more sensitive than the available quantitatively usable endpoints.
Saltwater Invertebrates Acute Toxicity:				
Mysid and Non-Guideline Saltwater Crustacea 850.1035 (or equivalent §72-3C):				
Mysid *Americamysis bahia*	TGAI: (46.3% paraquat dichloride) 33.5% cation	96-hr LC_{50} = 0.228 (0.188-0.277) Slope: 4.91	49320302 Acceptable	**Most sensitive/defensible E/M crustacean acute endpoint:** EC_{50} = 0.228 mg cation/L. Flow-through study with mean-measured concentrations.
Brown Shrimp (*Penaeus aztecus)*	Formulation	96-hr EC_{50} >0.72	40228401 Supplemental	This endpoint is from the U.S. EPA Gulfbreeze lab collection and was not the most sensitive endpoint and, therefore, was not further investigated to determine if the endpoint is quantitatively usable or to supply further details.
Oyster Shell Deposition 850.1025:				
Eastern Oyster *Crassostrea virgninica*	TGAI: (46.3% paraquat dichloride) 33.5% cation	96-hr EC/IC_{50} = 22.5 (14.0-36.3)	49320301 Acceptable New	**Most sensitive/defensible mollusk acute endpoint:** EC/IC_{50} = 22.5 mg cation/L. Flow-through study with mean-measured concentrations.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Eastern Oyster *C. virgninica*	Formulation	96-hr EC/IC$_{50}$ >0.72	40228401 Supplemental	This endpoint is from the U.S. EPA Gulfbreeze lab collection and was not the most defensible endpoint (did not appear to be tested at high enough concentrations for definitive endpoint)) and, therefore, was not further investigated to determine if the endpoint is quantitatively usable or to supply further details.
Invertebrate Chronic Toxicity – Life Cycle Test 850.1300/850.1350 (or equivalent §72-4b):				
Mysid *A. bahia*	TGAI: (46.3% paraquat dichloride) 33.5% cation	28-day (32-day total) NOAEC / LOAEC = 0.038/0.076 based on survival and reproduction	49320306 Acceptable NEW	**Most sensitive/defensible aquatic invertebrate chronic endpoint:** NOAEC / LOAEC = 0.038/0.076 mg cation/L based on survival and reproduction. Flow-through study with mean-measured concentrations. Study duration was 32 days total (second generation = 96 hours); at least 7 days past the median time of first brood release in controls (Day 19). The NOAEC/LOAEC of 0.038/0.076 mg cation/L was based on F_0 (post-pairing) survival and F_1 survival and on number of offspring/female day. At 0.076 mg cation/L, F_0 and F_1 respective survival were significantly ($p<0.05$) reduced by 38.4% and 20.5%; also offspring/female were reduced by 49.7% (also 51.7% reduction in offspring/reproductive day) and the pattern appeared to be dose:dependent with 100% reduction in the next higher treatment (only 32% of the adults survived in that treatment, which was the 0.153 mg cation/L treatment). Even though this was not statistically significant due to variability, it is deemed biologically significant. Both mortality and reproduction impairment measurements strongly support that effects are seen at or near the LOAEC. **Other Endpoints:** **Time to First Brood:** NOAEC: 0.076 mg cation/L LOAEC: >0.076 mg cation/L **Growth (Dry Weight and Length of both Males and Females):** NOAEC: 0.153 mg cation/L LOAEC: >0.153 mg cation/L

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Water Flea *D. magna*	TGAI: (46.3% paraquat dichloride) 33.5% cation	21-day NOAEC / LOAEC = 0.097/0.20 based on growth	49320305 Acceptable NEW	**Most sensitive/defensible freshwater invertebrate chronic endpoint:** NOAEC / LOAEC = 0.097/0.20 mg cation/L based on growth. Flow-through study with mean-measured concentrations. The NOAEC/LOAEC of 0.097/0.20 mg cation/L was based on a significant ($p<0.05$) 4% reduction in mean length and a 22% reduction in mean dry weight that was determined to be biologically significant, although it was not statistically significant ($p<0,05$) due to variability. The LOAEC was supported by a weight of evidence in that although the 4% reduction in mean total length was a significant ($p<0.05$) reduction, the small amount of change might be questionable. The next higher treatment level (0.40 mg cation/L) had no survival after 21 days, and significant ($p<0.05$) 86.5% reduction in mean young/surviving adult, which strongly supports that effects are seen at or near the LOAEC. **Other Endpoints:** **Reproduction:** **Mean Neonates Per Reproductive Day:** NOAEC: 0.20 mg cation/L LOAEC: 0.40 mg cation/L **Cumulative Offspring:** NOAEC: 0.20 mg cation/L LOAEC: >0.20 mg cation/L **Survival:** 21-day LC_{50} = 0.269 (0.252-0.288): Slope: N/A NOAEC: 0.20 mg cation/L LOAEC: 0.40 mg cation/L

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Water Flea *D. magna*	Unknown	21-day NOAEC/ LOAEC approximately 0.007/ 0.07 (0.01/ 0.1 mg a.i./L in paper) based on reproduction	E118906 (Ha and Choi, 2009) Supplemental (qualitatively usable) NEW	Based on significant ($p<0.05$) approximately (obtained from visual inspection of graph in publication) 30% reduction in reproduction (progeny) at 100 ug /L of paraquat. However, the paper was unclear whether test substance was paraquat dichloride or cation and whether measured or nominal. Due to insufficient information, the endpoints are qualitatively usable to describe risk but not quantitatively usable to calculate risk. so is qualitative and not quantitatively usable to calculate risk.
Sub-Acute Toxicity in Whole Sediment 850.1735 and 850.1740 (or similar):				
Freshwater Amphipod *Hyalella azteca*	TGAI (Paraquat dichloride): 99.4% (97.8 % radiochemical purity)	10-day NOAEC / LOAEC = 30/ 61 mg cation/kg-dw (0.00072/ 0.0015 mg cation/kg-TOC; 0.060/ 0.120 mg cation/L estimated pore water-see Notes) based on survival and growth (dry weight)	49577003 Acceptable NEW	**Most sensitive/defensible acute benthic invertebrate sediment-toxicity endpoint:** NOAEC / LOAEC = 0.00072/ 0.0015 mg cation/kg-TOC based on survival; NOAEC also based on growth (dry weight). Endpoint based on significant ($p<0.05$) 84% reduction in survival at the LOAEC; also, for dry weight there was no significant reduction at the NOAEC, but due to survival reduction at the next higher treatment, the LOAEC was not determined and is considered to be >0.00072 mg cation/kg-TOC. Single application of test substance to sediment with intermittent flow-through of overlying water and mean-measured sediment (bulk and OC-normalized). The mean-measured concentrations were total reactive residue of paraquat cation. Due to unreliable pore water measurement estimates, the pore water concentration at the NOAEC and LOAEC were not included in the DER for estimates of the NOAEC and LOAEC. However, the pore water NOAEC may be estimated using a simple ratio from the midge study (49577001), which had usable pore water concentrations: 0.21 ÷ 90 = adjustment factor of 0.00233. Using this factor, the estimated pore water NOAEC would be 0.070 mg cation/L. As a check, in this *Hyalella* study, two treatment levels (the lowest and highest) had measureable pore water concentrations. Using ratios from these data give similar NOAEC pore water estimates, ranging from 0.071-0.045 mg cation/L, with the highest

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
				slightly below (86% of) the estimate using the midge data: 6.3 mg/kg nominal: 5.5 mg cat./kg-dw, 0.013 mg cation/L --Ratio: 0.0024 (Pore water NOEC est. 30*0.0024 = 0.071 mg cation/L 100 mg/kg nominal: 87 mg cat./kg-dw – 0.13 mg cation/L --Ratio: 0.0015 (Pore water NOEC est.: 0.045mg cation/L} However, because the midge study was conducted using artificial sediment, and the *Hyalella* study using natural sediment, the pore water estimate using the mean ratio from the two measured treatments in the *Hyalella* study (0.0024 and 0.0015, mean: 0.0020) seems to be the best estimate and is used here to estimate the NOAEC and LOAEC; although the midge ratio estimate gives some support to this estimate, uncertainty is acknowledged. **Other Endpoints:** **Based on Organic Carbon:** 0.00072/ 0.0015 mg cation/kg-TOC based on survival and growth (dry weight)
Midge *Chironomus riparius*	TGAI (Paraquat dichloride): 99.4% (97.8 % radiochemical purity)	10-day NOAEC / LOAEC = 90/ >90 mg cation/kg-dw (0.21/ >0.21 mg cation/L pore water) based on survival and growth (AFDW)	49577001 Acceptable NEW	Single application of test substance to sediment with intermittent flow-through of overlying water and mean-measured sediment (bulk and OC-normalized), mean-measured pore water, and mean-measured overlying water concentrations. The mean-measured concentrations were total reactive residue of paraquat cation. **Other Endpoints:** **Overlying Water:** NOAEC / LOAEC = 0.090/ >0.090 mg cation/L based on no significant (p<0.05) reduction in survival or growth (AFDW) **Bulk Sediment:** NOAEC / LOAEC = 0.0047/ >0.0047 mg cation/kg-TOC based on no significant (p<0.05) reduction in survival or growth (AFDW)

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Estuarine-Marine Amphipod *Leptocheirus plumulosus*	TGAI (Paraquat dichloride): 99.4% (97.8 % radiochemical purity)	10-day NOAEC / LOAEC = 99/ >99 mg cation/kg-dw (no pore water estimate-see Notes) based on survival	49577002 Acceptable NEW	Single application of test substance to sediment with static conditions and mean-measured sediment (bulk and OC-normalized) concentrations. The mean-measured concentrations were total reactive residue of paraquat cation. Pore water measured concentrations had similar problems to those of the *Hyalella* study, with only detectable levels in the highest and lowest treatments. However, no further attempt was made to estimate pore water concentrations for this study since the saltwater amphipod was not as sensitive as the freshwater amphipod, *Hyalella*. **Other Endpoints:** **Bulk Sediment:** NOAEC / LOAEC = 0.0025/ >0.0025 mg cation/kg-TOC based on no significant ($p<0.05$) reduction in survival
Chronic Toxicity in Whole Sediment NG Chronic Sediment (OECD Guideline 218, or similar):				
Midge *C. riparius*	Chronic TGAI (Paraquat dichloride): 34.1%	21-day NOAEC / LOAEC = 68/ >68 mg cation (94/ >94 mg TRR)/ kg-dw (no pore water estimate-see Notes) based on emergence	48877201 Supplemental (quantitatively usable) NEW	**Most sensitive/defensible chronic benthic invertebrate sediment-toxicity endpoint:** NOAEC / LOAEC = 68/ >68 mg cation/ kg-dw based on emergence. Static initial-measured concentration of total reactive residues, with aeration. The study was conducted at a single level of 100 mg Paraquat ion/kg-dw sediment (nominal concentration). No significant effects were measured in number/percent emerged or mean time to emergence. DER reported result as TRR of paraquat dioxide; used conversion: 94* 186.258/257.158 = 68 mg. Pore water concentrations were not measured in this study. Based on the bulk sediment NOAEC/ LOAEC values, the midge chronic estimates from this 21-day study (68/ >68 mg cation/kg-dw) were not as sensitive as the *Hyalella* 10-day survival endpoints (30/ 61 mg cation/kg-dw). Therefore, no further attempt was made to estimate the pore water concentration. Due to the persistence of paraquat, this is a data gap and chronic data on *Hyalella* may be needed.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Freshwater Fish Acute Toxicity 850.1075 (or equivalent §72-1A):				
Fathead Minnow *Pimephales promelas*	TGAI: (paraquat dichloride: 46.3%) 33.5% cation	96-hr LC_{50} = 4.7 (3.0 to 8.5) Probit Slope: 4.0 (1.3 to 6.7)	49320303 Acceptable	**Most sensitive/defensible freshwater fish and aquatic-phase amphibians acute endpoint:** 96-hr LC_{50} = 4.7 mg cation/L. Flow-through study with mean-measured concentrations.
Rainbow Trout *Oncorhynchus mykiss*	Formulation	96-hr EC_{50} = 6.1	00162736 Supplemental	
Rainbow Trout *O. mykiss*	Formulation	96-hr EC_{50} = 8.1 (8.0-8.3)	162738/ Acc. No. 264880 Supplemental	
Rainbow Trout *O. mykiss*	Formulation: 21.2%	96-hr EC_{50} = 16 (12-20) Slope: 6.7	40098001 Supplemental	From collection of Mayer & Ellersieck, 1986.
Bluegill *Lepomis macrochirus*	Formulation: 21.2%	96-hr EC_{50} = 12 (7.8-15) Slope: 5.4	40098001 Supplemental	From collection of Mayer & Ellersieck, 1986.
Bluegill *L. macrochirus*	Formulation: 21.2%	96-hr EC_{50} = 32.7	162737 Supplemental	From collection of Mayer & Ellersieck, 1986.
Channel Catfish *Ictalurus punctatus*	TGAI: 42%	96-hr EC_{50} >100	40098001 Supplemental	From collection of Mayer & Ellersieck, 1986.
Bluegill *L. macrochirus*	Paraquat Chloride – Form Not specified: 29.1%	96-hr EC_{50} = 156 (68.3-356) ppm formulation Slope: 3.77	113705/ Acc. No. 103609 Supplemental	DER from 1979 – did not state study classification and assumed supplemental. Additionally, concentrations were stated to be based on total formulation in mg/L, but specifically what mg/L meant was not entirely clear. Did not further review since was not the most sensitive endpoint.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Gourami Fish *Trichogaster trichopterus*	30%	96-hr LC_{50} = approximately 1.41 (paper states is ion)	E172382 (Banaee, *et al.*, 2013) Supplemental (qualitatively usable) NEW	This LC_{50} is more sensitive than the quantitative fish endpoints that are available. However, the test substance may have been a formulation and the paper was unclear as to whether endpoints were measured or nominal. Other unavailable information included the health of the test organisms, whether they were cultured or wild caught, and effects at each treatment level. Due to insufficient information, the endpoints are qualitatively usable to describe risk but not quantitatively usable to calculate risk.
Freshwater Aquatic-Phase Amphibian Acute Toxicity 850.1075 (or equivalent §72-1A):				
Red-eyed Treefrog *Agalychnis callidryas*	Unknown	8-day LC_{50} = approximately 1.24 (1.706 mg/L in paper and NOAEC/ LOAEC of 0.226/0.453 mg/L) based on weight	E168034 (Ghose, *et al.*, 2014) Supplemental (qualitatively usable) NEW	Based on weight (although unclear whether wet or dry weight). This LC_{50} is more sensitive than the quantitative fish endpoints that are available. However, the duration was longer than 96-hours; the test substance was likely a formulation (but unclear); the paper was unclear as to whether endpoints were expressed as paraquat dichloride or cation and whether measured or nominal. Other unavailable information included the health of the test organisms, whether they were cultured or wild caught, and effects at each treatment level. Due to insufficient information, the endpoints are qualitatively usable to describe risk but not quantitatively usable to calculate risk.
Fowler's Toad *Bufo woodhousei fowleri*	TGAI: 42%	96-hr EC_{50} = 15 (7.8-23) Slope: 3.3	40098001 Supplemental	From collection of Mayer & Ellersieck, 1986.
Saltwater Fish Acute Toxicity 850.1075 (or equivalent §72-3A):				
Sheepshead Minnow *Cyprinodon variegatus*	TGAI: (paraquat dichloride: 46.3%) 33.5% cation	LC_{50}: >41	49320304 Acceptable NEW	**Most sensitive/defensible E/M fish acute endpoint:** LC_{50} >41 mg cation/L. Flow-through study with mean-measured concentrations. No mortality in any treatment; highest concentration tested was 41 mg cation/L mean measured concentration. No apparent sub-lethal effects were observed in the control or any of the treatment groups.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Longnose Killifish *Fundulus similis*	Formulation	96-hr EC_{50} >0.72	40228401 Supplemental	This endpoint is from the U.S. EPA Gulfbreeze lab collection and was not the most defensible endpoint (did not appear to be tested at high enough concentrations for definitive endpoint) and, therefore, was not further investigated to determine if the endpoint is quantitatively usable or to supply further details.
Fish Chronic Toxicity – Early Life-Stage Test 850.1400 (or equivalent §72-4A):				
Fathead Minnow *P. promelas*	Chronic Early Life-Stage TGAI: (paraquat dichloride: 46.3%) 33.5% cation	33-day NOAEC / LOAEC = 0.74/ 1.5 mg cation/L based on growth (dry and wet weight)	49320307 Acceptable NEW	**Most sensitive/defensible freshwater fish chronic endpoint:** NOAEC / LOAEC = 0. 74/ 1.5 mg cation/L based on growth. The LOAEC of 1.5 mg cation/L was based on significant ($p \leq 0.05$) reductions of 18.7% and 13.3% in dry and wet weight, respectively, as compared to the control. Due to a 65% reduction in survival at 3.0 mg cation/L (the highest treatment), that treatment was excluded from growth calculations and CETIS was rerun. In the CETIS rerun, a 7.6 and 8.8% wet weight drop from the control level at 0.094 and 0.37 mg cation/L, respectively, and the 8.9 to 12.4% drop from the control level in the lowest four treatments, were also determined to be significantly different from the controls according to Dunnett's ($p<0.05$). However, the pattern was not clearly dose-dependent / treatment-related and these were determined to not be biologically significant, but due to variability, although some uncertainty is associated with the lower and mid-range treatment levels (0.094-0.74 mg cation/L). Using data from this study and MRID 49320303, an acute-to-chronic ratio (ACR) for the fathead minnow can be calculated as 6.4 (4700/740). **Other Endpoints:** **Growth:** **Length:** NOAEC: 3.0 mg cation/L LOAEC: >3.0 mg cation/L (13.3% reduction)

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
				Survival - Juvenile Survival on Day-28: NOAEC: 1.5 mg cation/L LOAEC: 3.0 mg cation/L (69.6% mortality; 64.7% reduction from control) **Reproduction- Eggs Hatched/Embryo Viability and Time to Hatch:** NOAEC: 3.0 mg cation/L LOAEC: >3.0 mg cation
Sheepshead Minnow *C. variegatus*	Chronic Early Life-Stage TGAI: (paraquat dichloride: 46.3%) 33.5% cation	34-day NOAEC / LOAEC = 1.8/ 3.7 mg cation/L based on growth (length and dry and wet weights)	49320308 Acceptable NEW	**Most sensitive/defensible saltwater fish chronic endpoint:** NOAEC / LOAEC = 1.8/ 3.7 mg cation/L based on growth. At the LOAEC of 3.7 mg cation/L, length and wet weight were significantly ($p<0.05$) decreased by 5.3 and 11.7%, respectively, and dry weight was also reduced by 5.1%, although this was not statistically significant. Flow-through study with mean-measured concentrations **Other Endpoints:** **Growth:** **Dry Weight:** NOAEC: 3.7 mg cation/L LOAEC: >3.7 mg cation/L **Reproduction:** **Hatching Success and Time to Hatch:** NOAEC: 3.7 mg cation/L LOAEC: >3.7 mg cation/L **Larval Survival:** NOAEC: 3.7 mg cation/L LOAEC: >3.7 mg cation/L

Abbreviations: N/A = not applicable; a.i. = active ingredient; TGAI = technical grade active ingredient; TEP = typical end use product; -hr = hour; -wk = week; conc. = concentration; C.I. = confidence interval; LC/EC/ICxx = lethal/effects/inhibition concentration specifying percent of organisms affected; NOAEC/LOAEC = no/lowest observed adverse effects concentration; OC = organic carbon; TOC = total organic carbon; dw = dry weight (of sediment).

Toxicity to Terrestrial Vertebrates and Invertebrates

A comprehensive list of available toxicity data for terrestrial invertebrates and vertebrates is found in **Table B-2**. A summary of data from most of the studies is found in the problem formulation (USEPA, 2011) and the red-legged frog assessment (USEPA, 2009); the new data reviewed since the problem formulation are noted as "NEW" in the MRID/Classification column.

Table B-2. Summary of Terrestrial Toxicity Data for Paraquat Expressed as Paraquat Cation.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value (95% C.I. or standard deviation if noted) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Avian Acute Oral Toxicity 850.2100 (TG223, or equivalent §71-1):				
Zebra Finch *Poephila guttata*	Acute Oral TGAI: (96.1% paraquat dichloride) 72.4% cation	14-day (single-dose) LD_{50} = 26.5 mg cation/kg-bw	49349901 Acceptable NEW	**Most sensitive/defensible avian acute dose endpoint:** LD_{50} = 26.5 mg cation/kg-bw. Study conducted as TG223 on zebra finch.
Bobwhite Quail *Colinus virginianus*	Acute Oral TGAI: (study report says assumed to be 100% active material)	14-day (single-dose) LD_{50} = 124 (99-148) mg cation/kg-bw Slope: 6.6 (3.5-9.7)	00029001 Acceptable	Mortality, effects to body weight and lethargy were observed in birds dosed with 115 mg/kg-bw. The slope of the dose-response curve was (MRID 00029001).
Mallard Duck *Anas platyrhynchus*	Acute Oral TGAI	N/A	00160000 Invalid	From collection: Hudson et al. 1984.
Mallard Duck *A. platyrhynchus*	Acute Oral TGAI	LD_{50} = 436.8 mg/kg-bw	00160000 Supplemental	From collection: Hudson et al. 1984.
Mallard Duck *A. platyrhynchus*	Acute Oral TGAI: 32.3% w/w cation	14-day (single-dose) LD_{50} = 53 mg cation/kg-bw	49378001 Acceptable NEW	
Avian Acute Dietary Toxicity 850.2200 (or equivalent §71-2):				
Japanese Quail *Coturnix coturnix*	Acute Dietary Formulation: (29.1% paraquat dichloride) 21.1% cation	5-day LC_{50} = 698 (593-821) mg cation/kg-diet Slope: 6.06 (±1.31 sd)	00022923 Acceptable	**Most sensitive/defensible avian acute dose endpoint:** LC_{50} = 698 mg cation/kg-diet. Study amended in 2011 to re-calculate the endpoint.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value (95% C.I. or standard deviation if noted) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Bobwhite Quail *C. virginianus*	Acute Dietary Formulation: 29.1%	5-day LC_{50} = 706 (564-873) mg cation/kg-diet Slope: 5.02 (±1.28 sd)	00022923 Acceptable	Study amended in 2011 to re-calculate the endpoint.
Ring-necked pheasant *Phasianus colchicus*	Acute Dietary Formulation: 29.1%	5-day LC_{50} = 1060 (927-1210) mg cation/kg-diet Slope: 5.85 (±1.97 sd)	00022923 Acceptable	Study amended in 2011 to re-calculate the endpoint.
Mallard Duck *A. platyrhynchus*	Acute Dietary Formulation: 29.1%	5-day LC_{50} = 2920 (2470-3520) mg cation/kg-diet Slope: 6.77 (±1.28 sd)	00022923 Acceptable	Study amended in 2011 to re-calculate the endpoint.
Mallard Duck *A. platyrhynchus* and Pheaseant	Acute Dietary Formulation	N/A	55103/90975/ Acc. No. 180,000 Invalid	In 2011, study was amended to an invalid classification.
Avian Reproduction 850.2300 (or equivalent §71-4):				
Mallard Duck *A. platyrhynchus*	Chronic Reproduction TGAI: (43.5% paraquat dichloride) 31.5% cation by weight	18-wk NOAEC / LOAEC = 29.4/ 101 mg cation/kg-diet based on reproduction and food consumption	00110455 Acceptable	**Most sensitive/defensible avian chronic endpoint:** NOAEC / LOAEC = 29.4/ 101 mg cation/kg-diet based on reproduction and food consumption. At the LOAEL: significant ($p<0.05$) reductions of 59.0 % in eggs laid, 24.7% in viable embryos/egg set, 33.1% in live embryos/egg set, and 8.5% in mean food consumption. Marked treatment-related reductions ($p<0.01$) in the numbers of eggs laid and viable embryos were observed at the mean-measured 101 mg ai/kg diet level. Further, significant inhibitions were noted for viable embryos per egg set and live embryos per egg set ($p<0.01$) at 101 mg ai/kg; mean food consumption was also significantly reduced ($p<0.05$). The original study had nominal and measured concentrations expressed as cation and even though the DER has endpoints expressed in mg a.i./kg, the a.i. was already adjusted to cation.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value (95% C.I. or standard deviation if noted) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Bobwhite Quail *C. virginianus*	Chronic Reproduction TGAI: 31.5% cation by weight	18-wk NOAEC / LOAEC = 100 / >100 mg cation/kg-diet based on no effects to reproduction, growth or survival	00110454 Supplemental (qualitatively usable)	No measured effects in highest treatment, 100 mg cation/kg-diet (nominal concentration). The study was downgraded in 2018 to supplemental because several control reproduction validity requirements were not met. The study was determined to be scientifically sound; however, failure to meet reproduction validity criteria by the control group resulted in a Supplemental (Qualitative) classification. The revised DER notes that a number of control validity requirements were not met in the study: specifically, the number of 3-week old embryos of viable embryos averaged 94% (minimum validity requirement of 97%); the percentage of normal hatchlings of viable embryos averaged 66% (minimum validity requirement of 85%); and the percentage of normal hatchlings of eggs set averaged 57% (minimum validity requirement of 71%).
Bobwhite Quail *C. virginianus*	Chronic Reproduction Screen TGAI: 31.5% cation by weight	20-wk NOAEC / LOAEC not established	00110453 Invalid	Per 2018 memo, classified as Invalid due to insufficient replicates, no raw data submitted, low egg laying response for all birds, and no data on chick survival.
Avian Reproduction Non-Guideline:				
Mallard Duck *A. platyrhynchus*	Chronic Reproduction TEP: Formulation containing 17.3% paraquat dichloride	50+-d NOAEC / LOAEC = 1.0 / 2.0 lb cation/A based on reproduction and survival	43942604 Supplemental	Mallard eggs were sprayed with paraquat dichloride, an application rate of 2.0 lb cation/A increased the number of embryonic deaths (at days 13 and 19) as well as the number of dead embryos in the shell at day 31. At this concentration, the number of hatchlings and number of chicks surviving to 28 d were also decreased. The resulting NOAEC was 1.0 lb cation/A.
Mallard Duck *A. platyrhynchus*	Chronic Reproduction TEP: Formulation containing 17.3% paraquat dichloride	20-d NOAEC / LOAEC = 1.45/ 0.73 lb cation/A	43942604 Supplemental	Mallard eggs were sprayed with paraquat dichloride.
Mallard Duck *A. platyrhynchus*	Chronic Reproduction TEP: Formulation containing 17.3% paraquat dichloride	NOAEC not determined based on fertile eggs and embryo survival	43942605 Supplemental	

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value (95% C.I. or standard deviation if noted) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Ring-necked Pheasant *P. colchicus*	Chronic Reproduction TEP: Formulation containing 17.3% paraquat dichloride	50-d NOAEC / LOAEC = 0.5 / 0.72 lb cation/A based on reproduction and survival	43942605 Supplemental	Pheasant eggs were sprayed with paraquat dichloride, effects to the number of eggs hatched and number of 28-d old survivors were observed at 0.72 lb cation/A, resulting in a NOAEC of 0.36 lb cation/A.
Mallard Duck *A. platyrhynchus*	Chronic % Paraquat not reported	NOAEC not determined based on growth and mortality	00162746 Supplemental	This is an open lit submission (Hoffman and Eastin,1982).
Hen	Paraquat (% a.i. unknown)	N/A	00025808/ Acc. No. 108,000 Supplemental information	This was a study on the effect of some herbicides on the hatching rate of hen eggs. A dose of 1 ppm given at different intervals after the commencement of incubation resulted in a 20% hatch at 2- and 4-days but a hatch of 80% and above thereafter to the day-16. It was noted that a dose of 0.15 ppm resulted in 40% hatch and 0.25 ppm in 0% hatch. This is supplemental information for risk characterization, rather than quantitative risk calculations.
Hybrid White Leghorn Strain Chicken	Reproduction Paraquat (% a.i. unknown)	14-d NOAEC < 40 ppm paraquat in water based on number of abnormal eggs produced.	55110/ Acc. No. 180,000 Supplemental	Toxicant was administered in water rather than feed, and only for 14 days; test was initiated just after birds reached period of maximum lay and no water consumption data were provided. Author stated that the 40 ppm treatment appeared to have no effect on consumption of food or water. Analysis of paraquat in eggs showed that paraquat rose to about 0.1 ppm and then declined to below the level of detection (not provided in DER) 6 days after birds were taken off treated diet. Additionally, the author states that for hen eggs injected directly, paraquat was the most toxic of 25 herbicides tested and gave complete kill at a concentration in the egg of 0.3 ppm; also, at the 0.15 ppm level, only a third hatched. The author speculated that due to paraquat's low solubility in fat, the egg yolk provided no protection to the embryo and that paraquat seemed to interfere with metabolic processes specific to very early and very late development.
Unspecified Wildlife	Field Study – Paraquat Resin Soaking in Southern Pines Program	No dead or injured recorded. Effect noted: temporary	Acc. No. 232799 Supplemental information	These were casual field observations by untrained cooperators using no control plots. Each cooperator was provided a four-page checklist of wildlife and asked to report any observed wildlife, noting any sickness,

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value (95% C.I. or standard deviation if noted) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
		migration of wildlife away from areas of human activity.		injury, or death. Considered supplemental information.
Toxicity to Honey Bees 850.3020 (or equivalent §141-1); the oral test is currently non-guideline:				
Honey Bee *Apis mellifera L.*	Acute Contact TEP: EC Formulation containing 1.67 lb/gal paraquat dichloride (estimated to be 25.2% - see Notes)	48-hr LD_{50} = 52 µg cation/bee	43942603 Acceptable	**Most sensitive/defensible honey bee acute contact endpoint:** LD_{50} = 52 µg cation/bee. Available data suggest that formulated paraquat is more toxic than the TGAI. The DER did not provide the % purity except as lb paraquat dichloride/gal. Used a label for Gramoxone SL to calculate the purity. The label was for a 2.0 lb paraquat cation/gal formulation and specified 30.1% cation. Used the following ratio calculation to estimate the percent: 2.0 / 0.301 = 6.74 (cation/gal if 100%); 1.67 / 6.74 = 0.252; so 25.2%.
Honey Bee *A. mellifera*	Acute Contact TGAI: at least 95%	48-hr LD_{50} >35 µg cation/bee	05001991 Acceptable	This is an open lit submission (Stevensen, 1978).
Honey Bee *A. mellifera*	Acute Contact TGAI: 99%	48-hr LD_{50} >104 µg cation/bee	43942603 Acceptable	
Honey Bee *A. mellifera*	Acute Oral TEP: EC Formulation containing 1.67 lb/gal paraquat dichloride (25.2% cation)	48-hr LD_{50} = 22 µg cation/bee	43942603 Acceptable	**Most sensitive/defensible honey bee acute oral endpoint:** LD_{50} = 22 µg cation/bee. Available data suggest that formulated paraquat is more toxic than the TGAI and that paraquat is more toxic as an oral dose than a contact dose. For purity estimate, see Notes for the contact study.
Honey Bee *A. mellifera*	Acute Oral TGAI: 99%	48-hr LD_{50} = 37 µg cation/bee	43942603 Acceptable	
Toxicity to Honey Bees 850.3020 from non-guideline studies:				
Honey Bee *A. mellifera*	Acute NG (dusting) TGAI	LD_{50} >6.04 µg *a.i.*/bee	MRID 00036935/	In this study from the open literature, exposure of honey bees to technical paraquat through dusting to 6.04 µg a.i./bee resulted in 2.74% mortality.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value (95% C.I. or standard deviation if noted) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
			00028772	
Honey Bee *A. mellifera*	Acute NG TEP: Formulation of Paraquat CL was mixed with 20 gal water with a surfactant	2-d LC_{50} approximately 4 lb *a.i.*/A	MRID 00111488/ 00132710/ Acc. No. 252084 Supplemental	In this open literature study (Moffett *et al*., 1972), caged bees were exposed to a direct application of 4 lb a.i./A formulated paraquat. After 2 days, approximately 55% mortality was observed.

Abbreviations: N/A = not applicable; a.i. = active ingredient; TGAI = technical grade active ingredient; TEP = typical end use product; -hr = hour; -wk = week; conc. = concentration; C.I. = confidence interval; LC/EC/ICxx = lethal/effects/inhibition concentration specifying percent of organisms affected; NOAEC/LOAEC = no/lowest observed adverse effects concentration.

Toxicity to Aquatic and Terrestrial Plants

A comprehensive list of available toxicity data for aquatic and terrestrial plants is found in **Table B-3**. A summary of data from most of the studies is found in the problem formulation (USEPA, 2011) and the red-legged frog assessment (USEPA, 2009); the new data reviewed since the problem formulation are noted as "NEW" in the MRID/Classification column.

Table B-3. Summary of Aquatic and Terrestrial Plant Toxicity Data for Paraquat Expressed as Paraquat Cation.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Vascular Aquatic Plants 850.4400:				
Duckweed *Lemna gibba*	TGAI: (Paraquat dichloride technical 32.7%): 23.7% cation (w/w)	14-day EC/IC_{50} = 0.071 (0.063-0.079) mg cation/L NOAEC/ LOAEC = 0.023/ 0.047 mg cation/L Slope: 3.27 (-0.53-7.08) [1]	42601003 Acceptable	**Most sensitive/defensible aquatic vascular plant endpoints:** NOAEC/ LOAEC of 0.023/ 0.047 based on frond number. The LOAEC was based on significant ($p<0.05$) 18% inhibition of frond number. Endpoints were expressed as nominal concentrations adjusted for purity. Due to

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
		based on frond number		problems with the analytical methodology, not all of the treatments had measured concentrations but those with measurements had 75-94% recoveries. The NOAEC and LOAEC endpoints noted on the 2011 problem formulation were based on phytotoxic symptoms, but the one based on frond number was used in this assessment because they are more defensible. The phytotoxic endpoint was based on descriptive symptoms: plants in the 0.023 mg cation/L treatment were noted to be slightly chlorotic with reduced root growth at test termination. However, there was no measurable effect in frond number (0% inhibition) or weight (0% inhibition) at the LOAEC. At the next higher concentration of 0.047 mg cation/L, was 18% (significant at $p<0.05$ by Dunnett's) inhibition in frond number with a dose:dependant (and significant at $p<0.05$) 74% reduction at 0.093 mg cation/L treatment. At 0.093 mg cation/L, there was also a significant 62% reduction in dry weight at 0.093 mg cation/L. A slope of 3.27 (-0.53-7.08) is available from the probit analysis with an accompanying EC_{50} of 0.073 mg cation/L based on frond number but the EC_{50} reported in the problem formulation (and used in this analysis) was calculated using the moving average method. **Other Endpoints:** NOAEC/ LOAEC = 0.012/ 0.023 mg cation/L Based on phytotoxicity; plants in the 0.023 mg cation/L treatment were noted to be slightly chlorotic with reduced root growth at test termination.
Non-Vascular Aquatic Plants Guideline 850.4500:				
Freshwater Diatom *Navicula pelliculosa*	TGAI (Paraquat dichloride technical 32.7%): 23.7% cation	4-day EC/IC_{50} = 0.00040 mg cation/L NOAEC/ LOAEC = 0.00016/ 0.00033 mg cation/L Slope: 4.08 (-0.19-8.26) [1] based on cell density	42601006 Acceptable	**Most sensitive/defensible non-vascular plant endpoints:** NOAEC/ LOAEC = 0.00016/ 0.00033 mg cation/L based on cell density. The LOAEC was based on biologically significant 54% inhibition in cell density at the LOAEC, followed by dose:dependent pattern of 79 and 97% respective levels of inhibition at the next two higher treatments. Endpoints were expressed as estimated mean-measured concentrations, i.e., they were based on nominal concentrations adjusted using analytical results. Concentrations of the primary and intermediate stocks were measured at test initiation and termination and had

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
				68-90% recoveries. A slope of 4.08 (-0.19-8.26) is available from the probit analysis with an accompanying EC_{50} of 0.00038 mg cation/L based on cell density but the EC_{50} reported in the problem formulation (and used in this analysis) was calculated using the moving average method. Other Endpoints: Growth Rate: NOAEC/ LOAEC = 0.00046/ 0.00093 mg cation/L based on significant ($p<0.05$) 45% inhibition. AUC: NOAEC/ LOAEC = 0.00046/ 0.00093 mg cation/L based on significant ($p<0.05$) 78% inhibition.
Freshwater Diatom *N. pelliculosa*	TGAI (Paraquat dichloride technical): 32.6%	Non-Guideline Alteration of Study to Include Sediment: 4-day EC/IC_{50} >0.623 mg cation/L NOAEC/ LOAEC = 0.188/ 0.623 mg cation/L based on growth rate	48877202 Supplemental (quantitatively usable) New	NOAEC/LOAEC of 0.188/ 0.623 mg cation./L based on significant ($p<0.05$) 20% reduction in growth rate; concentrations were initial-measured paraquat dichloride concentrations. This study was altered in an attempt to address sediment toxicity by including a three gram bottom layer of sandy loam in each test vessel to represent sediment. Other Endpoints: Growth Rate: EC/IC_{05} = 0.0133 (NA to 0.905) mg/L Yield: EC/IC_{05} = 0.488 (NA to 0.617) mg/L EC/IC_{50} = 0.643 (0.605 to 0.684) mg/L NOAEC/LOAEC = 0.623/ >0.623 mg/L Biomass: EC/IC_{50} = 0.632 (0.581 to 0.687) mg/L NOAEC/LOAEC = 0.623/ >0.623 mg/L
Bluegreen Algae *Anabaena flos-aquae*	TGAI (Paraquat dichloride technical): 32.7%	5-day EC/IC_{50} = 0.011 (0.010-0.012) mg cation/L NOAEC/ LOAEC = 0.0023/	42601005 Acceptable	

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
		0.0046 mg cation/L Slope: 8.46 (-41.0-57.9)[1] based on cell density		
Green Algae *Selenastrum capricornutum*	TGAI (Paraquat dichloride technical): 32.7%	4-day EC/IC_{50} = 0.23 mg cation/L NOAEC/ LOAEC = 0.058/0.140 mg cation/L Slope: 3.26 (1.11-5.42)[1] based on cell density	42601002 Acceptable	
Marine Diatom *Skeletonema costatum*	TGAI (Paraquat dichloride technical): 32.7%	4-day EC/IC_{50} = 2.06 mg cation/L NOAEC/ LOAEC = 0.160/ 0.340 mg cation/L Slope: 1.53 (1.36-1.71) based on cell density	42601004 Acceptable	
Hapatophyte Algae *Isochrysis galbana*	Information not determined at time of assessment	10-day EC/IC_{50} = 3.60 mg cation/L NOAEC = NA	40228401 Supplemental	This endpoint is from the U.S. EPA Gulfbreeze lab collection and was not the most sensitive endpoint and, therefore, was not further investigated to determine if the endpoint is quantitatively usable or to supply further details.
Marine Diatom *Phaeodactylum tricornutum*	Information not determined at time of assessment	10-day EC/IC_{50} = 7.20 mg cation/L NOAEC = NA	40228401 Supplemental	This endpoint is from the U.S. EPA Gulfbreeze lab collection and was not the most sensitive endpoint and, therefore, was not further investigated to determine if the endpoint is quantitatively usable or to supply further details.
Green Algae *Dunaliella tertiolecta*	Information not determined at time of assessment	10-day EC/IC_{50} = 14.4 mg cation/L NOAEC = NA	40228401 Supplemental	This endpoint is from the U.S. EPA Gulfbreeze lab collection and was not the most sensitive endpoint and, therefore, was not further investigated to determine if the endpoint is quantitatively usable or to supply further details.
Green Algae *Chlorococcum sp.*	Information not determined at time of assessment	10-day EC/IC_{50} = 36.0 mg cation/L NOAEC = NA	40228401 Supplemental	This endpoint is from the U.S. EPA Gulfbreeze lab collection and was not the most sensitive endpoint and, therefore, was not further investigated to determine if the endpoint is quantitatively usable or to supply further details.

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Tier II Seedling Emergence 850.4100:				
Oat *Avena sativa*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	14-day EC/IC_{25} = 0.635 lb cation/A NOAEL/ LOAEL = 0.28/ 0.57 lb cation/A Slope: N/A Endpoint: emergence and survival	49320310 Supplemental (quantitatively usable) NEW	**Most sensitive/defensible monocot endpoints:** EC/IC_{25} = 0.635 lb cation/A; NOAEL/ LOAEL = 0.28/ 0.57 lb cation/A based on emergence and survival. The NOAEL/LOAEL of 0.28/ 0.57 lb cation/A was based on significant ($p<0.05$) inhibition in oat survival and emergence, reductions of 21.1 and 23.7% at 0.57 and 1.13 lb cation/A treatment levels, respectively ($p<0.05$); all endpoints were based on measured concentrations. The 0.14 and 0.28 lb cation/A treatments also had a 15.8% reduction, which were not statistically significant and the level was the same effect at two treatment levels; this was not considered treatment related, although some uncertainty is acknowledged. Overall, the effects seen in emergence and survival in the higher treatments appear to be dose:dependent, although the height and weight seem to go up when the weak ones died. Additionally, CETIS estimated the IC_{05} to be 0.00277, which was below the lowest treatment, and not usable.
Perennial Ryegrass *Lolium perenne*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	14-day EC/IC_{25} > 0.57 lb cation/A NOAEL = 0.57 lb cation/A Endpoint: emergence and survival	49320310 Supplemental (quantitatively usable) NEW	The NOAEL/ LOAEL of 0.57/ 1.13 lb cation/A also applies to height and weight. The dose:response patterns for ryegrass height and biomass (and emergence and survival to a lesser degree) were not linear and not clearly treatment related at the lower treatment levels, making the endpoints unclear; however, the 15.3%, and 25.7%, reductions in height and weight, and the 25.0% reduction in both emergence and survival, at the highest treatment level (1.13 lb cation/A) could not be discounted as biologically significant, even though they were not statistically significant. The NOAEL was assigned from visual inspection of the data; all endpoints were based on measured concentrations. Additionally, CETIS estimated an IC_{25} of 0.35 (0.0906-2.23); however the % effect went back up to only 3% in the 0.57 lb cation/A treatment and so the data point was not included in the table.
Corn *Zea mays*	TEP: (Formulation Gramoxone Extra): 294 g a.i./L; approx. 19.2% cation	21-day EC/IC_{25} > 0.67 lb cation/A NOAEL = 0.67 lb cation/A Endpoint: no effects to emergence or growth (dry wt.)	42639601 Acceptable	The DER said that the formulation contained 294 g a.i./L (a.i. was paraquat dichloride; this converts to 2.45 lb a.i./gal); looked up label for Gramoxone Extra and it specified a 3.454 lb salt per gal and 2.5 lb paraquat cation per gal) and 37.3% a.i.; using a simple ratio conversion, estimated that the formulation contained 26.5% salt, or 19.2% cation. Growth was measured by dry weight and growth stage (did not pursue the definition since was not most sensitive endpoint); also seedling

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
				damage was notes as unaffected.
Corn *Z. mays*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	14-day EC/IC_{25} > 1.04 lb cation/A NOAEL = 1.04 lb cation/A Slope: N/A Endpoint: none (height, weight, emergence and survival measured)	49320310 Supplemental (quantitatively usable) NEW	See below for more information; all endpoints were based on measured concentrations.
Onion *Allium cepa*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	14-day EC/IC_{25} > 1.13 lb cation/A NOAEL = 1.13 lb cation/A Endpoint: none (height, weight, emergence and survival measured)	49320310 Supplemental (quantitatively usable) NEW	See below for more information; all endpoints were based on measured concentrations.
Purple Nutsedge *Cyperus rotundus*	TEP: (Formulation Gramoxone Extra): 294 g a.i./L; approx. 19.2% cation	21-day EC/IC_{25} > 0.67 lb cation/A NOAEL = 0.67 lb cation/A Endpoint: no effects to emergence or growth (dry wt.)	42639601 Acceptable	Growth was measured by dry weight and growth stage (did not pursue the definition since was not most sensitive endpoint); also seedling damage was notes as unaffected. For information about purity estimate, see note (above) for the corn endpoint.
Wild Oat *Avena fatua* Winter Wheat *Triticum aestrivum*	TEP: (Formulation Gramoxone Extra): 294 g a.i./L; approx. 19.2% cation	Not available	42639601 Invalid	For wild oat and winter wheat, the DER states that wild oat and winter wheat are invalid due to poor control emergence. For information about purity estimate, see note (above) for the corn endpoint.
Dicot: Cocklebur *Xanthium strumarium*	TEP: (Formulation Gramoxone Extra): 294 g a.i./L; approx. 19.2% cation	21-day EC/IC_{25} = 0.67 lb cation/A NOAEL/ LOAEL = 0.171/ 0.341 lb cation/A Endpoint: emergence	42639601 Acceptable	**Most sensitive/defensible dicot endpoints:** EC/IC_{25} = 0.67 lb cation/A; NOAEL/ LOAEL= 0.171/ 0.341 lb cation/A based on emergence. The NOAEL/ LOAEL of 0.171/ 0.341 lb cation/A was based on a biologically (although not statistically) significant at $p<0.05$) 20.5% reduction in emergence at the LOAEL, along with demonstration of a dose-related general decrease in emergence with increasing treatment rate, although the dose:response was not

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
				completely linear. The number of days to emergence was unaffected. The original DER (1996) had erroneously listed the second highest treatment as the NOAEL (corresponding to 0.341 lb cation/A) but this was thought to be an error, because the next higher treatment (the LOAEL) actually had less reduction in emergence and the DER was amended to correct the error. Growth was measured by dry weight and growth stage (did not pursue the definition since was not most sensitive endpoint); also seedling damage was notes as unaffected. For information about purity estimate, see note (above) for the corn endpoint.
Morningglory *Ipomoea hederacea*	TEP: (Formulation Gramoxone Extra): 294 g a.i./L; approx. 19.2% cation	21-day EC/IC_{25} > 0.67 lb cation/A NOAEL = 0.67 lb cation/A Endpoint: no effects to emergence or growth (dry wt.)	42639601 Acceptable	Growth was measured by dry weight and growth stage (did not pursue the definition since was not most sensitive endpoint); also seedling damage was notes as unaffected. Morningglory appeared to be affected by seedling damage on day-7, but had recovered by day-14. Also, all treatments had significant reduction in dry weight on day-21, but this was thought to be due to one uncharacteristically high dry weight measurement in the control and since no visual damage was apparent after day-14, the reduction was not believed to be biologically significant. For information about purity estimate, see note (above) for the corn endpoint.
Oilseed Rape *Brassica napus* Soybean *Glycine max* Sugar Beet *Beta vulgaris* Velvetleaf *Abutilon theophrasti*	TEP: (Formulation Gramoxone Extra): 294 g a.i./L; approx. 19.2% cation	21-day EC/IC_{25} > 0.67 lb cation/A NOAEL = 0.67 lb cation/A Endpoint: no effects to emergence or growth (dry wt.)	42639601 Acceptable	Growth was measured by dry weight and growth stage (did not pursue the definition since was not most sensitive endpoint); also seedling damage was notes as unaffected. For information about purity estimate, see note (above) for the corn endpoint.
Oilseed rape	TEP: (Formulation	14-day EC/IC_{25} > 1.04 lb	49320310	See below for more information; all endpoints were based on measured

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
B. napus	A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	cation/A NOAEL = 1.04 lb cation/A Slope: N/A Endpoint: none (height, weight, emergence and survival measured)	Supplemental (quantitatively usable) NEW	concentrations.
Common bean *Phaseolus vulgaris* Cucumber *Cucumis sativa* Soybean *G. max* Radish *Raphanus sativus* Tomato *Lycopersicon esculentum*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	14-day EC/IC_{25} > 1.13 lb cation/A NOAEL = 1.13 lb cation/A Endpoint: none (height, weight, emergence and survival measured)	49320310 Supplemental (quantitatively usable) NEW	See below for more information; all endpoints were based on measured concentrations.
Tier II Vegetative Vigor 850.4150:				
Monocot: Perennial Ryegrass *L. perenne*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	21-day EC/IC_{25} = 0.0208 (0.016-0.0253) lb cation/A NOAEL = 0.018 lb cation/A Slope: N/A Endpoint: dry weight	49320309 Acceptable NEW	**Most sensitive/defensible monocot endpoints:** EC/IC_{25} = 0.0208 lb cation/A; NOAEL/ LOAEL = 0.018/0.033 lb cation/A based on dry weight. The NOAEL/LOAEL of 0.018/0.033 lb cation/A was based on significant ($p<0.05$) 59.5% inhibition at the LOAEL of 0.033 lb cation/A, followed by a dose:dependent 95.4% inhibition at 0.11 lb cation/A; all endpoints were based on measured concentrations. See below for more information.
Corn *Z. mays*	TEP: (Gramoxone Extra); 1,1-dimethyl-4,4-	28-d EC/IC_{25} = 0.16 (0.073-0.36) lb cation/A NOAEL/ LOAEL = 0.064/	42601001 Supplemental (may be used	For corn and six dicots, the original DER classified the studies as acceptable. These endpoints were downgraded by a 2010 addendium because of deviations from the study protocol, chiefly 5 or 6 plants (rather than the recommended 10) were

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
	bipyridylium dichloride; 29.4% a.i. w/v.	0.129 lb cation/A Endpoint: dry weight	quantitatively)	included in each replicate and height was not measured. However, the dry weight endpoints may be used quantitatively for risk calculation.
Corn *Z. mays*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	21-day EC/IC_{25} = 0.0271 lb cation/A NOAEL = 0.018 lb cation/A Endpoint: dry weight	49320309 Acceptable NEW	Significant decrease in corn weight, inhibition of 36.5 to 74.6% from the 0.033 to the 0.57 lb cation/A treatment level compared to the negative control ($p<0.05$). An IC_{25} of 0.0122 lb cation/A, estimated by CETIS using non-linear regression, did not appear reasonable, given the slightly higher NOAEL, which did appear to be a convincing measured no-effect level. This was likely due to the significant lack of fit. The author estimate using linear interpolation, converted to cation, of 0.0271 lb cation/A was considered a better estimate and reported. See below for more information; all endpoints were based on measured concentrations.
Oat *A. sativa*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	21-day EC/IC_{25} = 0.0416 lb cation/A NOAEL = 0.033 lb cation/A Endpoint: dry weight	49320309 Acceptable NEW	Significant decrease in oat weight, inhibition of 40 to 77% at the ≥0.071 lb cation/A treatment levels compared to the negative control ($p<0.05$). See below for more information; all endpoints were based on measured concentrations.
Onion *A. cepa*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	21-day EC/IC_{25} = 0.0208 lb cation/A NOAEL = 0.018 lb cation/A Endpoint: height	49320309 Acceptable NEW	Significant decrease in onion height, inhibition of 57.7 and 54.3% at the 0.071 and 0.28 lb cation/A treatment levels, respectively, compared to the negative control ($p<0.05$). See below for more information; all endpoints were based on measured concentrations.
Purple Nutsedge *C. rotundus* Wild Oat *A. fatua* Winter Wheat *T. aestrivum*	TEP: (Gramoxone Extra); 1,1-dimethyl-4,4-bipyridylium dichloride; 29.4% a.i. w/v.	Not available	42601001 Invalid	Winter wheat, purple nutsedge, and wild oat were treated with insecticide, and so, their results were determined to be invalid.
Dicot:	TEP: (Formulation	21-day EC/IC_{25} = 0.0217 lb	49320309	**Most sensitive/defensible dicot endpoints:** EC/IC_{25} = 0.0217 lb cation/A; NOAEL/

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
Soybean *G. max*	A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	cation/A NOAEL = 0.0048 lb cation/A Endpoint: height	Acceptable NEW	LOAEL = 0.0048/0.018 based on height. NOAEL/LOAEL of 0.0048/0.018 based on significant ($p<0.05$) decrease in soybean height of 19.8% at 0.018 lb cation/A, followed by dose:dependent pattern of inhibition of 39.0% and 46.2% at the next two higher treatment levels compared to the negative control. See below for more information; all endpoints were based on measured concentrations.
Soybean *G. max*	TEP: (Gramoxone Extra); 1,1-dimethyl-4,4-bipyridylium dichloride; 29.4% a.i. w/v.	28-d EC/IC_{25} = 0.0905 (0.0211-0.419) lb cation/A NOAEL/ LOAEL = 0.0162/ 0.0323 lb cation/A Endpoint: dry weight	42601001 Supplemental (may be used quantitatively)	For the six dicots, the original DER classified the studies as acceptable. These endpoints were downgraded by a 2010 addendium because of deviations from the study protocol, chiefly 5 or 6 plants (rather than the recommended 10) were included in each replicate and height was not measured. However, the dry weight endpoints may be used quantitatively for risk calculation.
Cocklebur *X. strumarium*	TEP: (Gramoxone Extra); 1,1-dimethyl-4,4-bipyridylium dichloride; 29.4% a.i. w/v.	28-d EC/IC_{25} = 0.014 (0.01-0.019) lb cation/A EC/IC_{05} = 0.0065 lb cation/A Endpoint: dry weight	42601001 Supplemental (may be used quantitatively)	For the six dicots, the original DER classified the studies as acceptable. These endpoints were downgraded by a 2010 addendium because of deviations from the study protocol, chiefly 5 or 6 plants (rather than the recommended 10) were included in each replicate and height was not measured. However, the dry weight endpoints may be used quantitatively for risk calculation.
Common bean *P. vulgaris*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	21-day EC/IC_{25} = NC (possibly >0.28 lb cation/A – information for qualitative use) NOAEL = 0.018 lb cation/A Endpoint: height	49320309 Acceptable NEW	Significant decrease in common bean height, inhibition of 20.9% and 20.2% at the 0.071 and 0.28 lb cation/A treatment levels, respectively, compared to the negative control ($p<0.05$). The IC_{25} is qualitatively >0.28 (the highest treatment level tested), but with 20-21% height reduction at the top two treatments, this is uncertain. See below for more information; all endpoints were based on measured concentrations.
Cucumber *C. sativa*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	21-day EC/IC_{25} = 0.0887 lb cation/A NOAEL = 0.018 lb cation/A Endpoint: survival	49320309 Acceptable NEW	Significant decrease in cucumber survival, inhibition of 33 and 48%, respectively, at the 0.071 and 0.28 lb cation/A treatment levels compared to the negative control ($p<0.05$). See below for more information; all endpoints were based on measured concentrations.
Morningglory	TEP: (Gramoxone	28-d EC/IC_{25} 0.0989	42601001	For the six dicots, the original DER classified the studies as acceptable. These

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
I. hederacea	Extra); 1,1-dimethyl-4,4-bipyridylium dichloride; 29.4% a.i. w/v.	(0.0173-0.175) lb cation/A NOAEL/ LOAEL = 0.0646/ 0.129 lb cation/A Endpoint: dry weight	Supplemental (may be used quantitatively)	endpoints were downgraded by a 2010 addendium because of deviations from the study protocol, chiefly 5 or 6 plants (rather than the recommended 10) were included in each replicate and height was not measured. However, the dry weight endpoints may be used quantitatively for risk calculation.
Oilseed rape *B. napus*	TEP: (Gramoxone Extra); 1,1-dimethyl-4,4-bipyridylium dichloride; 29.4% a.i. w/v.	28-d EC/IC_{25} = 0.0410 (0.0259-0.0526) lb cation/A NOAEL/ LOAEL = 0.0162/ 0.0323 lb cation/A Endpoint: dry weight	42601001 Supplemental (may be used quantitatively)	For the six dicots, the original DER classified the studies as acceptable. These endpoints were downgraded by a 2010 addendium because of deviations from the study protocol, chiefly 5 or 6 plants (rather than the recommended 10) were included in each replicate and height was not measured. However, the dry weight endpoints may be used quantitatively for risk calculation.
Oilseed rape *B. napus*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	21-day EC/IC_{25} = 0.0325 lb cation/A NOAEL = 0.018 lb cation/A Endpoint: dry weight	49320309 Acceptable NEW	Significant decrease in oilseed rape weight, inhibition of 44.6 and 33.4% at the 0.071 and 0.28 lb cation/A treatment levels, respectively, compared to the negative control ($p<0.05$). See below for more information; all endpoints were based on measured concentrations.
Radish *R. sativus*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as free paraquat cation [plus 0.14% (wt/wt) as emetic]	21-day EC/IC_{25} = 0.162 lb cation/A NOAEL = 0.018 lb cation/A Endpoint: height	49320309 Acceptable NEW	Significant decrease in radish height, inhibition of 10.2-28.5% at the ≥0.033 lb cation/A treatment levels compared to the negative control ($p<0.05$). See below for more information; all endpoints were based on measured concentrations.
Sugar Beet *B. vulgaris*	TEP: (Gramoxone Extra); 1,1-dimethyl-4,4-bipyridylium dichloride; 29.4% a.i. w/v.	28-d EC/IC_{25} = 0.0176 (0.00230-0.0350) lb cation/A NOAEL/ LOAEL = 0.0323/ 0.0646 lb cation/A Endpoint: dry weight	42601001 Supplemental (may be used quantitatively)	For the six dicots, the original DER classified the studies as acceptable. These endpoints were downgraded by a 2010 addendium because of deviations from the study protocol, chiefly 5 or 6 plants (rather than the recommended 10) were included in each replicate and height was not measured. However, the dry weight endpoints may be used quantitatively for risk calculation.
Tomato *L. esculentum*	TEP: (Formulation A7813Q) cation: 22.4% (wt/wt) as	21-day EC/IC_{25} = 0.0422 lb cation/A NOAEL = 0.033 lb cation/A	49320309 Acceptable NEW	Significant decrease in tomato weight, inhibition of 42.9 to 64.7% from the 0.071 to the 0.57 lb cation/A treatment level compared to the negative control ($p<0.05$). See below for more information; all endpoints were based on measured

Species Tested	Guideline Note (if Applicable) Test Substance: % a.i.	Toxicity Value, mg cation/L or lb cation/A (as specified) (95% C.I.) Slope (if applicable)	MRID (or other Citation) Classification NEW Studies Noted	Notes
	free paraquat cation [plus 0.14% (wt/wt) as emetic]	Endpoint: dry weight		concentrations.
Velvetleaf *A. theophrasti*	TEP: (Gramoxone Extra); 1,1-dimethyl-4,4-bipyridylium dichloride; 29.4% a.i. w/v.	28-d EC/IC_{25} = 0.0448 (0.0232-0.0659) lb cation/A NOAEL/ LOAEL = 0.0323/ 0.0646 lb cation/A Endpoint: dry weight	42601001 Supplemental (may be used quantitatively)	For the six dicots, the original DER classified the studies as acceptable. These endpoints were downgraded by a 2010 addendium because of deviations from the study protocol, chiefly 5 or 6 plants (rather than the recommended 10) were included in each replicate and height was not measured. However, the dry weight endpoints may be used quantitatively for risk calculation.

Abbreviations: N/A = not applicable; NC = not calculable; a.i. = active ingredient; AUC = area under the curve; TGAI = technical grade active ingredient; TEP = typical end use product; -hr = hour; conc. = concentration; C.I. = confidence interval; LC/EC/ICxx = lethal/effects/inhibition concentration specifying percent of organisms affected; NOAEC (or NOAEL) = no-observed adverse effect concentration (or level); LOAEC/L) = lowest observed adverse effect concentration (level).

[1]Note: Slope based on Probit method, but reported endpoint based on moving average method.

Summary of Information on Most Sensitive Parameters by Species (lb cation/A) from 14-Day Seedling Emergence Study MRID 49320310.

Species	Endpoint	NOEC	EC_{05}	EC_{25}	EC_{50}
Common bean	None	1.13	NC	>1.13	>1.13
Cucumber	Height	1.13	0.316	>1.13	>1.13
Oat	Emergence/Survival	0.28	NC [1.16 (weight)]	0.635	>1.13
Onion	None	1.13	NC	>1.13	>1.13
Perennial Ryegrass	Emergence/Survival	0.57 [also height/ weight]	NC [1.03 (height)]	>0.57 [1.14 (height/weight)]	>1.13
Radish	None	1.13	NC	>1.13	>1.13
Soybean	None	1.13	NC	>1.13	>1.13
Tomato	None	1.13	NC	>1.13	>1.13
Corn	None	1.04	NC	>1.04	>1.04
Oilseed Rape	None	1.04	NC	>1.04	>1.04

Abbreviations: NC = not calculable; LC/EC/ICxx = lethal/effects/inhibition concentration specifying percent of organisms affected; NOAEC (or NOAEL) = no-observed adverse effect concentration (or level).

Summary of Information on Most Sensitive Parameters by Species (lb cation/A) from 21-Day Vegetative Vigor Study MRID 49320309.

Species	Endpoint	NOAEL	EC_{05}	EC_{25}	EC_{50}
Common bean	Height	0.018	0.00302	NC (possibly >0.28, qualitative estimate)	>0.28
Cucumber	Survival	0.018	0.0215	0.0887	0.238
Oat	Dry Weight	0.033	0.0124	0.0416	0.0964
Onion	Height	0.018	0.00166	0.0297	0.121
Perennial Ryegrass	Dry Weight	0.018	0.0113	0.0208	0.0316
Radish	Height	0.018	0.00824	0.162	>0.28
Soybean	Height	0.0048	0.00059	0.0217	0.265
Tomato	Dry Weight	0.033	0.00579	0.0422	0.168
Corn	Dry Weight	0.018	NC	0.0271	0.0716
Oilseed Rape	Dry Weight	0.018	0.000228	0.0325	>0.28

Abbreviations: NC = not calculable; LC/EC/ICxx = lethal/effects/inhibition concentration specifying percent of organisms affected; NOAEC (or NOAEL) = no-observed adverse effect concentration (or level).

References Cited in This Appendix:

Hoffman, D.J. and W.C. Eastin, Jr. 1982. “Effects of Lindane, Paraquat, Toxaphene, and 2,4,5-Trichlorophenoxyacetic Acid on Mallard Embryo Development.” *Arch. Environ. Contam. Toxicol.* 11: 79-86.

Hudson, R.; Tucker, R.; Haegele, M. 1984. “Handbook of toxicity of pesticides to wildlife: Second edition.” US Fish and Wildlife Service: Resource Publication 153. 91 pp.

Mayer, F. 1986. “USEPA Gulfbreeze Estuarine Toxicity Tests - marine algaes, brown shrimp, oyster, longnose killifish.”

Mayer, F.; Ellersieck, M. 1986. “Manual of Acute Toxicity: Interpretation and Data Base for 410 Chemicals and 66 Species of Freshwater Animals.” US Fish & Wildlife Service, Resource Publication 160. 579 pp.

Stevenson, J.H. 1978. “The Acute Toxicity of Unformulated Pesticides to Worker Honey Bees (*Apis mellifera* L.)” *Pl. Pathol*.:27(1978)38-40.

USEPA. 2007. ECOTOXicology Database. Office of Research and Development National Health and Environmental Effects Research Laboratory’s (NHEERL’s) Mid-Continent Ecology Division (MED). http://cfpub.epa.gov/ecotox/.

USEPA. 2009. “Risks of Paraquat Use to Federally Threatened California Red-legged Frog (*Rana aurora draytonii*). June 10, 2009.

USEPA. 2011. “EFED Registration Review: Preliminary Problem Formulation for Paraquat Dichloride.” Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. December 12, 2011 (DP Barcode: 392076).

USEPA. 2012. “Response to Comments from Syngenta on Paraquat Dichloride Preliminary Problem Formulation.” Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. April 18, 2012 (DP Barcode: 399985).

USEPA. 2014. “Review of 6 Submitted Sediment Toxicity Study Protocols for Paraquat Dichloride and Review of 2 Submitted Sediment Toxicity Studies.” Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. March 13, 2014 (DP Barcodes: 404036+).

Cited these from ECOTOX Database:
Banaee, M., et al. (2013). Histopathological Changes Induced by Paraquat on Some Tissues of Gourami Fish (*Trichogaster trichopterus*). Open Vet. J. banaee@bkatu.ac.ir//Aquaculture Department, Natural Resource Faculty, Behbahan Khatam Alanbia University of Technology, Behbahan, Iran//, AQUA. 3: 36-42. E172382.

Ghose, S. L., et al. (2014). Acute Toxicity Tests and meta-Analysis Identify Gaps in Tropical Ecotoxicology for Amphibians. Environ. Toxicol. Chem., AQUA. 33: 2114-2119 (Supplemental Journal Materials). E168034.

Ha, M. H. and J. Choi (2009). Effects of Environmental Contaminants on Hemoglobin Gene Expression in Daphnia magna: A Potential Biomarker for Freshwater Quality Monitoring. Arch. Environ. Contam. Toxicol., AQUA. **57:** 330-337. E118906.

Leboulanger, C., et al. (2009). Responses of Planktonic Microorganisms from Tropical Reservoirs to Paraquat and Deltamethrin Exposure. Arch. Environ. Contam. Toxicol., AQUA,MIXTURE. 56: 39-51. E112408.

Appendix C. Example Aquatic Modeling Output

Below is an example output (MS cotton without sediment burial) summary file from a single PWC modeling simulation.

Summary of Water Modeling of Paraquat and the USEPA Standard Pond

Estimated Environmental Concentrations for Paraquat are presented in Table 1 for the USEPA standard pond with the MScottonSTD field scenario. A graphical presentation of the year-to-year peaks is presented in Figure 1. These values were generated with the Pesticide Water Calculator (PWC), Version 1.52. Critical input values for the model are summarized in Tables 2 and 3.

This model estimates that about 7.5% of Paraquat applied to the field eventually reaches the water body. The main mechanism of transport from the field to the water body is by erosion (55.8% of the total transport), followed by runoff (27.4%) and spray drift (16.8%).

In the water body, pesticide dissipates with an effective water column half-life of 8022454000000.0 days. (This value does not include dissipation by transport to the benthic region; it includes only processes that result in removal of pesticide from the complete system.)
.

In the benthic region, pesticide is stable. The vast majority of the pesticide in the benthic region (99.96%) is sorbed to sediment rather than in the pore water.

Table 1. Estimated Environmental Concentrations (ppb) for Paraquat.

Peak (1-in-10 yr)	151.
4-day Avg (1-in-10 yr)	144.
21-day Avg (1-in-10 yr)	137.
60-day Avg (1-in-10 yr)	135.
365-day Avg (1-in-10 yr)	134.
Entire Simulation Mean	69.7

Table 2. Summary of Model Inputs for Paraquat.

Scenario	MScottonSTD
Cropped Area Fraction	1
Kd (ml/g)	1e3

Water Half-Life (days) @ 25 °C	0
Benthic Half-Life (days) @ 25 °C	0
Photolysis Half-Life (days) @ 40 °Lat	0
Hydrolysis Half-Life (days)	0
Soil Half-Life (days) @ 25 °C	0
Foliar Half-Life (days)	
Molecular Weight	257.2
Vapor Pressure (torr)	1e-9
Solubility (mg/l)	700000
Henry's Constant	0.0

Table 3. Application Schedule for Paraquat.

Date (Days Since Emergence)	Type	Amount (kg/ha)	Eff.	Drift
-5	Foliar	1.13	.95	.125
2	Placed at a depth of cm	1.13	.95	.125
9	T-band: top 2 cm fraction = , depth = cm	1.13	.95	.125
16	Ground	1.13	.95	.125

Figure 1. Yearly Peak Concentrations

The image part with relationship ID rId49 was not found in the file.

Appendix D. Example Output for Terrestrial Modeling

Alfalfa and Clover (1.5 lb cation/acre, 1x per crop cycle, interval not specified; modeled 3x annually with 120-day interval):

TREX MODEL INPUTS

These values will be used in the calculation of exposure estimates for foliar, granular, liquid and/or seed applications of pesticides.

Chemical Identity and Application Information

Chemical Name:	Paraquat	
Seed Treatment? (Check if yes)	FALSE	Seeding Rate (lbs/acre)
Use:	Clover	
Product name and form:	Paraquat Cation	
% A.I. (leading zero must be entered for formulations <1% a.i.):	100.00%	
Application Rate (lb ai/acre)	1.5	
Half-life (days):	35	
Application Interval (days):	120	
Number of Applications:	3	
Are you assessing applications with variable rates or intervals?	no	

Assessed Species Inputs (optional, use defaults for RQs for national level assessments)

What body weight range is assessed (grams)?	Birds	Mammals
Small	20	15
Medium	100	35
Large	1000	1000

Endpoints

Avian

Endpoint	Toxicity value	Indicate test species below	Optional Test Organism Body weight (g)	Optional Test Species Name	Toxicity Value Reference (MRID)
LD50 (mg/kg-bw)	26.50		14.30	Zebra Finch	49349901
LC50 (mg/kg-diet)	698.00		43.00	Japanese Quail	00022923 (got wt. from CRLF TREX sheet)
NOAEL (mg/kg-bw)					
NOAEC (mg/kg-diet)	29.40				110455
Enter the Mineau et al. Scaling Factor		1.15			

Mammalian

	Acute Study	Chronic Study
Size (g) of mammal used in toxicity study Default rat body weight is 350 grams	350	350

Endpoint	Toxicity value		Reference (MRID)
LD50 (mg/kg-bw)	93.00		43685001
LC50 (mg/kg-diet)			
Reported Chronic Endpoint	7.50		126783 NOTE: No LOAEC
Is dietary concentration (mg/kg-diet) reported from the available chronic mammal study? (yes or no)	yes		
Enter dietary concentration (mg/kg-diet)	108.00		

Summary of Risk Quotient Calculations Based on Upper Bound Kenaga EECs

Table X. Upper Bound Kenaga, Acute Avian Dose-Based Risk Quotients													
Size Class (grams)	Adjusted LD50	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	27.87	451.62	16.21	206.99	7.43	254.04	9.12	28.23	1.01	176.88	6.35	6.27	0.23
100	35.48	257.53	7.26	118.04	3.33	144.86	4.08	16.10	0.45	100.87	2.84	3.58	0.10
1000	50.11	115.30	2.30	52.85	1.05	64.86	1.29	7.21	0.14	45.16	0.90	1.60	0.03

Table X. Upper Bound Kenaga, Subacute Avian Dietary Based Risk Quotients										
	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods	
LC50	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
698	396.54	0.57	181.75	0.26	223.05	0.32	24.78	0.04	155.31	0.22

Size class not used for dietary risk quotients

Table X. Upper Bound Kenaga, Chronic Avian Dietary Based Risk Quotients										
	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods	
NOAEC (ppm)	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
29	396.54	13.49	181.75	6.18	223.05	7.59	24.78	0.84	155.31	5.28

Size class not used for dietary risk quotients

Table X. Upper Bound Kenaga, Acute Mammalian Dose-Based Risk Quotients

Size Class (grams)	Adjusted LD50	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	204.40	378.07	1.85	173.28	0.85	212.66	1.04	23.63	0.12	148.0776675	0.7245	5.251	0.0257
35	165.38	261.30	1.58	119.76	0.72	146.98	0.89	16.33	0.10	102.3414784	0.6188	3.6291	0.0219
1000	71.53	60.58	0.85	27.77	0.39	34.08	0.48	3.79	0.05	23.72823056	0.3317	0.8414	0.0118

Table X. Upper Bound Kenaga, Acute Mammalian Dietary Based Risk Quotients

LC50 (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
0	396.54	#DIV/0!	181.75	#DIV/0!	223.05	#DIV/0!	24.78	#DIV/0!	155.31	#DIV/0!

Size class not used for dietary risk quotients

Table X. Upper Bound Kenaga, Chronic Mammalian Dietary Based Risk Quotients

NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds/ Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
108	396.54	3.67	181.75	1.68	223.05	2.07	24.78	0.23	155.31	1.44

Size class not used for dietary risk quotients

NOTE: The mammalian chronic RQ estimates are < values because the rat NOAEC used did not have an accompanying LOAEC.

Table X. Upper Bound Kenaga, Chronic Mammalian Dose-Based Risk Quotients

Size Class (grams)	Adjusted NOAEL	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	16.48	378.07	22.94	173.28	10.51	212.66	12.90	23.63	1.43	148.08	8.98	5.25	0.32
35	13.34	261.30	19.59	119.76	8.98	146.98	11.02	16.33	1.22	102.34	7.67	3.63	0.27
1000	5.77	60.58	10.50	27.77	4.81	34.08	5.91	3.79	0.66	23.73	4.11	0.84	0.15

NOTE: The mammalian chronic RQ estimates are < values because the rat NOAEC used did not have an accompanying LOAEC.

Using Mean Kenaga:

Summary of Risk Quotient Calculations Based on Mean Kenaga EECs at Single App. of 0.5 lb cation/A

Table X. Mean Kenaga, Acute Avian Dose-Based Risk Quotients

Size Class (grams)	Adjusted LD50	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/ Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	27.87	48.40	**1.74**	20.50	**0.74**	25.63	**0.92**	3.99	0.14	37.01	**1.33**	0.89	0.03
100	35.48	27.60	**0.78**	11.69	0.33	14.61	0.41	2.27	0.06	21.11	**0.59**	0.51	0.01
1000	50.11	12.36	0.25	5.23	0.10	6.54	0.13	1.02	0.02	9.45	0.19	0.23	0.00

Table X. Mean Kenaga, Subacute Avian Dietary Based Risk Quotients

LC50	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/ Seeds		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
698	42.50	0.06	18.00	0.03	22.50	0.03	3.50	0.01	32.50	0.05

Size class not used for dietary risk quotients

Table X. Mean Kenaga, Chronic Avian Dietary Based Risk Quotients

NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/ Seeds		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
29	42.50	**1.45**	18.00	0.61	22.50	0.77	3.50	0.12	32.50	**1.11**

Size class not used for dietary risk quotients

Table X. Mean Kenaga, Acute Mammalian Dose-Based Risk Quotients

Size Class (grams)	Adjusted LD50	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/ Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	204.40	40.52	0.20	17.16	0.08	21.45	0.10	3.34	0.02	30.99	0.15	0.74	0.00
35	165.38	28.01	0.17	11.86	0.07	14.83	0.09	2.31	0.01	21.42	0.13	0.51	0.00
1000	71.53	6.49	0.09	2.75	0.04	3.44	0.05	0.53	0.01	4.97	0.07	0.12	0.00

Table X. Mean Kenaga, Chronic Mammalian Dietary Based Risk Quotients

NOAEC	EECs and RQs

(ppm)	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/ Seeds/Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
108	42.50	0.39	18.00	0.17	22.50	0.21	3.50	0.03	32.50	0.30

Size class not used for dietary risk quotients

Table X. Mean Kenaga, Chronic Mammalian Dose-Based Risk Quotients													
Size Class (grams)	Adjusted NOAEL	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/ Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	16.48	40.52	**2.46**	17.16	**1.04**	21.45	**1.30**	3.34	0.20	30.99	**1.88**	0.74	0.04
35	13.34	28.01	**2.10**	11.86	0.89	14.83	**1.11**	2.31	0.17	21.42	**1.61**	0.51	0.04
1000	5.77	6.49	**1.13**	2.75	0.48	3.44	0.60	0.53	0.09	4.97	0.86	0.12	0.02

Based on Avian LOAEC:

NOAEC = 29.4

LOAEC = 101 mg cation/kg-diet

Avian

Endpoint	Toxicity value	Indicate test species below
LD50 (mg/kg-bw)	26.50	
LC50 (mg/kg-diet)	698.00	
NOAEL (mg/kg-bw)		
LOAEC (mg/kg-diet)	101.00	

Based on Lowest Single App. Rate: 0.50 lb cation/A:

Table X. Upper Bound Kenaga, Chronic Avian Dietary Based Risk Quotients										
	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods	
NOAEC (ppm)	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
101	120.00	**1.19**	55.00	0.54	67.50	0.67	7.50	0.07	47.00	0.47

Table X. Mean Kenaga, Chronic Avian Dietary Based Risk Quotients										
	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods	
NOAEC (ppm)	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
101	42.50	0.42	18.00	0.18	22.50	0.22	3.50	0.03	32.50	0.32

Based on Single App. at 1.01 lb cation/A:

Table X. Upper Bound Kenaga, Chronic Avian Dietary Based Risk Quotients										
	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods	
NOAEC (ppm)	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
101	242.40	**2.40**	111.10	**1.10**	136.35	**1.35**	15.15	0.15	94.94	0.94

Table X. Mean Kenaga, Chronic Avian Dietary Based Risk Quotients										
	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods	
NOAEC (ppm)	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
101	85.85	0.85	36.36	0.36	45.45	0.45	7.07	0.07	65.65	0.65

Based on Highest Rates: 1.01 lb cation/A, 10 apps with 7-day intervals:

Table X. Upper Bound Kenaga, Chronic Avian Dietary Based Risk Quotients										
	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods	
NOAEC (ppm)	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
101	1404.41	**13.91**	643.69	**6.37**	789.98	**7.82**	87.78	0.87	550.06	**5.45**

Table X. Mean Kenaga, Chronic Avian Dietary Based Risk Quotients										
	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods	
NOAEC (ppm)	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
101	497.39	**4.92**	210.66	**2.09**	263.33	**2.61**	40.96	0.41	380.36	**3.77**

TREX Runs Using the Additional Line-of-Evidence for Mammals – PreNatal Growth Endpoint:

TREX MODEL INPUTS

These values will be used in the calculation of exposure estimates for foliar, granular, liquid and/or seed applications of pesticides.

Chemical Identity and Application Information

Chemical Name:	Paraquat
Seed Treatment? (Check if yes)	FALSE
Use:	Alfalfa/Clover
Product name and form:	Paraquat Cation
% A.I. (leading zero must be entered for formulations <1% a.i.):	100.00%
Application Rate (lb ai/acre)	1.5
Half-life (days):	35
Application Interval (days):	120
Number of Applications:	3
Are you assessing applications with variable rates or intervals?	no

Mammalian

		Acute Study	Chronic Study
Size (g) of mammal used in toxicity study Default rat body weight is 350 grams		350	350
Endpoint	**Toxicity value**		**Reference (MRID)**
LD50 (mg/kg-bw)	93.00		43685001
LC50 (mg/kg-diet)			
Reported Chronic Endpoint	1.00		113714

Is dietary concentration (mg/kg-diet) reported from the available chronic mammal study? (yes or no)	no		

Estimated Chronic Diet Concentration Equivalent to Reported Chronic Daily Dose	20	mg/kg-diet based on standard FDA lab rat conversion

Summary of Risk Quotient Calculations Based on Upper Bound Kenaga EECs

Table X. Upper Bound Kenaga, Chronic Mammalian Dietary Based Risk Quotients										
NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds/Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	396.54	19.83	181.75	9.09	223.05	11.15	24.78	1.24	155.31	7.77

Size class not used for dietary risk quotients

Table X. Upper Bound Kenaga, Chronic Mammalian Dose-Based Risk Quotients														
Size Class (grams)	Adjusted NOAEL	EECs and RQs												
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	2.20	378.07	**172.02**	173.28	**78.84**	212.66	**96.76**	23.63	**10.75**	148.08	**67.37**	5.25	**2.39**
35	1.78	261.30	**146.94**	119.76	**67.35**	146.98	**82.65**	16.33	**9.18**	102.34	**57.55**	3.63	**2.04**
1000	0.77	60.58	**78.76**	27.77	**36.10**	34.08	**44.31**	3.79	**4.92**	23.73	**30.85**	0.84	**1.09**

Summary of Risk Quotient Calculations Based on Mean Kenaga EECs

NOAEC (ppm)	Short Grass EEC	Short Grass RQ	Tall Grass EEC	Tall Grass RQ	Broadleaf Plants EEC	Broadleaf Plants RQ	Fruits/Pods/Seeds/Large Insects EEC	Fruits/Pods/Seeds/Large Insects RQ	Arthropods EEC	Arthropods RQ
	Table X. Mean Kenaga, Chronic Mammalian Dietary Based Risk Quotients									
	EECs and RQs									
20	140.44	**7.02**	59.48	**2.97**	74.35	**3.72**	11.57	0.58	107.40	**5.37**

Size class not used for dietary risk quotients

Table X. Mean Kenaga, Chronic Mammalian Dose-Based Risk Quotients

Size Class (grams)	Adjusted NOAEL	Short Grass EEC	Short Grass RQ	Tall Grass EEC	Tall Grass RQ	Broadleaf Plants EEC	Broadleaf Plants RQ	Fruits/Pods/Seeds EEC	Fruits/Pods/Seeds RQ	Arthropods EEC	Arthropods RQ	Granivore EEC	Granivore RQ
		EECs and RQs											
15	2.20	133.90	**60.92**	56.71	**25.80**	70.89	**32.25**	11.03	**5.02**	102.39	**46.59**	2.45	**1.11**
35	1.78	92.54	**52.04**	39.19	**22.04**	48.99	**27.55**	7.62	**4.29**	70.77	**39.80**	1.69	0.95
1000	0.77	21.46	**27.90**	9.09	**11.81**	11.36	**14.77**	1.77	**2.30**	16.41	**21.33**	0.39	0.51

Mean Kenega:

Dose-based RQs (Dose-based EEC/LD50 or NOAEL)	Small mammal 15 grams		Medium mammal 35 grams		Large mammal 1000 grams	
	Acute	Chronic	Acute	Chronic	Acute	Chronic
Short Grass	**0.66**	**60.92**	**0.56**	**52.04**	0.30	**27.90**
Tall Grass	0.28	**25.80**	0.24	**22.04**	0.13	**11.81**
Broadleaf plants	0.35	**32.25**	0.30	**27.55**	0.16	**14.77**
Fruits/pods	0.05	**5.02**	0.05	**4.29**	0.02	**2.30**
Arthropods	**0.50**	**46.59**	0.43	**39.80**	0.23	**21.33**
Seeds	0.01	**1.11**	0.01	0.95	0.01	0.51

Chemical Identity and Application Information

Chemical Name:	**Paraquat**
Seed Treatment? (Check if yes)	FALSE
Use:	**Premeses/Areas**
Product name and form:	**Paraquat Cation**

% A.I. (leading zero must be entered for formulations <1% a.i.):	100.00%
Application Rate (lb ai/acre)	1.01
Half-life (days):	35
Application Interval (days):	7
Number of Applications:	10
Are you assessing applications with variable rates or intervals?	no

Summary of Risk Quotient Calculations Based on Upper Bound Kenaga EECs

Table X. Upper Bound Kenaga, Chronic Mammalian Dietary Based Risk Quotients

NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds/Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	1404.41	**70.22**	643.69	**32.18**	789.98	**39.50**	87.78	**4.39**	550.06	**27.50**

Size class not used for dietary risk quotients

Table X. Upper Bound Kenaga, Chronic Mammalian Dose-Based Risk Quotients

Size Class (grams)	Adjusted NOAEL	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	2.20	1339.00	**609.24**	613.71	**279.23**	753.19	**342.70**	83.69	**38.08**	524.44	**238.62**	18.60	**8.46**
35	1.78	925.43	**520.41**	424.15	**238.52**	520.55	**292.73**	57.84	**32.53**	362.46	**203.83**	12.85	**7.23**
1000	0.77	214.56	**278.96**	98.34	**127.86**	120.69	**156.91**	13.41	**17.43**	84.04	**109.26**	2.98	**3.87**

Table X. Mean Kenaga, Chronic Mammalian Dietary Based Risk Quotients

NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds/Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	497.39	**24.87**	210.66	**10.53**	263.33	**13.17**	40.96	**2.05**	380.36	**19.02**

Size class not used for dietary risk quotients

Table X. Mean Kenaga, Chronic Mammalian Dose-Based Risk Quotients													
Size Class (grams)	Adjusted NOAEL	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	2.20	474.23	**215.77**	200.85	**91.39**	251.06	**114.23**	39.05	**17.77**	362.64	**165.00**	8.68	**3.95**
35	1.78	327.76	**184.31**	138.81	**78.06**	173.52	**97.58**	26.99	**15.18**	250.64	**140.94**	6.00	**3.37**
1000	0.77	75.99	**98.80**	32.18	**41.84**	40.23	**52.30**	6.26	**8.14**	58.11	**75.55**	1.39	**1.81**

Dose-based RQs (Dose-based EEC/LD50 or NOAEL)	Small mammal 15 grams		Medium mammal 35 grams		Large mammal 1000 grams	
	Acute	Chronic	Acute	Chronic	Acute	Chronic
Short Grass	**2.32**	**215.77**	**1.98**	**184.31**	**1.06**	**98.80**
Tall Grass	**0.98**	**91.39**	**0.84**	**78.06**	0.45	**41.84**
Broadleaf plants	**1.23**	**114.23**	**1.05**	**97.58**	**0.56**	**52.30**
Fruits/pods	0.19	**17.77**	0.16	**15.18**	0.09	**8.14**
Arthropods	**1.77**	**165.00**	**1.52**	**140.94**	**0.81**	**75.55**
Seeds	0.04	**3.95**	0.04	**3.37**	0.02	**1.81**

Chemical Identity and Application Information

Chemical Name:	**Paraquat**
Seed Treatment? (Check if yes)	FALSE
Use:	**Multi Ag and Non-Ag**
Product name and form:	**Paraquat Cation**
% A.I. (leading zero must be entered for formulations <1% a.i.):	**100.00%**
Application Rate (lb ai/acre)	**1.01**
Half-life (days):	**35**
Application Interval (days):	**7**
Number of Applications:	**5**
Are you assessing applications with variable rates or intervals?	**no**

Table X. Upper Bound Kenaga, Chronic Mammalian Dietary Based Risk Quotients

NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds/Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	936.27	**46.81**	429.13	**21.46**	526.65	**26.33**	58.52	**2.93**	366.71	**18.34**

Size class not used for dietary risk quotients

Table X. Upper Bound Kenaga, Chronic Mammalian Dose-Based Risk Quotients

Size Class (grams)	Adjusted NOAEL	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	2.20	892.66	**406.16**	409.14	**186.16**	502.12	**228.46**	55.79	**25.38**	349.63	**159.08**	12.40	**5.64**
35	1.78	616.95	**346.94**	282.77	**159.01**	347.03	**195.15**	38.56	**21.68**	241.64	**135.88**	8.57	**4.82**
1000	0.77	143.04	**185.97**	65.56	**85.24**	80.46	**104.61**	8.94	**11.62**	56.02	**72.84**	1.99	**2.58**

Summary of Risk Quotient Calculations Based on Mean Kenaga EECs

Table X. Mean Kenaga, Chronic Mammalian Dietary Based Risk Quotients										
NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds/Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	331.60	**16.58**	140.44	**7.02**	175.55	**8.78**	27.31	**1.37**	253.57	**12.68**

Size class not used for dietary risk quotients

Table X. Mean Kenaga, Chronic Mammalian Dose-Based Risk Quotients														
Size Class (grams)	Adjusted NOAEL	EECs and RQs												
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	2.20	316.15	**143.85**	133.90	**60.92**	167.37	**76.15**	26.04	**11.85**	241.76	**110.00**	5.79	**2.63**
35	1.78	218.50	**122.87**	92.54	**52.04**	115.68	**65.05**	17.99	**10.12**	167.09	**93.96**	4.00	**2.25**
1000	0.77	50.66	**65.87**	21.46	**27.90**	26.82	**34.87**	4.17	**5.42**	38.74	**50.37**	0.93	**1.21**

Dose-based RQs (Dose-based EEC/LD50 or NOAEL)	Small mammal 15 grams		Medium mammal 35 grams		Large mammal 1000 grams	
	Acute	Chronic	Acute	Chronic	Acute	Chronic
Short Grass	**1.55**	**143.85**	**1.32**	**122.87**	**0.71**	**65.87**
Tall Grass	**0.66**	**60.92**	**0.56**	**52.04**	**0.30**	**27.90**
Broadleaf plants	**0.82**	**76.15**	**0.70**	**65.05**	**0.37**	**34.87**
Fruits/pods	0.13	**11.85**	0.11	**10.12**	0.06	**5.42**
Arthropods	**1.18**	**110.00**	**1.01**	**93.96**	**0.54**	**50.37**
Seeds	0.03	**2.63**	0.02	**2.25**	0.01	**1.21**

Chemical Identity and Application Information

Chemical Name:	Paraquat
Seed Treatment? (Check if yes)	FALSE
Use:	Ag and Non-Ag Single App
Product name and form:	Paraquat Cation
% A.I. (leading zero must be entered for formulations <1% a.i.):	100.00%
Application Rate (lb ai/acre)	1.01
Half-life (days):	35
Application Interval (days):	
Number of Applications:	1
Are you assessing applications with variable rates or intervals?	no

Summary of Risk Quotient Calculations Based on Upper Bound Kenaga EECs

Table X. Upper Bound Kenaga, Chronic Mammalian Dietary Based Risk Quotients										
NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds/Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	242.40	**12.12**	111.10	**5.56**	136.35	**6.82**	15.15	0.76	94.94	**4.75**

Size class not used for dietary risk quotients

Table X. Upper Bound Kenaga, Chronic Mammalian Dose-Based Risk Quotients													
Size Class (grams)	Adjusted NOAEL	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	2.20	231.11	**105.15**	105.93	**48.20**	130.00	**59.15**	14.44	**6.57**	90.52	**41.19**	3.21	**1.46**
35	1.78	159.73	**89.82**	73.21	**41.17**	89.85	**50.52**	9.98	**5.61**	62.56	**35.18**	2.22	**1.25**
1000	0.77	37.03	**48.15**	16.97	**22.07**	20.83	**27.08**	2.31	**3.01**	14.50	**18.86**	0.51	0.67

Summary of Risk Quotient Calculations Based on Mean Kenaga EECs

Table X. Mean Kenaga, Chronic Mammalian Dietary Based Risk Quotients										
NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds/Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	85.85	**4.29**	36.36	**1.82**	45.45	**2.27**	7.07	0.35	65.65	**3.28**

Size class not used for dietary risk quotients

Table X. Mean Kenaga, Chronic Mammalian Dose-Based Risk Quotients														
Size Class (grams)	Adjusted NOAEL	EECs and RQs												
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	2.20	81.85	**37.24**	34.67	**15.77**	43.33	**19.72**	6.74	**3.07**	62.59	**28.48**	1.50	0.68
35	1.78	56.57	**31.81**	23.96	**13.47**	29.95	**16.84**	4.66	**2.62**	43.26	**24.33**	1.04	0.58
1000	0.77	13.12	**17.05**	5.56	**7.22**	6.94	**9.03**	1.08	**1.40**	10.03	**13.04**	0.24	0.31

Dose-based RQs (Dose-based EEC/LD50 or NOAEL)	Small mammal 15 grams		Medium mammal 35 grams		Large mammal 1000 grams	
	Acute	Chronic	Acute	Chronic	Acute	Chronic
Short Grass	0.40	**37.24**	0.34	**31.81**	0.18	**17.05**
Tall Grass	0.17	**15.77**	0.14	**13.47**	0.08	**7.22**
Broadleaf plants	0.21	**19.72**	0.18	**16.84**	0.10	**9.03**
Fruits/pods	0.03	**3.07**	0.03	**2.62**	0.02	**1.40**
Arthropods	0.31	**28.48**	0.26	**24.33**	0.14	**13.04**
Seeds	0.01	0.68	0.01	0.58	0.00	0.31

Chemical Identity and Application Information

Chemical Name:	**Paraquat**
Seed Treatment? (Check if yes)	FALSE
Use:	**Ag and Non-Ag Lower Rate**
Product name and form:	**Paraquat Cation**
% A.I. (leading zero must be entered for formulations <1% a.i.):	**100.00%**
Application Rate (lb ai/acre)	**0.5**
Half-life (days):	**35**
Application Interval (days):	
Number of Applications:	**1**
Are you assessing applications with variable rates or intervals?	**no**

Summary of Risk Quotient Calculations Based on Upper Bound Kenaga EECs

Table X. Upper Bound Kenaga, Chronic Mammalian Dietary Based Risk Quotients

NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds/Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	120.00	**6.00**	55.00	**2.75**	67.50	**3.38**	7.50	0.38	47.00	**2.35**

Size class not used for dietary risk quotients

Table X. Upper Bound Kenaga, Chronic Mammalian Dose-Based Risk Quotients

Size Class (grams)	Adjusted NOAEL	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	2.20	114.41	**52.06**	52.44	**23.86**	64.36	**29.28**	7.15	**3.25**	44.81	**20.39**	1.59	0.72
35	1.78	79.07	**44.47**	36.24	**20.38**	44.48	**25.01**	4.94	**2.78**	30.97	**17.42**	1.10	0.62
1000	0.77	18.33	**23.84**	8.40	**10.92**	10.31	**13.41**	1.15	**1.49**	7.18	**9.34**	0.25	0.33

Summary of Risk Quotient Calculations Based on Mean Kenaga EECs

Table X. Mean Kenaga, Chronic Mammalian Dietary Based Risk Quotients										
NOAEC (ppm)	EECs and RQs									
	Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds/Large Insects		Arthropods	
	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
20	42.50	**2.13**	18.00	0.90	22.50	**1.13**	3.50	0.18	32.50	**1.63**

Size class not used for dietary risk quotients

Table X. Mean Kenaga, Chronic Mammalian Dose-Based Risk Quotients													
Size Class (grams)	Adjusted NOAEL	EECs and RQs											
		Short Grass		Tall Grass		Broadleaf Plants		Fruits/Pods/Seeds		Arthropods		Granivore	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
15	2.20	40.52	**18.44**	17.16	**7.81**	21.45	**9.76**	3.34	**1.52**	30.99	**14.10**	0.74	0.34
35	1.78	28.01	**15.75**	11.86	**6.67**	14.83	**8.34**	2.31	**1.30**	21.42	**12.04**	0.51	0.29
1000	0.77	6.49	**8.44**	2.75	**3.58**	3.44	**4.47**	0.53	0.70	4.97	**6.46**	0.12	0.15

Dose-based RQs (Dose-based EEC/LD50 or NOAEL)	Small mammal 15 grams		Medium mammal 35 grams		Large mammal 1000 grams	
	Acute	Chronic	Acute	Chronic	Acute	Chronic
Short Grass	0.20	**18.44**	0.17	**15.75**	0.09	**8.44**
Tall Grass	0.08	**7.81**	0.07	**6.67**	0.04	**3.58**
Broadleaf plants	0.10	**9.76**	0.09	**8.34**	0.05	**4.47**
Fruits/pods	0.02	**1.52**	0.01	**1.30**	0.01	**0.70**
Arthropods	0.15	**14.10**	0.13	**12.04**	0.07	**6.46**
Seeds	0.00	0.34	0.00	0.29	0.00	0.15

TerrPlant v. 1.2.2
Green values signify user inputs (Tables 1, 2 and 4).
Input and output guidance is in popups indicated by red arrows.

Table 1. Chemical Identity.	
Chemical Name	**Paraquat**
PC code	**61601**
Use	**Alfalfa and Clover**
Application Method	**Aerial**
Application Form	**Spray**
Solubility in Water (ppm)	**336,000**

Table 2. Input parameters used to derive EECs.			
Input Parameter	**Symbol**	**Value**	**Units**
Application Rate	A	**1.5**	**y**
Incorporation	I	**1**	none
Runoff Fraction	R	**0.05**	none
Drift Fraction	D	**0.05**	none

Table 3. EECs for Paraquat. Units in y.		
Description	**Equation**	**EEC**
Runoff to dry areas	(A/I)*R	0.075
Runoff to semi-aquatic areas	(A/I)*R*10	0.75
Spray drift	**A*D**	**0.075**
Total for dry areas	**((A/I)*R)+(A*D)**	**0.15**
Total for semi-aquatic areas	**((A/I)*R*10)+(A*D)**	**0.825**

Table 4. Plant survival and growth data used for RQ derivation. Units are in y.				
	Seedling Emergence		**Vegetative Vigor**	
Plant type	**EC_{25}**	**NOAEC**	**EC_{25}**	**NOAEC**
Monocot	**0.635**	**0.28**	**0.0208**	**0.018**
Dicot	**0.67**	**0.171**	**0.0217**	**0.0048**

Table 5. RQ values for plants in dry and semi-aquatic areas exposed to Paraquat through runoff and/or spray drift.*				
Plant Type	**Listed Status**	**Dry**	**Semi-Aquatic**	**Spray Drift**
Monocot	non-listed	0.24	1.30	3.61
Monocot	listed	0.54	2.95	4.17
Dicot	non-listed	0.22	1.23	3.46
Dicot	listed	0.88	4.82	15.63
*If RQ > 1.0, the LOC is exceeded, resulting in potential for risk to that plant group.				

BeeRex Output:

Table 1. User inputs (related to exposure)

Description	Value
Application rate	1.5
Units of app rate	lb a.i./A
Application method	foliar spray
Are empirical residue data available?	no

Table 5. Results (highest RQs)

Exposure	Adults	Larvae
Acute contact	0.077885	NA
Acute dietary	2.19	#DIV/0!
Chronic dietary	#DIV/0!	#DIV/0!

μg a.i./mg
μg a.i./mg
μg a.i./mg

Table 2. Toxicity data

Description	Value (μg a.i./bee)
Adult contact LD50	52
Adult oral LD50	22
Adult oral NOAEL	
Larval LD50	
Larval NOAEL	

Table 3. Estimated concentrations in pollen and nectar

Application method	EECs (mg a.i./kg)	EECs (μg a.i./mg)
foliar spray	165	0.165
soil application	NA	NA
seed treatment	NA	NA
tree trunk	NA	NA

Table 4. Daily consumption of food, pesticide dose and resulting dietary RQs for all bees

Life stage	Caste or task in hive	Average age (in days)	Jelly (mg/day)	Nectar (mg/day)	Pollen (mg/day)	Total dose (μg a.i./bee)	Acute RQ
Larval	Worker	1	1.9	0	0	0.003135	#DIV/0!

		2	9.4	0	0	0.01551	#DIV/0!
		3	19	0	0	0.03135	#DIV/0!
		4	0	60	1.8	10.197	#DIV/0!
		5	0	120	3.6	20.394	#DIV/0!
	Drone	6+	0	130	3.6	22.044	#DIV/0!
	Queen	1	1.9	0	0	0.003135	#DIV/0!
		2	9.4	0	0	0.01551	#DIV/0!
		3	23	0	0	0.03795	#DIV/0!
		4+	141	0	0	0.23265	#DIV/0!
Adult	Worker (cell cleaning and capping)	0-10	0	60	6.65	10.99725	0.499875
	Worker (brood and queen tending, nurse bees)	6 to 17	0	140	9.6	24.684	1.122
	Worker (comb building, cleaning and food handling)	11 to 18	0	60	1.7	10.1805	0.46275
	Worker (foraging for pollen)	>18	0	43.5	0.041	7.184265	0.3265575
	Worker (foraging for nectar)	>18	0	292	0.041	48.186765	2.1903075
	Worker (maintenance of hive in winter)	0-90	0	29	2	5.115	0.2325
	Drone	>10	0	235	0.0002	38.775033	1.7625015
	Queen (laying 1500 eggs/day)	Entire lifestage	525	0	0	0.86625	0.039375

AgDrift Output:
Aerial Applications:
Fine Droplets:

The image part with relationship ID rId66 was not found in the file.

The image part with relationship ID rId67 was not found in the file.

The image part with relationship ID rId68 was not found in the file.

The image part with relationship ID rId69 was not found in the file.

Appendix E. Incident Report Outputs

Aggregate Incident Reports--PC Codes 061601 (Paraquat Dichloride) and 061603 (Paraquat):

The image part with relationship ID rId70 was not found in the file.

The image part with relationship ID rId71 was not found in the file.

The image part with relationship ID rId72 was not found in the file.

IDS Output Table for Incidents from 1975 to June 2018

Incident Number	Year	State	Product	Legality	Certainity Index	Use Site	Species	Scientific Name	Distance	# Affected	Magnitude
B0000502-18	1981	VA		Undetermined	Possible	Agricultural Area	Sunfish	Centrarchidae	ADJACENT	53	53
I000097-015	1989	VA	N/R	Undetermined	Unlikely	N/R	Chipping Sparrow	Spizella passerina	Vicinity	1	1
I000097-015	1989	VA	N/R	Undetermined	Unlikely	N/R	Common Grackle	Quiscalus quiscula	Vicinity	1	1
I000097-015	1989	VA	N/R	Undetermined	Unlikely	N/R	American Robin	Turdus migratorius	Vicinity		At least 2
I007334-001	1998	IL	GRAMOXOME	Undetermined	Possible	N/R	Corn	Zea mays	Vicinity		18 of 103 acres
I007371-008	1997	PA	GRAMOXONE	Misuse (accidental)	Highly Probable	Soybean	Soybean	Glycine max	VICINITY		UNKNOWN
I007371-033	1997	PA	GRAMOXONE	Misuse (accidental)	Probable	CORN	Grass	Poaceae	VICINITY		UNKNOWN
I007371-034	1997	PA	GRAMOXONE	Misuse (accidental)	Probable	CORN	Grass	Poaceae	VICINITY		UNKNOWN
I008168-001	1998	VA	GRAMOXONE EXTRA	Registered Use	Probable	Corn	Canada Goose	Branta canadensis	10 feet from creek	5	5
I009314-005	1997	IN	GRAMOXONE EXTRA	Registered Use	Possible	FIELD	Bluegill	Lepomis macrochirus	250 FEET		
I009314-005	1997	IN	GRAMOXONE EXTRA	Registered Use	Possible	FIELD	Crappie	Pomoxis sp.	250 FEET		
I009314-005	1997	IN	GRAMOXONE EXTRA	Registered Use	Possible	FIELD	Bass	Micropterus spp.	250 FEET		
I009573-009	1999	AL	GRAMOXONE	Undetermined	Possible	N/R	Corn	Zea mays	Treated directly		75% OF 200 ACRES
I011838-038	2001	GA	GRAMOXONE	Undetermined	Possible	Peanut	Peanut	Arachis hypogaea	Treated directly		ALL 25 ACRES
I011838-038	2001	GA	GRAMOXONE	Undetermined	Possible	Peanut	Peanut	Arachis hypogaea	Treated directly		ALL 25 ACRES
I011838-055	2001	NC	Gramoxone	Registered Use	Possible	N/R	Peanut	Arachis hypogaea	N/R		10 acres
I011838-091	2001	OK	Cyclone	Undetermined	Possible	Peanut	Peanut	Arachis hypogaea			80 acres
I011838-091	2001	OK	Cyclone	Undetermined	Possible	Peanut	Peanut	Arachis hypogaea			80 acres
I012366-023	2000	VA	Gramoxone	Undetermined	Possible	Corn, field	Corn, Field	Zea mays			120 acres
I012684-010	2001	VA	Gramoxone	Registered	Possible	Peanut	Peanut	Arachis hypogaea			5 acres

				Use								
I012684-010	2001	VA	Gramoxone	Registered Use	Possible	Peanut	Peanut	Arachis hypogaea			5 acres	
I013554-040	2002	IL	Gramoxone Max	Misuse	Probable	N/R	Corn, Field	Zea mays	On site		1040 acres	
I013636-029	1996	OR	Gramoxone	Registered Use	Possible	N/R	Peppermint	Mentha x piperita	Treated directly		181 acres	
I013884-014	1998	WA		Undetermined	Possible	Potato ?	Apple	Malus domestica	Vicinity		Not given	
I013884-038	1998	WA		Registered Use	Probable	Pea	Ornamental		Vicinity		Not given	
I014034-009	2003	GA	Gramoxone MAX	Registered Use	Possible	Pasture	Pasture Grass		Treated directly		60 acres	
I014034-009	2003	GA	Gramoxone MAX	Registered Use	Possible	Pasture	Pasture Grass		Treated directly		60 acres	
I014409-001	1992	WA		Undetermined	Possible	N/R	Radish	Raphanus sativus	Vicinity		Not given	
I014409-001	1992	WA		Undetermined	Possible	N/R	Radish	Raphanus sativus	Vicinity		Not given	
I014409-024	1992	WA		Misuse	Possible	Wheat	Alfalfa	Medicago sativa	Vicinity		Not given	
I014409-024	1992	WA		Misuse	Possible	Wheat	Alfalfa	Medicago sativa	Vicinity		Not given	
I016940-005	2005	CA	Gramoxone	Misuse (intentional)	Probable	Wheat	Wheat	Triticum sp.	Adjacent		120 of 184 acres	
I020459-025	2000	WA		Undetermined	Probable	Corn, sweet	Winter Wheat		Adjacent		2.5 acres	
I020459-025	2000	WA		Undetermined	Probable	Corn, sweet	Winter Wheat		Adjacent		2.5 acres	
I020627-019	2001	WA		Undetermined	Probable	Agricultural area	Blueberry	Vaccinium sp.	Adjacent			
I020627-019	2001	WA		Undetermined	Probable	Agricultural area	Blueberry	Vaccinium sp.	Adjacent			
I020627-033	2001	WA		Undetermined	Probable	Agricultural area	Dog	Canis familiaris		2		2
I020627-036	2001	WA		Undetermined	Probable	Agricultural area	Alfalfa	Medicago sativa				
I020627-036	2001	WA		Undetermined	Probable	Agricultural area	Alfalfa	Medicago sativa				
I020998-023	2002	WA		Misuse	Possible		Cherry	Prunus sp.				
I021276-006	2004	WA		Undetermined	Probable	Agricultural area	Corn	Zea mays	Vicinity			

I021457-015	2006	WA		Undetermined	Possible	N/R	Ornamental		Adjacent		many	
I021457-015	2006	WA		Undetermined	Possible	N/R	Ornamental		Adjacent		many	
I021685-002	2009			Undetermined	Probable	Bait, carcass/meat	Eagle	Buteoninae				
I021685-002	2009			Undetermined	Probable	Bait, carcass/meat	Golden Eagle	Aquila chrysaetos				
I021685-002	2009			Undetermined	Probable	Bait, carcass/meat	Eagle	Buteoninae				
I021685-002	2009			Undetermined	Probable	Bait, carcass/meat	Golden Eagle	Aquila chrysaetos				
I021848-003	2010			Undetermined	Possible	Bait, carcass/meat	Eagle	Buteoninae	N/R	13		13
I023444-012	2011	PA	Gramoxone Inteon	Undetermined	Possible	Corn, field	Corn	Zea mays	On site		100% of 130 acres	
I023587-006	2011	CA	Gramoxone Inteon	Undetermined	Possible	Cotton	Vegetable		Vicinity		100% of 25 acres	
I023587-006	2011	CA	Gramoxone Inteon	Undetermined	Possible	Cotton	Vegetable		Vicinity		100% of 25 acres	
I027242-001					Possible		Dog	Canis familiaris	Vicinity	1		1
I028934-00016	2016	CA	GRAMOXONE SL 2.0	Undetermined	Possible	Agricultural area	Onion	Allium cepa	Vicinity	145	145 acres	
I029512-00004	2016		GRAMOXONE SL 2.0	Undetermined	Possible		Honey Bee	Apis mellifera	N/R	2	2 hives	

Information on New Incidents and Others Not Previously Summarized

New Incidents Not Previously Summarized
I021685-002 UNDETERMINED LEGALITY 02/18/2009 Ireland Probable Likelihood This incident involves the death of a young golden eagle in Dunlewy, Ireland. Toxicity tests showed that the cause of death was paraquat poisoning, despite paraquat being banned in the EU in 2007 for marketing and use as a pesticide. The bird had been dead for some time when found.
I021848-003 UNDETERMINED LEGALITY 05/08/2010 Ireland Possible Likelihood This incident involves the deaths of thirteen sea eagles in Kerry, Ireland since their release in Killarney National Park in 2007. The eagles were killed by different poisons, sometimes in cocktail form, laced into pieces of meat or animal carcasses. Paraquat and carbofuran were each identified in at least one body by a lab examination. Paraquat is banned in the EU.
I021848-004 UNDETERMINED LEGALITY November 2007 – May 2010 Ireland Possible Likelihood This incident involves the death of 1-4 red-kites in Wicklow, Ireland following a re-introduction program. The birds were killed by different poisons, including paraquat and carbofuran, in cocktail form laced into pieces of meat or animal carcasses. Paraquat is banned in the EU.
I023444-012 UNDETERMINED LEGALITY 07/26/2011 PA Possible Likelihood This incident involves damage to a corn field in Huntington County, PA. One-hundred percent of 130 acres of corn was damaged after an application of Gramoxone Inteon (a.i. paraquat) was applied at a rate of 1.50pt/A.
I026156-001 UNDETERMINED LEGALITY 01/25/2014 HI Highly Probable Likelihood This incident involves the death of four dogs and one cat in Kalaheo, HI with paraquat, as determined by Hawaiian authorities. It is unclear as to whether the restricted-use pesticide was being used on a residential yard or if the animals came across it elsewhere, according to the Kauai Humane Society field services supervisor.
I027242-001 UNDETERMINED LEGALITY 11/07/2014 Cayman Islands Possible Likelihood This incident involves the death of a pet owner's dog in the Cayman Islands after ingesting paraquat, as determined by a local veterinarian.
I029512-00004 UNDETERMINED LEGALITY 4/22/2016 Unknown Location Possible Likelihood On April 22, 2016 a bee kill involving two hives was reported in North Carolina. Bees began dying on March 30. There had been no varroa mite threatments made to any of the hives. It was discovered that Gramoxone SL 2.0 (para-quat dichloride), EPA Reg. No. 100-l431 was applied to the field next to the Apiary. No pesticides were detected in samples. (PDF of incident could not be attached due to inclusion of personal identity information)
Additional Incidents Prior to Previous Reviews but Not Included in Previous Reviews
I014409-001 UNDETERMINED LEGALITY 4/24/1992 WA Possible Likelihood This incident was reported in the Washington State Dept. of Health Annual Report 1993, Pesticide Incident Reporting Review Panel, April 1994, prepared by the Washington State Department of Agriculture. It was alleged that paraquat herbicide drifted onto a radish crop causing damage. Alleged infractor applied a federal restricted use pesticide without a license or supervision. No action by the State was taken. No analysis.
I013884-038 REGISTERED USE 7/28/1998 WA Probable Likelihood This is from the 1999 Annual Report from the Washington State Department of Health Pesticide Incident Reporting and Tracking Review Panel, November 2000, from the 1998 PIRT Data. Over spray of paraquat on peas affected

ornamental and vegetable garden plants. State inspector observed paraquat symptoms.
I020627-033 UNDETERMINED LEGALITY 08/01/2001 WA Probable Likelihood This incident is reported in the Washington State Department of Agriculture annual report 2003 by the Office of Environmental Health and Safety. The case suspects paraquat poisoning as the cause of death of two dogs and the cause of the sickening of several other dogs. A vet stated that symptoms were consistent with paraquat poisoning. Two locations were found where paraquat may have been used.
I020627-036 UNDETERMINED LEGALITY 09/07/2001 WA Probable Likelihood This incident is reported in the Washington State Department of Agriculture annual report 2003 by the Office of Environmental Health and Safety. The case involves the alleged drift of paraquat as the cause of damage to alfalfa fields. The drift caused spotting on the alfalfa.
I020459-025 UNDETERMINED LEGALITY 05/02/2000 WA Probable Likelihood This incident is reported in the Washington State Department of Agriculture 2002 PIRT Report. The case involves the alleged drift from the application of paraquat sprayed on sweet corn to winter wheat (seed wheat) in an adjacent field, causing damage. Approximately 2.5 acres were affected.
I020627-019 UNDETERMINED LEGALITY 06/25/2001 WA Probable Likelihood This incident is reported in the Washington State Department of Agriculture Annual report 2003 by the Office of Environmental Health and Safety. The case involves the alleged drift of paraquat from a ground application onto blueberry plants in an adjacent field. Symptoms of effected plants consistent with drift.
I020998-023 MISUSE 04/19/2002 WA Possible Likelihood This incident is reported in the Washington State Department of Agriculture annual report 2002 by the Office of Environmental Health and Safety. The case involves the alleged drift and application of paraquat and carfentrazone-ethyl on hops field that damaged cherry plants. It is unclear which of the two active ingredients is responsible for the damage.
I021276-006 UNETERMINED LEGALITY 07/03/2004 WA Probable Likelihood This incident is reported in the Washington State Department of Health and Pesticide Incident Reporting and Tracking Review Panel annual report 2005. The case involves the alleged aerial application and drift of paraquat from an onion field to a corn field in the vicinity, causing damage to the corn.
I021457-015 UNDETERMINED LEGALITY 07/07/2006 WA Possible Likelihood This incident is reported by the Washington State Department of Health's Division of Environmental Health in 2006. The case involves the drift of paraquat and glyphosate onto an adjacent garden, causing damage to ornamental plants. The incident was verified by a state inspector, but it is not clear which of the two active ingredients is responsible for the damage.

Appendix F. Crop Attractiveness to Bees

Information on the Attractiveness of Registered Use Patterns for Paraquat to Bees

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive?[1,2]	Solitary Bee Attractive?[1,2]	Acreage in the U.S.	Notes
Acerola (West Indies Cherry) Not in Database, info for Mazzard, Sweet Cherries	Y (pollen[2] & nectar[1])	Yes[1]	Yes[2] Osmia	868800 Sweet, 36500 Tart	
Alfalfa *Medicago sativa*	Y (pollen[1] & nectar[2])	Yes[1]	Yes[2] Alfalfa leafcutting bee, Alkali bee	18 million	Only a small percentage of alfalfa is grown for seed; typically using managed alfalfa leafcutting bees, alkali bees or honey bees. Timing of hay or silage harvest, relative to bloom, varies by agronomic practice, with earlier cuts typically occurring prior to bloom and later cuts being harvested up to 25% bloom.
Almond *Prunus amygdalus*; *P. communis*; *Amygdalus communis*	Y (pollen[2] & nectar[1])	Yes[1]	Yes[1] Osmia	780,000	
Apple *Malus pumila*; *M. sylvestris*; *M. communis*; *Pyrus malus*	Y (pollen[2] & nectar[1])	Yes[1]	Yes[2] *Andrena, Anthidium, Halictus, Osmia, Anthophora, Habropoda*	327,800	
Apricot *Prunus armeniaca*	Y (pollen[2] & nectar[2])	Yes[2]	Yes[1]	12,150	
Artichoke *Cynara scolymus*	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1]	7,000	
Asparagus *Asparagus officinalis*	Y (pollen[1] & nectar[1])			24,500	Only a small % of asparagus acreage is grown for seed.
Avocado *Persea americana*	Y (pollen[1] & nectar[1])		Yes[1]	59,950	
Banana	Y (nectar[1])	No	No	1,000	

Crop Name	**Honey Bee Attractive?[1,2]**	**Bumble Bee Attractive? [1, 2]**	**Solitary Bee Attractive? [1, 2]**	**Acreage in the U.S.**	**Notes**
Musa sapientum; *M. cavendishii*; *M. nana*					
Barley *Hordeum* spp.	N	No	No	3,000,000	Wind pollinated
Beans, Dried-Type Represented in database by Broadbean *Vicia faba*	Y (pollen[2] & nectar[2])	Yes[2]	Yes[1] *Anthophora, Eucra, Megachile*	1,310,000	
Cabbages and Other Brassica Vegetables This also represents Turnips and Tyfon	Y (pollen[2] & nectar[2])	Yes[1]	Yes[1]	Cabbage 60, 200 (Annual); Brussels Sprouts 7,570 (Census); Kale 6,250 (Census); Collards 12,500 (Census)	Only a small % of acerage is grown for seed.
Bushberries (e.g., blueberries, cranberries, gooseberries, currants) Represented here by Blueberries and Cranberries	Y (pollen[1] & nectar[1])	Yes[2]	Yes[1] Andrena, Colletes (blue.), Osmia (blue.), Anthophora (blue.), Agapostemon (cran.), Melita (cran.), Megachile (cran.)	77,700 blueberries 40,300 cranberries (also 580 for currants)	
Caneberries (e.g., raspberries, and blackberries) Represented here by Raspberries	Y (pollen[1] & nectar[1])	Yes[2]	Yes[1] Osmia, Andema, Coletes, Halicutus	17,300	
Carrot *Daucus carota*	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1] *Megachile rotundata*	84,710 (71,400 Fresh Market; 13,310 Processing)	Only a small % of acreage is grown for seed.
Cherry Mazzard, sweet cherry (*Prunus avium*; *Cerasus avium*); hard-fleshed cherry (var. *duracina*); heart cherry (var. *juliana*)	Y (pollen[2] & nectar[1])	Yes[1]	Yes[2] *Osmia*	123,290 (86,790 Sweet; 36,500 Tart)	
Citrus Represented here by Oranges	Y (pollen[2] & nectar[2])	Yes[1]	Yes[1] Andrena,	613,000 (also 52,100	Variable among orange cultivars;

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive?[1,2]	Solitary Bee Attractive?[1,2]	Acreage in the U.S.	Notes
			Xylocopa	tangerines and mandarins)	honey bees brought to groves for orange blossom honey
Clary Lamiaceae	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1]	Not Available	Note in database that this is for seed production, only. Also that only a small % of acreage is grown for seed.
Clover *Trifolium* spp	Y (pollen[2] & nectar[2])	Yes[1]	Yes[2] Megachile, Osmia, Andrena, Anthidium	28,506 White, Red and Crimson	Only a small % of acreage is grown for seed.
Cocoa Not in Database	Not Available	Not Available	Not Available	Not Available	
Coffee Represented here by Green *Coffea* spp. (*arabica, robusta*, *liberica*)	Y (pollen[1])		Yes[1]	7300	Acreage related to all coffee, not specific to green coffee
Coniferous/Evergreen/Softwood (Non-Food) Not in Database	Not Available	Not Available	Not Available	Not Available	
Corn, Field – Also represents Popcorn and Sweet Corn *Zea mays*	Y (pollen[1])	Yes[1]	Yes[1]	87,668,000	Wind pollinated, but can be visited during pollen shedding
Cotton Upland cotton (*Gossypium hirsutum*) Pima Cotton (*Gossypium barbardense*)	Y (nectar[1])	Yes[1]	Yes[1] *Halictus, Anthophora, Xylocopa, Megachile, Nomia, Ptilothrix*	7,664,400	Used by some beekeepers for honey production
Cucurbit Vegetables Represented here by Cucumbers and Gherkins	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1] Melissodes, Andrena	40,800 Fresh; 82100 for Pickles	Small seed acreage
Deciduous/Broadleaf/Hardwood (Non-Food) Not in Database	Not Available	Not Available	Not Available	Not Available	
Eggplant *Solanum melongena*	N	Yes[2]	Yes[1]	5,004	Only a small % of acreage is grown for seed.
Fallow Land Not in Database	Not Available	Not Available	Not Available	Not Available	
Fig *Ficus carica*	N	No	No	8,600	Wasp pollinated
Flowering Plants Not in Database	Not Available	Not Available	Not Available	Not Available	

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive?[1,2]	Solitary Bee Attractive?[1,2]	Acreage in the U.S.	Notes
Fruiting Vegetables Not in Database	Not Available	Not Available	Not Available	Not Available	
Garlic	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1]	Not Available	Rarely grown for seed.
Ginger	Uncertainty	Uncertainty	Uncertainty	Uncertainty	Note in database stating that no data were identified.
Grapes *Vitis vinifera*	Y (pollen[1])	No	No	962,100	Wind pollinated
Grass/Turf and Grasses Grown for Seed Represented by Grasses Grown for Forage Including inter alia: bent, redtop, fiorin grass (*Agrostis* spp.); bluegrass (*Poa* spp.); Columbus grass (*Sorghum almum*); fescue (*Festuca* spp.); Napier, elephant grass (*Pennisetum purpureum*); orchard grass (*Dactylis glomerata*); Rhodes grass (*Chloris gayana*); *Phleum, Agropyron, Elymus, Phalaris, Koeleria,* *Stipa, Danthonia, Deschampsia, Bromus, Trisetum, Calamagrostis, Carex and Juncus*	Y (pollen[1])	No	No	35,328,000	Wind pollinated, source of pollen only when no other forage sources are available
Guar (Fabaceae)	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1]	Not Available	Extrapolated from Bean (lupines)
Guava	Not Available	Not Available	Not Available	Not Available	
Hops *Humulus lupulus*	Y (pollen[1])	No	No	35,224	
Kiwi Fruit *Actinidia chinensis*	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1]	4,200	
Leafy Vegetables Not in Database in this grouping	Not Available	Not Available	Not Available	Not Available	
Legume Vegetables *Vicia faba* Also includes Peanuts	Y (pollen[2] & nectar[2])	Yes[2]	Yes[1] *Anthophora, Eucra, Megachile*		
Lentils *Lens esculenta*; *Ervum lens*	Y (pollen[1] & nectar[1]) Extra-floral nectaries	Yes[1]	Yes[1]	347,000	
Lettuce *Lactuca sativa*	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1]	259,100 Head, leaf, and romaine	Self-pollinating
Macadamia Nut (Bushnut)	Y (pollen[1] &	Not Available	Not Available	Not	

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive? [1, 2]	Solitary Bee Attractive? [1, 2]	Acreage in the U.S.	Notes
	nectar[1])			Available	
Manioc (Cassava) Euphorbiaceae	N	No	No	Not Available	
Melons Represented here by Watermelon *Citrullus vulgaris*	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1] *Agapostemon, Floridegus, Halictus, Hoplitus, Melissodes*	123,300	
Mint – not listed in database as mint but 11 listings were found for members of the mint family, Lamiaceae (lemon balm, basil, catnip, clary, horehound, hyssop, lavender, marjoram, rosemary, sage, and savory)	Not Available – see Notes	Not Available – see Notes	Not Available – see Notes	Not Available	Most of the 11 entries for the mint family were at least opportunistically attractive to pollinators.
Okra *Abelmoschus esculentus*; *Hibiscus esculentus*	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1]	2,377	
Olive *Olea europaea*	Y (pollen[1])			44,000	
Onion *Allium cepa*	Y (pollen[1] & nectar[1])	No	Yes[1] *Halictus, Nomia*	143,340	Only a small % of acreage is grown for seed.
Papaya	Not Available	Not Available	Not Available	Not Available	
Passion Fruit (Granadilla)	Not Available	Not Available	Not Available	Not Available	
Pastureland/Rangeland Not in Database	Not Available	Not Available	Not Available	Not Available	
Peaches/ Nectarines *Prunus persica, Amygdalus persica, Persica laevis*	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1] *Osmia*	112,900 Peaches 26,400 Nectarines	
Pear *Pyrus communis*	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1] *Osmia, Andrena*	54,400	
Peas (Unspecified) Garden pea (*Pisum sativum*); field pea (*P. arvense*) This also represents Peas, Dried-Type and Peas, Pigeon	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1] *Eucera, Xylocopa*	797,000	
Pepper In Database as Chilies and Peppers	Y (pollen[1])	Yes[2]	Yes[1]	71,200 Chile and Bell	May be grown in glasshouses, with bumblebees for pollination.
Persimmon *Diospyros kaki*; *D. virginiana*	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1]	4,968	

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive? [1, 2]	Solitary Bee Attractive? [1, 2]	Acreage in the U.S.	Notes
Pineapple	Not Available	Not Available	Not Available	Not Available	
Pistachio *Pistacia vera*	N	No	No	178,000	Wind pollinated.
Plum Greengage, mirabelle, damson (*Prunus domestica*); sloe (*P. spinosa*) This also represents Prunes	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1] *Osmia, Anthophora*	82,780	
Potato, White/Irish (Or Unspecified) *Solanum tuberosum* Irish potato Also used here to represent Yams and Taro	N	Yes[1]	Yes[1] *Andrena*	1,052,000	Only small % of acreage is grown for breeding
Premises/Areas Not in Database	Not Available	Not Available	Not Available	Not Available	
Rhubarb Polygonacaea	See Notes	See Notes	See Notes	Not Available	Open pollinated, rarely self-pollinated. Crop may be inherently attractive to bee pollinators, but harvested prior to bloom.
Rice *Oryza* spp., mainly *Oryza sativa*.	N	No	No	2,468,000	Wind pollinated
Root and Tuber Vegetables Not in Database in this Grouping	Not Available	Not Available	Not Available	Not Available	
Safflower *Carthamus tinctorius*	Y (pollen[1] & nectar[1])		Yes[1]	170,000	Safflower is basically self-pollinated, but bees or other insects are generally necessary for optimum fertilization and maximum yield
Sage Lamiaceae	Uncertainty	Uncertainty	Uncertainty	Uncertainty	Note in database stating that no data were identified.
Sorghum *Sorghum bicolor, spp. bicolor*	Y (pollen[1])		Yes[1]	6,910,000 Grain and silage	
Soybeans *Glycine soja*	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1]	75,869,000	
Strawberry *Fragaria* spp.	Y (pollen[1] & nectar[1])	Yes[1]	Yes[1] *Andrena*,	58,190	Not essential, but some growers add

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive?[1,2]	Solitary Bee Attractive?[1,2]	Acreage in the U.S.	Notes
			Halictids, *Osmia*		supplemental hives to compliment wind pollination
Subtropical/Tropical Fruit Not in Database in this Grouping	Not Available	Not Available	Not Available	Not Available	
Sugar Beet *Beta vulgaris* var. *altissima*	N	Yes[1]		1,154,200	Only a small % of acreage grown for breeding
Sugarcane	N	No	No	905,600	Wind pollinated
Sunflower *Helianthus annuus*	Y (pollen[2] & nectar[2])	Yes[2]	Yes[2] *Halictus*, *Dieunomia, Megachile, Melissodes, Svastra, Xylocopa*	1,502,000 (measured in 2013)	
Tobacco *Nicotiana tabacum*	Y (pollen[1])	Yes[1]	Yes[1]	355,700	Typically deflowered as a standard production practice
Tomato *Lycopersicon esculentum*	N	Yes[1]	Yes[1]	93,600 Fresh; 277,000 Processing	May be grown in glasshouses where bumble bees are needed for pollination
Tree Nuts	Not Available	Not Available	Not Available	Not Available	
Trees (Non-Food) Not in Database	Not Available	Not Available	Not Available	Not Available	
Tuberous and Corm Vegetables Not in Database in this Grouping but some specific crops listed here	Not Available	Not Available	Not Available	Not Available	
Vegetables (Unspecified) Not in Database in this Grouping	Not Available	Not Available	Not Available	Not Available	
Wheat *Triticum* spp.: common (*T. aestivum*), durum (*T. durum*), spelt (*T. spelta*).	N	No	No	45,157,000	

[1] attractiveness rating is a single "+", denoting a use pattern is opportunistically attractive to bees.
[2] attractiveness rating is a double "++" denoting a use pattern is attractive in all cases