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Santé Canada
Pest Management Regulatory Agency
Agence de réglementation de la lutte antiparasitaire

Proposed Acceptability for Continuing Registration

PACR2007-06

Re-evaluation of the Agricultural, Forestry, Aquatic and Industrial Site Uses of (2,4-Dichlorophenoxy)acetic Acid [2,4-D]

(publié aussi en français)

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Foreword

Previously, Health Canada's Pest Management Regulatory Agency (PMRA) published a review of the lawn and turf uses of (2,4-dichlorophenoxy)acetic acid, commonly known as 2,4-D. More details are available in Proposed Acceptability for Continuing Registration document PACR2005-01, *Re-evaluation of the Lawn and Turf Uses of (2,4-Dichlorophenoxy)acetic Acid [2,4-D]*.

The PMRA has now reviewed the available information regarding the use of 2,4 D in agriculture, aquaculture and forestry as well as the use of 2,4-D to maintain industrial and aquatic sites. Under the authority of the *Pest Control Products Act*, the PMRA is proposing that the use of 2,4-D in the above-mentioned terrestrial sites is acceptable for continued registration.

The previous publication regarding lawn and turf uses of 2,4-D (PACR2005-01) and this Proposed Re-evaluation Decision are consultation documents[1] that summarize the science evaluation for the use of 2,4-D. This Proposed Re-evaluation Decision also provides a rationale for this proposed regulatory decision for the non-turf uses of 2,4-D and describes risk-reduction measures that will be required to further protect human health and the environment.

These mitigation measures include the following:

- discontinuation of products containing the diethanolamine salt (DEA) form of 2,4-D as well as products used for weed control in aquaculture and other aquatic sites, unless adequate additional data are provided;

- upgrades to product labels that further increase protection of workers
    - the use of personal protective equipment (PPE);
    - for the mixer/loader and applicator scenarios with the highest potential for exposure, a variety of mitigation measures such as maximum amounts of product to be applied in a day, the use of closed cabs or respirators, closed mixer/loader systems, a prohibition against the use of human flaggers during aerial application or the hand application of granular products to industrial sites; and
    - restricted-entry intervals

- upgrades to product labels that describe the form of 2,4-D contained in more detail and label statements that further increase protection of the environment;

- for some uses, revised maximum application rates of products and/or the number of applications per year.

The PMRA will accept written comments on this proposal to continue all terrestrial uses of 2,4-D up to 60 days from the date of publication of this document. Please forward all comments to Publications (please see contact information on the cover page of this document). The comments received in response to the turf review will also be considered in a final decision for all uses of 2,4-D.

1 "Consultation statement" as required by subsection 28(2) of the *Pest Control Products Act* 2002.

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1.0 Purpose

This document describes the proposed outcome of the re-evaluation of the herbicide (2,4-dichlorophenoxy)acetic acid, commonly known as 2,4-D, and its end-use products for non-turf use in Canada. This document follows and supplements a previous assessment of the turf uses of 2,4-D published in 2005. Both assessments considered the potential impact of 2,4-D on the health and safety of users and others incidentally exposed when these products are used as well as the potential environmental impact associated with using 2,4-D.

2.0 Background

2.1 The PMRA's Review of the Turf Uses of 2,4-D

Proposed Acceptability for Continuing Registration (PACR) document PACR2005-01, *Re-evaluation of the Lawn and Turf Uses of (2,4-Dichlorophenoxy)acetic Acid [2,4-D]* was released in 2005 for a 60-day comment period that ended 22 April 2005. That document considered the potential impact of 2,4-D on the health and safety of users as well as others incidentally exposed when products are used on residential lawns. It also considered the potential environmental impact associated with use of 2,4-D on turf and its value as a herbicide in the maintenance of lawns and turf.

The turf assessment also included:

- a history of the registration of 2,4-D in Canada;
- a review of the chemistry of 2,4-D;
- an extensive review of the mammalian toxicology;
- an epidemiology assessment;
- a dietary risk assessment; and
- an aggregate assessment of the risk of human exposure to food, drinking water and residential exposures.

The PMRA received numerous comments in response to the turf assessment. The Agency summarized these comments and provided a response in Re-evaluation Note REV2006-11, *Lawn and Turf Uses of (2,4-Dichlorophenoxy)acetic Acid [2,4-D]*, published on 16 August 2006. The Re-evaluation Note also indicated the interim mitigation measures to be implemented for products used on lawns and turf.

Whenever possible, comments received in response to the previous turf assessment were considered in this review of the non-turf uses. The PMRA will make a final decision on the continued acceptability of lawn and turf uses after comments regarding the non-turf uses have been considered.

2.2 Information Used in This Assessment

Information considered by the PMRA in this assessment of 2,4-D included proprietary data from individual registrants, as well as the Industry Task Force II on 2,4-D Research Data, the Pesticide Handlers Exposure Database, the Agricultural Reentry Task Force, the United States Reregistration Eligibility Document dated June 2005, data from the United States Department of Agriculture Interregional Research Project Number 4 (IR-4) and additional published studies. A partial list of published studies for 2,4-D is included in the References section of this document.

2.3 Scope of This Review

Appendix I lists 2,4-D products that are registered with the PMRA. Appendix II, Table 1, lists the uses for which 2,4-D is presently registered. All uses are supported by the registrants and were considered in the health and environmental risk assessments of 2,4-D.

Uses of 2,4-D included in this review are in the following use-site categories: Forests and Woodlots; Terrestrial Feed Crops; Terrestrial Food Crops; Industrial and Domestic Vegetation Control Non-Food Sites; Aquaculture; and Aquatic Non-Food Sites.

PACR2005-01, *Re-evaluation of the Lawn and Turf Uses of (2,4-Dichlorophenoxy)acetic Acid [2,4-D]*, focussed on the use of 2,4-D on fine turf, which includes residential turf, sport and recreational turf, and sod grown commercially for transplanting. The present assessment reviews the agricultural, forestry and aquatic uses of 2,4-D as well as use on rough turf or industrial sites. The vegetation of industrial sites is primarily intended for soil stabilization and requires less maintenance than fine turf. Industrial sites include roadsides, drainage ditches, rights-of-way, railways, hydro installations, pipelines and highways, highway interchanges, airports, industrial parks, wasteland, vacant lots, fencerows and woody growths in all these areas.

2.4 Forms of 2,4-D

2,4-D is sold in a number of different amine salt or ester forms, all based on 2,4-D acid. Different forms facilitate absorption of the 2,4-D acid into the plant differently. The ester form increases the lipid solubility of the herbicide, which allows it to penetrate more easily the waxy cuticle of the plant leaf. The amine form greatly increases the water solubility of the herbicide, which is desirable when effective use of the product depends on uptake by the plant via the roots.

The parent acid is the herbicidally active portion of the form. The parent acid is what binds to the herbicide target site within the plant and causes plant death, while the amine or ester portion of the formulated product may allow for greater absorption into the plant. For example, when an ester herbicide penetrates the cuticle, enzymes remove the ester moiety to yield the parent acid. As a result, the ester part of the form plays no direct role in herbicidal activity following absorption. Therefore, when assessing 2,4-D, the application rates were expressed in terms of the amount of acid equivalent per hectare (i.e., kg a.e./ha).

Other differences in the various forms of 2,4-D will be explained in the mammalian toxicology as well as the environmental toxicology and fate sections of this review. The names of the various forms of 2,4-D assessed are listed in Table 2.4.1. The butyl glycol ester form was not included in this assessment because the only registered product was no longer available in the marketplace and the registrant has indicated they intend to discontinue the registration.

Table 2.4.1 Forms of 2,4-D Included in this Assessment

Grouping	Form
Parent compound	2,4-D acid
Salts[2]	DEA: diethanolamine salt DMA: dimethylamine salt IPA: isopropylamine salt TIPA: triisopropanolamine salt
Low volatile esters	EHE: isooctyl ester (2-ethylhexyl ester, 2-octyl, 2-ethyl-4-methylpentyl) BEE: butoxyethyl ester (*or* butoxyethanol ester)

3.0 Re-evaluation of Agricultural, Forestry, Aquatic and Industrial Site Uses of 2,4-D

2,4-D is one of the pesticides subject to re-evaluation in Canada as announced in Re-evaluation Document REV2004-06, *PMRA Re-evaluation Program Workplan (April 2004 to June 2005)*. 2,4-D is a broadleaf weed herbicide belonging to Herbicide Resistance Management Group 4 (phenoxys) that mimics the natural plant hormone indole-3-acetic acid (also known as auxin). These herbicides produce an "auxin overload", thereby causing susceptible plants to be injured and controlled.

3.1 Identity of the Active Substances, Their Properties and Uses

3.1.1 Identity of 2,4-D

Active substance: 2,4-D

Function: Herbicide

[2] The registrations of products containing the sodium salt form of 2,4-D have been discontinued by registrants; therefore, they are not addressed in this assessment.

Chemical names:

IUPAC: (2,4-Dichlorophenoxy)acetic acid

CAS: (2,4-Dichlorophenoxy)acetic acid

CAS number: 94-75-7

Molecular formula: $C_8H_6Cl_2O_3$

Molecular weight: 221.0

Structural formula:

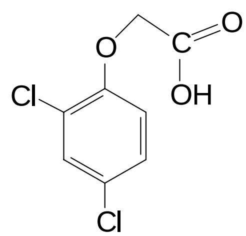

Table 3.1.1 Registration Number, Purity and Registrant of the Technical Grade Active Ingredient 2,4-D

Registration Number	Purity of Technical Grade Active Ingredient[1]	Registrant
16981	97.0%	Dow AgroSciences Canada Inc.
24836	74.8%	Dow AgroSciences Canada Inc.
17007	98.5%	GroWell Ltd.
18611	92.0% (minimum)	Nufarm Agriculture Inc.
24562	96.0%	Nufarm Agriculture Inc.
17134	94.0% (minimum)	Nufarm Agriculture Inc.
17044	98.5%	Nufarm Agriculture Inc.
17291	98.2%	PBI/Gordon Corp.
27437	98.2%	Albaugh Inc.
17045	99.0% (minimum)	Nufarm Agriculture Inc.

1 Nominal guarantee, unless otherwise specified.

3.1.2 Identity of 2,4-D 2-EHE

Active substance: 2,4-D 2-EHE

Function: Herbicide

Chemical names:

IUPAC: 2-ethylhexyl (2,4-dichlorophenoxy)acetate

CAS: 2-ethylhexyl (2,4-dichlorophenoxy)acetate

CAS number: 1928-43-4

Molecular formula: $C_{16}H_{22}Cl_2O_3$

Molecular weight: 333.3

Structural formula:

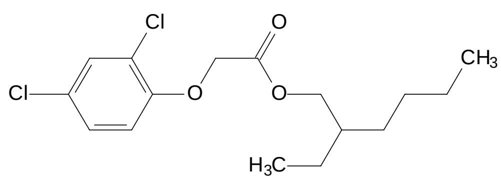

Table 3.1.2 Registration Number, Purity and Registrant of the Technical Grade Active Ingredient 2,4-D, Present as the 2-Ethylhexyl Ester

Registration Number	Purity of the Technical Grade Active Ingredient[1]	Registrant
16982	63.9%	Dow AgroSciences Canada Inc.
16990	66.4%	Dow AgroSciences Canada Inc.
17135	62.4%	Nufarm Ltd.
17012	64.7%	GroWell Ltd.
27263	64.7%	Nufarm Agriculture Inc.
19348	63.0% (minimum)	Nufarm Agriculture Inc.

[1] Nominal guarantee, unless otherwise specified.

3.2 Physicochemical Properties of 2,4-D Acid and Interpretation

Property	Result	Interpretation
Vapour pressure at 25°C	1.87×10^{-2} mPa	Low potential to volatilize
Henry's law constant	7.26×10^{-6} Pa m^3 mol^{-1}	Non volatile from water or moist surfaces
Ultraviolet (UV)/visible spectrum	Not expected to show significant UV absorption at wave length > 300 ηm.	Low potential for phototransformation
Solubility of 2,4-D acid in water at 25°C	569 mg a.i./L	Very soluble
n-Octanol–water partition coefficient at 25°C	pH 5 Log K_{ow} = 0.04–0.33	Unlikely to bioaccumulate.
Dissociation constant	p*K*a = 2.8	Dissociates rapidly to anion at environmental pH levels.

4.0 Effects Having Relevance to Human Health

4.1 Toxicology Summary

The toxicology database for the various forms of 2,4-D in agricultural products consisted of proprietary and published studies conducted in laboratory animals. A review of this database was conducted during the re-evaluation of 2,4-D for use on lawns and turf and is included in PACR2005-01. In addition to studies already examined for PACR2005-01 and for the PMRA's response to public comments published in REV2006-11, additional data on 2,4-D-induced kidney toxicity in rats and toxicity information on diethanolamine provided by the 2,4-D Task Force II have been reviewed and integrated into this assessment.

Each of the various forms of 2,4-D registered for agricultural use in Canada (2,4-D as acid, BEE, EHE, DMA, IPA, TIPA and DEA) were assessed for acute and short-term toxicity in several mammalian species via various routes of exposure as well as for mutagenic potential and developmental toxicity in rodent and non-rodent species. Mammalian metabolism and pharmacokinetic data were examined; reproductive toxicity in rats as well as chronic toxicity and carcinogenicity in rats, mice and dogs were assessed using 2,4-D acid. Regulatory documents from the United States Environmental Protection Agency (USEPA), the Joint World Health Organization/Food and Agriculture Organization (WHO/FAO) Meeting on Pesticide Residues and the European Commission as well as peer-reviewed articles and other relevant publications were also considered, as were a number of expert assessments of the evidence available from numerous epidemiological studies on 2,4-D and other phenoxy herbicides.

A comparison of acute, short-term and developmental toxicity data as well as the mutagenic potential indicated that the BEE, EHE, DMA, IPA and TIPA forms of 2,4-D had similar toxicology profiles to 2,4-D acid. However, certain quantitative differences were noted between 2,4-D BEE, IPA and TIPA, and 2,4-D acid, DMA and EHE, as evidenced by different no-effect levels in short-term toxicity studies. These differences in no-effect levels were taken into consideration as part of the risk assessment.

The DEA form of 2,4-D had a different toxicity profile compared to the other forms listed above. Available studies and foreign review summaries showed both a qualitative and quantitative difference in the toxic effects that occurred after oral and dermal administration of 2,4-D DEA. Liver effects observed in a three-week dermal study in rabbits were not noted with the other forms of 2,4-D, and dietary studies in rats indicated that 2,4-D DEA induced more severe thyroid and reproductive organ toxicity at lower dose levels when compared to all other forms of 2,4-D. Both 2,4-D acid and pure DEA induce kidney effects, with brain and spinal cord demyelination occurring at higher doses, while DEA on its own was positive for immunotoxicity in mice (National Toxicology Program 1992a, 1992b, 1992c, 1994). Thus, it is likely that the lack of toxicological equivalence between DEA and the acid form of 2,4-D is related to the DEA moiety.

Additional concerns arise from published data showing that repeated dermal applications of DEA on its own are carcinogenic in mice (National Toxicology Program 1999, 2001). No tumours were evident in a similar study conducted in rats, although the doses used were lower than those used in mice. The most recent literature suggests that DEA suppresses the uptake of choline into cells and that this suppression is a potential mechanism for DEA-induced liver tumours in mice, which may not be relevant to humans. DEA also appears to be non-genotoxic. However, several outstanding issues have yet to be addressed to substantiate the choline-suppression hypothesis for DEA-induced carcinogenicity in mice. For example, despite some clinical findings in rats that were consistent with choline deficiency, short- or long-term exposures to DEA failed to elicit the one key hallmark for choline deficiency in mice or rats, which is fatty deposition in the liver. Also, increased tumour incidence in mice was not associated with any effect specific to choline deficiency. Currently, six mechanisms are proposed for choline deficiency and cancer induction. Further understanding of any interplay between these proposed mechanisms and substantiation of their role in DEA tumour formation is required before this hypothesis and rationale for lack of human relevance can be accepted. As the additional data required to address the uncertainty regarding carcinogenic potential of 2,4-D DEA have not been provided, products containing the DEA form of 2,4-D are no longer supported and have been discontinued.

4.1.1 Toxicology Profile of 2,4-D Acid, BEE, EHE, DMA, IPA and TIPA

Available data indicated that all tested forms of 2,4-D were readily absorbed and excreted after oral administration. Peak plasma levels were attained four hours after dosing. Urine was the main route of excretion, and tissue residues were low. The acid and amine forms were excreted unchanged, and 2,4-D esters (BEE and EHE) were rapidly hydrolyzed to 2,4-D acid, which was excreted, unchanged, in the urine and, to a lesser extent, in the feces. Volatile metabolites of the esters were eliminated via expired air. Other metabolites of 2,4-D esters were recovered in the excreta. Despite the formation of other metabolites, 2,4-D esters and amine salts did not appear to impart higher toxic potential or show different target organ toxicity relative to 2,4-D acid in acute and short-term toxicity studies.

The metabolite 2,4-dichlorophenol (2,4-DCP) is not a human or rat metabolite, but does arise as a transient metabolite in aquatic environments and to a lesser extent in soil (see Section 5.1) that is further oxidized, hydroxylated and dehalogenated. Degradation into smaller organic molecules occurs until the various components are finally mineralized into carbon dioxide and water. 2,4-DCP can also be a metabolite of certain plant species, but is not formed in significant concentrations in the crop species relevant to dietary considerations. Based on known chemical reactions, it is unlikely that 2,4-D will degrade into 2,4-DCP during storage at ambient temperature. The levels of 2,4-DCP present in the manufactured 2,4-D technical product are very low and are further diluted in formulated products. Toxicity data indicate that 2,4-DCP is less toxic than 2,4-D. The International Agency for Research on Cancer (IARC 1999) states that "there is evidence suggesting lack of carcinogenicity of 2,4-DCP in experimental animals". As the human health risk assessment is based on 2,4-D, it is also inherently protective of less toxic metabolites.

Although the pharmacokinetics of 2,4-D showed some variability within and between species, allometric scaling of data from mice, rats, dogs and humans indicated that renal clearance of 2,4-D was approximately 30-fold slower in dogs compared to humans, making the dog less relevant as an indicator species for human toxicity. For this reason, the PMRA did not consider the dog studies in the 2,4-D risk assessment.

Acute toxicity data from laboratory animals indicated that the various forms of 2,4-D were slightly to moderately toxic via the oral route of exposure. All forms of 2,4-D had low acute dermal and inhalation toxicity, and were mild to severe eye irritants. 2,4-D DMA and EHE were irritating to skin, whereas other forms of 2,4-D were non-irritating. None of the forms were dermal sensitizers.

No systemic toxicity was noted in any of the short-term dermal studies in rabbits using 2,4-D as acid, EHE, BEE, DMA, IPA or TIPA. Short-term dietary exposure to 2,4-D at toxic doses adversely affected food consumption and body weight and induced kidney and liver pathology. Higher doses in short-term and long-term studies in the rat resulted in pathological changes in the liver, testes, ovary, uterus, adrenal, thyroid, thymus, bone marrow, lungs and eyes (retinal damage, cataracts). In all species, the primary target organ for toxicity was the kidney. Short- and long-term exposures via dietary administration induced similar effects and levels of toxicity in mice and rats, whereas dogs exhibited toxic effects at lower doses than rodents.

In vitro and in vivo test results showed that 2,4-D acid, EHE, BEE, DMA, IPA and TIPA were not mutagenic or genotoxic; 2,4-D was not carcinogenic to either rats or mice. Results from these long-term toxicity and oncogenicity studies in mice and rats, which were conducted using 2,4-D acid in the diet, were considered applicable to the other forms of 2,4-D.

In 1991, a National Cancer Institute survey reported an association between dogs with canine malignant lymphoma (CML) and dog-owners who applied 2,4-D to their lawns (Hayes et al. 1991). However, a subsequent report by an independent panel concluded that the study design, analysis and interpretation were severely flawed and, in fact, did not show an association between CML and 2,4-D use (Carlo et al. 1992). Although a further set of analyses by the National Cancer Institute addressed some of the outstanding concerns (Hayes et al. 1995), a full re-examination of the 1991 data set by Michigan State University revealed an overestimation of the effect of 2,4-D due to misclassification of the exposure group ("unknowns" coded as positive). Furthermore, no differentiation was made between the number of times 2,4-D was used and the number of times other lawn care products were applied, the amount used or the type of application (i.e., spot versus full-lawn treatment). Once this correction was made, the original association between 2,4-D use and CML could no longer be supported, and no relationship could be established (Kaneene and Miller 1999). Kelsey et al. (1998) report only a modest association between canine lymphoma and the use of lawn herbicides. A more recent study investigated the association between CML and living in industrial areas versus the use of chemicals (e.g., paints, solvents) by dog owners (Gavazza et al. 2001). This study concluded that pesticide use was either not associated with the disease or was uninformative. The weight of this evidence, combined with the lack of any indicators for lymphoma in short- and long-term dietary studies in dogs, indicates that the original report of an association between homeowner use of 2,4-D and CML cannot be substantiated or supported.

In adult rats, neurotoxic effects were evident after a single high-dose exposure. The observed incoordination and slight gait abnormality were no longer evident four days later. Repeated high doses also affected forelimb grip strength and induced retinal degeneration. Published studies involving intraperitoneal and subcutaneous administration of 2,4-D acid to pregnant rats as well as studies focusing on oral exposure of pups through mother's milk during postnatal days 15 to 25, resulted in myelin deficiency in the central nervous system of pups. Another study using a combination of prenatal and postnatal exposures showed a delay in the development of the surface righting reflex, geotaxic response and hindlimb support in rat pups, which correlated with alterations in the development of the monoamine systems in the brains of these rats as adults (Bortolozzi et al. 1999, 2003; Duffard et al. 1995, 1996; Rosso et al. 1997, 2000; Sturtz et al. 2000). Although these effects were observed at much higher dose levels relative to the doses causing the primary target effects (i.e., kidney toxicity) in the short- and long-term studies, these findings may be an indication of offspring sensitivity after exposure to 2,4-D during prenatal and postnatal development.

The potential for offspring sensitivity was also noted in the multigeneration reproductive toxicity study in rats, which showed significant effects on prenatal and postnatal pup survival at high-dose levels that were only marginally toxic to the dams. Although this rat study was deemed deficient for several reasons, the severity of the effects noted in the pups (i.e., mortality) relative to marginally toxic effects occurring in the dams may be an indication of selective sensitivity in the offspring. Other effects included a decreased sex ratio (more males) in the F_{1a} generation at the high dose, an increased gestation period, reduced litter size and a marked increase in still births.

Developmental toxicity studies in rats and rabbits showed no indication of increased sensitivity in young animals relative to adult animals. Guideline studies indicated that 2,4-D acid, EHE, BEE, DMA, IPA and TIPA did not cause birth defects in rats and rabbits. At maternally toxic doses, developmental effects observed in some studies consisted of delayed skeletal growth, skeletal variations and lower pup weights. With regard to published studies, fetal urogenital malformations have been observed in rats at maternally toxic doses, but these doses were generally above those used in the standard guideline studies (Fofana et al. 2002, Sulik et al. 2002). Although a preliminary study reported fewer implantations in 2,4-D treated rats, errors in the study design negated the study authors' interpretation (Cavieres et al. 2002). In addition, a study using a coformulation of 2,4-D and picloram was negative for male-mediated birth defects (Oakes et al. 2002). An increased incidence of maternal death in pregnant rabbits indicated that rabbits were more sensitive than rats to the toxic effects of 2,4-D. The developmental toxicity studies, which used gavage dosing, often indicated a steep dose-response between serious effects (i.e., mortality, abortions) and the no-effect level. Although a similar response was not evident in the dietary studies, suggesting that the steep dose-response was attributed to bolus dosing, this observation remains of concern.

Both the potential sensitivity of young developing rats and maternal mortality in rabbits were considered in the human health risk assessment to ensure that adequate margins of safety were achieved between the amount to which humans would be exposed and the dose that had no effects in animal toxicity studies. Reference doses for various population subgroups have been set based on no observed adverse effect levels (NOAELs) for the most relevant endpoints, namely effects on body weight, renal toxicity, neurotoxicity and maternal mortality. These reference doses incorporate various uncertainty factors to account for extrapolating between rats and humans, for variability within human populations and for data uncertainties. Additional safety factors have also been applied, where warranted, to protect pregnant females and their unborn children as well as nursing children from identified endpoints of concern.

4.1.2 Human Evidence—Cancer

Numerous epidemiology studies on 2,4-D and related chlorophenoxy herbicides have provided contradictory findings with respect to an association between 2,4-D and the development of soft-tissue sarcoma and non-Hodgkin's lymphoma. A number of experts and expert panels have examined these studies in detail and have concluded that while some of the studies suggest a possible association between 2,4-D exposure and an increase in these tumours in humans, other epidemiological studies fail to support such an association. In 1996, a USEPA Carcinogenicity Peer Review Committee examined the 2,4-D databases for animal carcinogenicity and epidemiology. The Committee concluded that these studies did not provide sufficient evidence to merit changes to the conclusions previously reached and that 2,4-D should remain classified as a "Group D carcinogen" (not classifiable as to human carcinogenicity) (USEPA 1997a).

Since the release of the USEPA Cancer Peer Review Committee report in 1997 (USEPA 1997a), other assessments of the epidemiological and animal evidence regarding 2,4-D and cancer risk also indicated that there is inadequate evidence that 2,4-D is a human carcinogen (Gandhi et al. 2000, Garabrant and Philbert 2002). Other regulatory authorities that have finalized their assessments for 2,4-D include the World Health Organization (WHO/FAO 1997), the United

States Department of Agriculture (USDA Forest Service 1999), the New Zealand Pesticides Board Expert Panel on 2,4-D (New Zealand 2000), the European Commission (EC 2001), the Joint WHO/FAO Meeting on Pesticide Residues (WHO 2003) and the USEPA (USEPA 2005). All are in agreement that there is no evidence of carcinogenicity in the animal toxicity studies and that the epidemiology studies show no clear association between exposure to phenoxy herbicides and human cancers. The epidemiological analyses of De Roos et al. (2003) and Alavanja et al. (2002, 2004) lend further support for this classification, yet positive associations also continue to be reported (Mills et al. 2005, Chiu et al. 2006).

Where possible, epidemiology studies that identify associations rather than causation should be examined in conjunction with well-conducted toxicity studies that are specifically designed to elicit toxic effects over a series of dose levels, and study limitations must be weighed in conjunction with the overall data for a particular compound. For example, in a recent study by Mills et al. (2005), the authors identified several limitations such as the use of a relatively small sample size (50 cases and 250 controls) and thus limited statistical power to establish a 2,4-D positive association; cases and controls were not interviewed; odds ratios were adjusted for only a few potential confounders (age, race/ethnicity, gender) but not for smoking history, diet, or medical history, which may be involved in the etiology of lymphohaematopoietic cancers; and exposure assessment methodology was limited as the use of surrogate or indirect measures for pesticide exposure (e.g., area treated, amount used, amount purchased), which can lead to unreliable estimates of risk. Reliance on epidemiology studies in regulatory decision making is challenging in the absence of a direct measure of exposure. The most useful and relevant epidemiological studies for regulatory decision making are those that properly characterize and measure exposure to a specific product.

The etiology of most non-Hodgkin's lymphoma cases remains unexplained and multiple causal factors are likely. Although associations between non-Hodgkin's lymphoma and pesticide use have been reported, this has not been a consistent finding and warrants further investigation.

The inconsistent epidemiological associations, the recognition that there are many other factors that may have contributed to the weakly positive associations and the fact that the animal studies designed to show causality were consistently negative have lead the PMRA scientists to concur that on the basis of all available and relevant data, 2,4-D cannot be classified as to its human carcinogenicity. However, the PMRA and the 2,4-D Science Advisory Panel agree with the stated premise of Gandhi et al. (2000) that, as with any chemical, caution should be exerted in its use, storage and disposal.

4.1.3 Human Evidence—Reproductive Effects

Several epidemiological studies have been published that examine possible reproductive and fetal effects in humans following exposure to chlorophenoxy herbicides. A study involving Ontario farmers reported detectable levels of 2,4-D in both semen and urine. However, a separate assessment to identify any association between chlorophenoxy herbicides and spontaneous abortions in Ontario farm populations indicated that the Ontario farm families who participated were not at increased risk for spontaneous abortion. Risk estimates for early versus late spontaneous abortions indicated a moderate increase in risk for early abortions; however, the exposure could not be adequately characterized as the number of pregnancies was too small to also incorporate potential confounders of the exposure-disease relationship (Arbuckle et al. 1998, 1999a, 1999b, 2001; Savitz et al. 1997; Sever et al. 1997).

A series of studies conducted in four wheat-growing states in the United States has reported associations between general pesticide use and birth defects, with the most recent study reporting an association between high-wheat growing areas and certain birth defects. The high-wheat growing area was used as a surrogate indicator for chlorophenoxy herbicide exposure. However, this same study also reported that separate analyses showed similar increases in these anomalies in low-wheat growing areas as well, suggesting other factors need to be considered. In the absence of any direct measurements of exposure to 2,4-D, the current scientific evidence to support adverse reproductive and developmental effects in humans, in association with exposure to 2,4-D, remains unclear.

Interpretation of epidemiological results for potential cancer or developmental and reproductive effects were often confounded by factors such as the general grouping of 2,4-D with other pesticides (2,4,5-trichlorophenoxyacetic acid [2,4,5-T][3], 4-(2,4-dichlorophenoxy)butyric acid [2,4-DB], MCPA, MCPB, mecoprop, atrazine etc.) and, in older studies, pesticide contamination with 2,3,7,8-TCDD[4]. This highlights the need for more precise epidemiological study designs with proper exposure characterizations to identify any specific associations between 2,4-D exposure and human health effects.

4.1.4 Selection of Toxicological Endpoints for Risk Assessment

The toxicology endpoints used in the risk assessment of 2,4-D for agricultural use are based on studies in laboratory animals. These are summarized in Appendix III, Table 1. Reference doses for various populations and subgroups have been set based on NOAELs for the most relevant endpoints, namely effects on body weight, renal toxicity (the primary target organ), neurotoxicity and maternal mortality. These reference doses incorporate uncertainty factors (UF) to account for extrapolating between rats and humans and for variability within human populations. Consistent with past PMRA policy and now formalized under the new *Pest Control Products Act* that came into force recently, additional safety factors have also been applied, where warranted, to protect children and pregnant females from relevant endpoints of concern or any database uncertainty regarding a potential for increased sensitivity in these population subgroups.

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3 Contamination of 2,4,5-T with 2,3,7,8-TCDD was identified in the early 1970s and the manufacturing process was then improved to reduce this contaminant significantly (< 0.5 ppm). 2,4,5-T, once registered in Canada for forestry use (not lawn and garden), has not been used in Canada since 1982. Registration was discontinued in 1985.

4 Since 1983, the manufacturing process for 2,4-D has been carefully controlled to avoid the production of dioxins and furans. A production limit of “not detectable at 1 ppb” was established for 2,3,7,8-TCDD in Agriculture Canada’s Pesticides Division Memorandum to Registrants R-1-216 and has not been exceeded.

4.2 Occupational and Residential Risk Assessment

Occupational and residential risk is estimated by comparing potential exposures with the most relevant endpoints from toxicology studies to calculate a margin of exposure (MOE). This is compared to a target MOE incorporating safety factors protective of the most sensitive sub-population. MOEs greater than or equal to the target MOE do not require risk mitigation. If the calculated MOE is less than the target MOE, it does not necessarily mean exposure will result in adverse effects. However, mitigation measures will be necessary to reduce exposure to 2,4-D. As the same toxicological study was used to determine the endpoint for dermal and inhalation exposure routes, it is appropriate to combine both these exposures to generate a single risk estimate. Where the target MOEs for exposure routes are the same, a "combined MOE" may be generated.

For workers entering treated sites, restricted-entry intervals (REIs) were calculated for specific tasks under Canadian conditions of use (e.g., application rates). An REI is the amount of time that must elapse to allow for a decline in dislodgeable residues to such a level that entry into a treated area to perform a specific activity does not result in unacceptable exposures.

Residential risk assessment is concerned with estimating risks to the general population, including children, during or after pesticide application. Postapplication exposure in turf scenarios has been assessed and documented separately (PACR2005-01).

A dermal absorption value of 10% was incorporated into the dermal estimates of exposure for all scenarios after considering the following:

- the comments from an independent 2,4-D Expert Panel that was convened by the PMRA during the review of lawn and turf uses of 2,4-D;
- published dermal absorption studies in humans (Feldmann and Maibach 1974, Harris and Solomon 1992a, Moody et al. 1992, Moody et al. 1990, Wester et al. 1998);
- further information and data by Harris (2004);
- the variability in the data; and
- the limitations of the various studies.

4.2.1 Relevant Toxicological Endpoints and Target Margins of Exposure for Acute, Short-Term and Intermediate-Term Exposure for Applicators and Re-Entry Workers

To protect the most sensitive subpopulation, the unborn child of pregnant workers (females 13 to 50 years), the most relevant endpoints for acute worker risk assessments were considered to be increased skeletal variations in rat fetuses noted in a rat developmental study. Protection of the most sensitive subpopulation is inherently protective of the general population. In this study, the NOAEL was 25 mg/kg bw/day acid equivalent (a.e.) based on increased skeletal variations in rat fetuses noted at the lowest observed adverse effect level (LOAEL) of 75 mg/kg bw/day, an endpoint that could potentially occur following a single exposure event. The target MOE was 300, based on the standard uncertainty factors (10-fold for interspecies variation, 10-fold for intraspecies variation) as well as an extra threefold safety factor to protect for potential sensitivity to the young noted in a series of published neurotoxicity studies.

For short- and intermediate-term (> 1 day to 6 months) dermal and inhalation exposures to all equivalent forms of 2,4-D, effects resulting from the oral route of exposure were used for risk assessment. This was because the 21-day dermal studies did not demonstrate any systemic toxicity and the inhalation studies submitted were for acute exposure only. Again, the adult risk assessment was based on the most sensitive subpopulation, pregnant women. The maternal NOAEL of 30 mg/kg bw/day (2,4-D acid, DMA, EHE) or 10 mg/kg bw/day (2,4-D BEE, IPA and TIPA) established in the respective rabbit developmental studies was selected, based on an increase in maternal morbidity and mortality at the LOAEL (90 mg/kg bw/day 2,4-D acid, DMA, EHE; 30 mg/kg bw/day 2,4-D BEE, IPA and TIPA). In each case, the target MOE was 1000, based on the standard uncertainty factors (10-fold for interspecies variation, 10-fold for intraspecies variation) and an additional 10-fold safety factor to account for the severity of the maternal endpoint (morbidity and mortality). This target MOE is inherently protective of any uncertainty regarding potential sensitivity to the young, including the unborn child of the pregnant worker.

As most animal toxicity studies involve exposure via the oral route, estimations of risk resulting from dermal exposure to humans must include a correction for the differences between oral and dermal absorption. A dermal absorption value of 10% was incorporated into the dermal estimates of exposure for all scenarios. This value is based on the weight of evidence from several published studies (Feldmann and Maibach 1974, Harris and Solomon 1992, Moody et al. 1990, Wester et al. 1996, Pelletier et al. 1988), taking into consideration the variability in the data and the limitations of the various studies.

As stated in Section 4.1, the PMRA does not consider the DEA form of 2,4-D to be toxicologically equivalent to the other forms of 2,4-D. 2,4-D formulations containing DEA are no longer supported and have been discontinued (see Section 8.1.1).

4.2.2 Occupational Mixer/Loader/Applicator Exposure and Risk Assessment

As the BEE, IPA and TIPA forms of 2,4-D have different NOAELs than the acid, DMA and EHE forms of 2,4-D, the two groups were assessed separately.

There are potential exposures to mixers, loaders, applicators, or other handlers. Based on typical use patterns, the major scenarios identified were as follows.

- Mixing/loading of liquids (emulsifiable concentrates, solutions)
- Mixing/loading of granules (soluble granules, wettable granules, pellets)
- Aerial application in forest areas (conifer release and forest site preparation), grasses (established grasslands not in agricultural production, forage sorghum, forage millet, grass grown for seed), fallow land, crop stubble, cereal grains (wheat, barley, rye, oats), corn, alfalfa stand removal, non-cropland

- Groundboom application on grasses (established grasslands not in agricultural production, forage sorghum, forage millet, grass grown for seed), fallow land, crop stubble, cereal grains (wheat, barley, rye, oats), corn, alfalfa stand removal, bearing fruit trees (orchard floors), strawberries, asparagus, cranberries, raspberries, non-cropland
- Right-of-way sprayer application in non-cropland
- Handwand application on bearing fruit trees (orchard floors), cranberries, raspberries, non-cropland
- Solid broadcast spreaders on non-cropland
- Push rotary spreader on non-cropland
- Granules by hand on non-cropland
- Granular boat spreader on oyster farms and in aquatic areas (ponds, lakes, reservoirs, marshes, drainage ditches, canals, rivers and streams that are quiescent or slow moving)

Based on the number of applications and use information, workers handling 2,4-D would generally have a short to intermediate-term (1 day to 6 months) duration of exposure. The PMRA estimated handler exposure based on the following different levels of personal protective equipment (PPE):

- Baseline PPE (Current Label PPE): A long-sleeved shirt and long pants, chemical-resistant gloves
- Minimum PPE: Coveralls over a long-sleeved shirt and long pants, chemical-resistant gloves
- Maximum PPE: Chemical-resistant coveralls over a long-sleeved shirt and long pants, chemical-resistant gloves
- Partial engineering controls (mixer/loader): closed mixing/loading, open cab for application, coveralls over a long-sleeved shirt and long pants, chemical-resistant gloves
- Engineering controls: closed mixing/loading, closed cab for application, coveralls over a long-sleeved shirt and long pants

Mixer/loader/applicator exposure estimates are based on the best available data at this time. Chemical-resistant gloves are not required to be worn while driving a tractor to pull spray equipment or flying aircraft, but are required for clean-up and repair activities. The assessment might be refined with exposure data representative of modern application equipment and engineering controls.

No suitable chemical-specific handler exposure data were submitted for 2,4-D; therefore, dermal and inhalation exposure were estimated for the various application methods using the Pesticide Handlers Exposure Database Version 1.1 (PHED). The PHED is a compilation of generic mixer/loader/applicator passive dosimetry data with associated software that facilitates the generation of scenario-specific exposure estimates, based on formulation type, application equipment, mix/load systems and level of PPE.

In most cases, the PHED did not contain appropriate data sets to estimate exposure to workers wearing chemical-resistant coveralls or a respirator. This was estimated by incorporating a 90% protection factor for chemical-resistant coveralls and a 90% protection factor for a respirator into the unit exposure data.

For most scenarios, the area treated per day was refined to more accurately reflect typical daily application areas or volumes. If no data were available for refinement, default values for areas and volumes were used.

Dermal, inhalation and combined MOEs are presented in Appendix III, Tables 2 and 3. Provided engineering controls or PPE are used as indicated, the calculated combined-route MOEs for current label uses generously exceed the target MOE. Exceptions are noted below:

Table 2 Margins of Exposure for Mixers/Loaders and Applicators Using 2,4-D: Acid, DMA, 2-EHE

All combined-route MOEs are greater than the target MOE of 1000 except for:

- Liquid (emulsifiable concentrate, soluble concentrate/liquid, soluble concentrate/solid), high-pressure handwand, non-cropland (woody plant control), tree and brush control
- Granular/granules dispersed by hand, non-cropland

Table 3 Margins of Exposure for Mixers/Loaders and Applicators Using 2,4-D: BEE, IPA, TIPA

All combined-route MOEs are greater than the target MOE of 1000 except for:

- Liquid (emulsifiable concentrate, soluble concentrate/liquid), right-of-way sprayer, non-cropland (woody plant control)
- Liquid (emulsifiable concentrate, soluble concentrate/liquid), backpack, non-croplands
- Liquid (emulsifiable concentrate, soluble concentrate/liquid), high-pressure handwand non-cropland, tree and brush control
- Granular, boat spreader, aquatic areas

For those scenarios that did not exceed the target MOE, even with the maximum PPE or engineering controls, the kilograms of acid equivalent that can be safely handled per day for each application equipment and formulation was calculated using the following equation:

$$\text{kg a.e. handled/day to reach target MOE} = \frac{\text{AR} \times \text{ATPD} \times \text{MOE}}{\text{target MOE}}$$

Where:

AR: application rate (kg a.e./ha or kg a.e./L)
ATPD: area treated per day (ha/day or L/day)

The maximum amount of active ingredient handled per day must have acceptable exposure for all handheld application equipment. Thus, the amount (kg a.e.) handled per day for high-pressure handwands was used to determine a limit (kg a.e.) handled per day for handheld equipment.

For acid, DMA and EHE products, the maximum amount that could be handled per day for handwands was determined to be 8 kg a.e./day (1.8 ha or 2000 L at a maximum rate of 4.48 kg a.e./ha), when wearing coveralls over single layer and respirator. This amount was considered to be agronomically feasible for low-pressure and backpack sprayers, and potentially feasible for high-pressure handwands. For granules dispersed by hand, the maximum amount handled per day was not considered to be agronomically feasible.

For BEE, IPA and TIPA products, the maximum amount handled per day for woody plant control by commercial applicators using handwands and right-of-way sprayers was not considered to be agronomically feasible in non-cropland. However, the limitation of 12.4 kg a.e./day (55 ha or 5500 L at maximum rate of 2.24 kg a.e./ha) wearing coveralls over a long-sleeved shirt, chemical-resistant gloves and respirator was considered to be feasible for annual and perennial control in scenarios where right-of-way sprayers would be used. For handwands, the limit of 2.7 kg a.e./day (1.2 ha or 120 L at maximum rate of 2.24 kg a.e./ha) was considered to be feasible for backpack and low-pressure handwand application when the current minimum spray volume was increased to 100 L/ha.

The results of seven biomonitoring studies that assessed exposure to farmers as well as commercial applicators applying 2,4-D in non-cropland and forest areas were also considered in this assessment. Frank, et al. (1985) and Lavy et al. (1982) assessed exposure following aerial application to forest areas. These studies showed that exposure to aerial applicators applying to forest areas was low, exposure to mixer and loaders handling large amounts of 2,4-D, as required when aerially treating forest areas was also low, provided a closed system is used; these results support the calculated MOEs, in Appendix III, Tables 2 and 3.

A number of other biomonitoring studies (Arbuckle et al. 2002, Garry et al. 2001, Knopp and Glass 1991, Libich et al. 1984) were also considered for comparison purposes. When compared to the calculated MOEs in Appendix III, Tables 2 and 3, the exposure estimates were in agreement with the results in that exposure was lower with higher levels of PPE, exposure was low when farmers wore minimum PPE, and commercial applicators using handheld equipment to treat non-cropland areas had the potential for high exposure.

All proposed regulatory actions are described in Section 8.0.

4.2.3 Occupational Postapplication Exposure Risk Assessment

The postapplication occupational risk assessment considered exposures to workers who enter treated sites to conduct agronomic activities involving foliar contact (e.g., pruning, thinning, harvesting or scouting). Based on the 2,4-D use pattern, there is potential for short- to intermediate-term postapplication exposure (> 1 day to 6 months).

Potential exposure to re-entry workers was estimated using activity-specific transfer coefficients (TCs) and default dislodgeable foliar residue (DFR) values. The TC is a measure of the relationship between exposure and DFRs for individuals engaged in a specific activity and is calculated from data generated in field exposure studies. As most registrants are members of the Agricultural Reentry Task Force (ARTF), refined ARTF transfer coefficients were used. The default peak DFR level of 20% of the application rate dislodgeable on day 0 and the default dissipation rate of 10% per day were used in the assessment because no DFR studies were submitted to the PMRA.

Postapplication risk is managed by establishing an REI for specific tasks. Pesticide residues dissipate and/or breakdown over time, and an REI is the length of time required for the dislodgeable pesticide residues to dissipate to such a level that entry into a treated area does not result in MOEs that reach target MOEs.

As 2,4-D is highly selective for broadleaf plants, products are usually applied during the dormant season or prior to planting. If an application is required after the crop is developed, sprays are directed to row middles, and drop booms and/or shields are used to prevent crop damage. Thus, it is unlikely that there will be significant residues on crop foliage, which workers could come into contact with when performing various postapplication activities. For those activities that may result in contact with the soil or foliage close to the soil, the default peak DFR residue and dissipation rate were used; the resulting exposure values were considered to be overestimates.

Postapplication exposure and risk estimates, based on the currently available data, are presented in Appendix III, Tables 4 and 5. At the maximum application rates, calculated MOEs for most postapplication activities are above the Agency target of 1000 on day 0, and exceptions are noted below.

Table 4 Restricted-Entry Interval for Commercial Postapplication Activities for 2,4-D: Acid, DMA, 2-EHE

- Use-Site Category 13 and 14
  - Corn (sweet), hand detasseling, hand harvesting, 14-day REI
  - Corn (sweet), Jerusalem artichoke control, hand detasseling, hand harvesting, 30-day REI
  - Alfalfa stand removal (fall application), scouting, 3-day REI
- 12-hour REI for all liquids

Table 5 Restricted-Entry Interval for Commercial Postapplication Activities for 2,4-D: IPA, TIPA, BEE

- Use-Site Category 13
  - Established grass pastures, rangeland, perennial grasslands not in agricultural production, scouting, 3-day REI
  - Grass grown for seed, scouting, 2-day REI
  - Fallow land or crop stubble, scouting, 3-day REI
- Use-Site Category 13 and 14
  - Corn (field), scouting, irrigation (tall, full foliage), 3-day REI
  - Alfalfa stand removal (fall application), scouting, 13-day REI
- Use-Site Category 16
  - Non-cropland (woody plants), tree and brush control: scouting, 9-day REI
  - Non-cropland (woody plants), tree and brush control: bystander (adult), 2-day REI
  - Non-cropland (annual and perennial weeds), scouting, 2-day REI
- 12-hour REI for all liquids

The above REIs are considered to be feasible for growers, with the exception of 30 days for detasseling sweet corn and 2 days for bystanders in non-cropland areas.

The REI for sweet corn following application for Jerusalem artichoke control is not considered to be agronomically feasible. However, the label instructions specify that only the corn stalk below the point where the first leaf meets the stem is to be treated. While worker contact with foliage during detasseling is potentially high, the proportion of treated foliage is low (less than 20%); therefore, exposure is expected to be minimal and mitigated by the general 14-day REI for detasseling sweet corn.

Following application on woody plants at the maximum rate, the two-day REI for adults is not considered to be feasible. Entry into non-cropland areas would generally be difficult to restrict as they are often large areas and easily accessible to the public. As this REI cannot be enforced and there is no REI required for bystanders when the rate is 2.24 kg a.e./ha or lower, a reduced rate or removal of the woody plant application is recommended unless additional data are provided to refine the risk assessment.

4.2.4 Non-Occupational (Residential) Exposure and Risk Assessment

4.2.4.1 Turf Exposure

Residential exposure resulting from the use of 2,4-D on fine turf was addressed in PACR2005-01.

4.2.4.2 Bystander Exposure

A number of biomonitoring studies that looked at exposure to children and wives who live on farms were examined to determine the potential risk from exposure to these populations. Some of the women and children sampled in these studies had assisted in pesticide applications. 2,4-D could not be detected in the urine of more than 80% of the sampled children and women (Arbuckle et al. 2004, Arbuckle and Ritter 2005). Those women and children who did have detectable levels of 2,4-D had estimated MOEs that were well above the target MOE, indicating that there were no health concerns for this exposure group.

4.2.4.3 Pick-Your-Own

As 2,4-D is highly selective for broadleaf plants, products are usually applied on crops that are grown at pick-your-own operations (such as strawberries, etc.) in the dormant season or prior to planting. If an application is required at other times, sprays are directed to row middles, and drop booms and/or shields are used to prevent crop damage. As this is the case, it is unlikely that there will be significant residues on crops that adults or children could come into contact with when picking their own fruit. This is supported by residue field trials data that detected no residues above the limit of detection for crops that could potentially be grown at pick-your-own operations.

4.2.4.4 Swimming in Water Treated With 2,4-D BEE

2,4-D can be used to treat aquatic weeds in ponds, lakes, etc. where people may swim, so there is potential for non-occupational (residential) postapplication swimmer exposure.

The only product currently registered for application to aquatic areas is a 2,4-D BEE granule, which is designed to slowly release BEE into the surrounding water following application. Although the BEE form is released into the water, it is thought to quickly degrade into the 2,4-D acid form; however, this is highly dependant on a number of factors, such as pH, water temperature, concentration of bacteria in the water, degree of sunlight, availability of oxygen, etc.

A maximum application rate of 42.75 kg a.e./ha is registered for aquatic areas in Canada. This rate was used to determine a target concentration of 2 to 4 ppm of 2,4-D in the water following application.

The primary degradation pathway of BEE to the acid form is aerobic biotransformation. Chemical hydrolysis becomes an important mode of transformation under alkaline pH levels (8 or 9 and above). Under alkaline conditions, the half-life of BEE decreases with increasing temperatures and increasing pH levels.

A number of studies are available in the literature that measure the concentration of BEE and acid in water following application of 2,4-D. All of these studies took place under alkaline conditions, so no data are available to predict the concentration or degradation rate of BEE following application to neutral or acidic lakes. Further information is required to evaluate swimmer exposure because Canadian lake waters range from acidic to alkaline on the pH scale.

Five studies measuring the concentration of 2,4-D BEE and acid following application of 2,4-D were examined (Birmingham, Thorndyke and Colman 1981; Bothwell and Daley 1981; Hoeppel and Westerdahl 1983; Paris et al. 1981; Norris 1998). As there were a number of limitations with all the available studies, the highest concentration of BEE (0.68 ppm) from Hoepple and Westerdahl (1983) was used in the assessment to estimate exposure to swimming in alkaline waters. This value was considered to be an underestimate of the BEE concentration that would be found in Canadian conditions due to the high water temperature in the study.

As no data that examine the degradation of 2,4-D BEE into acid under neutral or acidic conditions are currently available to the PMRA, a conservative assumption of no degradation of BEE into acid was used. A maximum concentration of four ppm was used to assess swimming exposure in neutral and acidic waters. This value is considered to be an overestimate of BEE residues; however, the degree to which is unknown.

The Swimmer Exposure Assessment Model SWIMODEL, developed by the USEPA, was used to estimate swimmer exposure to 2,4-D in water following application. Exposure from the dermal, incidental ingestion (oral), inhalation, aural (ear), buccal/sublingual and orbital/nasal routes were combined because swimmers have potential for exposure by multiple routes. For buccal/sublingual and orbital/nasal routes, exposure is highly dependant on the lipophilicity of the substance and the molecular size. As the acid and BEE forms of 2,4-D have log K_{ow}s and molecular weights ranging from 2.83 to 4.10 and from 221 to 321, respectively, there is potential for exposure by this route; therefore, these forms should be included in exposure calculation.

Where acceptable chemical-specific parameters, such as sublingual absorption, were not available, default or estimated parameters were used to calculate swimmer exposure. Daily exposure estimates from all routes are shown in Appendix III, Table 10.

Total exposure from all routes is below the target MOE for both adult and children in neutral/acidic conditions, and for children in alkaline conditions. For adults, the MOEs for both acid and BEE forms were combined since both are likely to be present in the water following application. The combined MOE was below the target MOE.

As MOEs do not exceed target MOEs for swimming scenarios for adults or children and the degree of conservatism with the exposure values does not provide an adequate buffer to those scenarios that had unacceptable exposure, additional data are required to assess continued registration of this use.

4.3 Dietary Exposure and Risk Assessment

4.3.1 Acute Dietary Exposure and Risk Assessment

An acute dietary exposure assessment considers the highest probable consumption of 2,4-D on any one day. A probabilistic statistical analysis allows all possible combinations of food consumption and residue levels to be combined to generate a distribution of the amount of 2,4-D residue that might be eaten in a day. A value representing the high end (95^{th} percentile) of this distribution, which is referred to as the potential daily intake (PDI), is compared to the acute reference dose (ARfD). The acute dietary risk from 2,4-D was assessed at the 95^{th} percentile because high-end field trial and tolerance level residues were used to estimate exposure. The ARfD is the dose at which an individual could be exposed on any given day and expect no adverse health effects. When the expected intake (PDI) from residues is less than the ARfD, this intake is not considered to be of concern.

To protect expectant mothers and unborn children, an ARfD was set at 0.08 mg/kg bw. This was based on the lowest rat developmental NOAEL of 25 mg/kg bw/day (a.e.) and applies a 300-fold uncertainty/safety factor (10-fold for interspecies variation, 10-fold for intraspecies variation and an additional 3-fold to account for potential sensitivity to the young noted in a series of published neurotoxicity studies). In the rat developmental study, increased skeletal variations were noted at the LOAEL of 75 mg/kg bw/day. The acute PDI (95^{th} percentile) for females of childbearing age accounted for less than 5% of the ARfD. The acute PDI for all other subpopulations was less than 4% of the ARfD (Table 4.3.2.1).

4.3.2 Chronic Dietary Exposure and Risk Assessment

Chronic dietary exposure is calculated using the average consumption of different foods and average residue values on those foods over a 70-year lifetime. This expected intake of residues is compared to the acceptable daily intake (ADI), which is the dose at which an individual could be exposed over the course of a lifetime and expect no adverse health effects. When the expected intake from residues is less than the ADI, this intake is not considered to be of concern.

The ADI was set at 0.017 mg/kg bw/day. This ADI is based on a NOAEL of 5 mg/kg bw/day from long-term dietary studies in rats and applying a 300-fold uncertainty/safety factor. At the next highest dose level, kidney effects were noted. In addition to the standard uncertainty factors (10-fold for interspecies variation, 10-fold for intraspecies variation), an additional safety factor of threefold was applied for potential sensitivity to the young noted in a limited rat reproduction study and in a series of published neurotoxicity studies. This provides a margin of safety of 1200 to the NOAEL of 20 mg/kg bw/day in the rat reproduction study, where selective pup mortality was noted at 80 mg/kg bw/day. The chronic PDI accounted for less than 1.6% of the ADI for all population subgroups.

The chronic and acute dietary risk assessments demonstrated that there were no health concerns for any population subgroup in Canada, including infants, children, teenagers, adults and seniors. The dietary exposure estimates for the general population and the most exposed subpopulations are presented hereafter in Table 4.3.2.1.

Table 4.3.2.1 Chronic and Acute Dietary Exposure and Risk Summary for 2,4-D

Population Subgroup	Chronic Dietary Exposure		Acute Dietary Exposure	
	mg/kg bw/day	% ADI	mg/kg bw/day	% ARfD
General population	0.00012	0.7	0.0035	1.4
Children 1–2 years	0.00027	1.6	0.0078	3.1
Children 7–12 years	0.00016	1	0.0042	1.7
Females 13–19 years	0.00008	0.5	0.0034	4.3

Body weight is 70 kg for adults, 62 kg for adult females, 39 kg for children 7–12 and 10 kg for children/infants.

4.3.3 Drinking Water Exposure

Residues in drinking water can be a potential source of exposure to 2,4-D. To evaluate the contribution from this source to overall exposure, drinking water quality monitoring data from several sources, ranging from provincial reports to scientific studies, were considered. The combined Canadian data set incorporated monitoring results from ambient surface water and groundwater as well as treated municipal drinking water. These data were supplemented by relevant monitoring information from the United States. Based on these data, the locations of high 2,4-D concentrations are generally randomized and 2,4-D does not persist. When detected, residues of 2,4-D in ambient and treated drinking water were generally < 1 µg/L. The maximum estimates of acute and chronic residues of 2,4-D in drinking water were 50 and 0.3 µg/L, respectively (see Section 5.3).

The calculated drinking water levels of comparison (DWLOCs) express the difference between the reference dose and the non-drinking water exposure. It is only calculated if all other exposures are not of concern to the Agency. The chronic DWLOCs ranged from 250 µg/L for the most affected subpopulation of children 1 to 2 years of age to 590 µg/L for the general population. The acute DWLOCs ranged from 2400 µg/L for the most affected subpopulation of females 13 to 19 years of age to 8600 µg/L for the general population.

As the acute and chronic anticipated residues of 2,4-D in drinking water do not exceed the respective DWLOCs, they were not of concern.

4.4 Aggregate Exposure and Risk Assessment

Aggregation of food, water, residential and of other non-occupational sources is addressed in the PACR document for lawn and turf use of 2,4-D (PACR2005-01). No concerns were identified.

5.0 Environmental Assessment

The environmental assessment of agricultural and non-cropland uses of 2,4-D includes 2,4- D acetic acid as well as the following forms of 2,4-D: DMA, DEA, IPA, TIPA, EHE and BEE). It also includes the use of granular BEE form to control aquatic vegetation. This review is based on data obtained from a USEPA environmental risk assessment (USEPA 2004), a United Kingdom Ministry of Agriculture, Forestry and Food review (1993), a review by the World Health Organization/Food and Agriculture Organization (WHO/FAO 1998) as well as published literature in journal papers and numerous original studies and data summaries submitted by the 2,4-D Industry Task Force II. The review of the risks from turf and lawn uses of 2,4-D is provided in PACR2005-01.

In assessing the environmental risk from the use of various forms of 2,4-D (acid, amines and esters) in agricultural land and non-cropland, a deterministic approach was used. In this standard PMRA approach, the risk-quotient method was used to characterize the risk. The risk quotient (RQ) is defined as the ratio of the estimated environmental concentration to the toxicological endpoint of concern. Risk levels are classified on a logarithmic scale. For example, RQ < 0.1 is classified as negligible risk, RQ ≥ 0.1 to < 1.0 is low risk, RQ ≥ 1.0 to < 10.0 is moderate risk, RQ ≥ 10.0 to < 100.0 is high risk and so on.

Initial and cumulative expected environmental concentrations (EECs) were calculated for soil, water and wildlife food sources for spray applications of 2,4-D. Incremental application rates were used to calculate the EECs. For uses involving multiple applications, the maximum number of applications and minimum intervals between applications were used in the calculations. The application rates evaluated are as follows:

- 1 application at 0.329 kg a.e./ha used on cereal grains, corn and sorghum (minimum rate);
- 2 applications at 2.24 kg a.e./ha (spaced 30 days apart) used on pasture, fallow land and crop stubble; and
- 1 application at 4.48 kg a.e./ha used for control of brush and woody growth on non-cropland (maximum rate).

Applications rates for the different forms of 2,4-D are expressed as kg acid equivalent a.e./ha. The cumulative EECs were estimated by adjusting the sum of the applications for dissipation between applications using the half-life ($t_{1/2}$) or the time for 50% decline (DT_{50}) for the appropriate environmental media.

For the screening-level assessment of risk to the aquatic organisms, the EECs were computed assuming direct application (overspray) of 2,4-D to a 1-ha body of water that is 30-cm deep (15 cm for forestry uses). To refine the risk assessment the EECs in water were determined by the Pesticide Root Zone Model and the Exposure Analysis Modeling System (PRZM/EXAMS). The runoff concentrations were predicted for a 1-ha wetland that is 80-cm deep following 2,4-D applications in a 10-ha drainage area. The 90th percentile of the peak annual concentrations (maximum EECs) over the simulation time period was used in the acute risk assessment of freshwater and estuarine/marine fish and aquatic invertebrates. The 90th percentile of the average of the yearly concentrations (minimum EECs) over the simulation time period were used to assess the risk of chronic effects (embryo larval stage) in freshwater and estuarine/marine fish. For the risk to aquatic plants and algae and the chronic (life-cycle) risk to freshwater and estuarine/marine aquatic invertebrates, the 90th percentile of the 21-day concentrations over the simulation time period were used.

Effects endpoints included acute and chronic toxicities, chosen from the range of toxicity tests on species available. Effects endpoints, chosen from the most sensitive species, were used as surrogates for the wide range of species that can be potentially exposed following treatment with 2,4-D.

The risk assessment was also conducted for a 2,4-D BEE granular aquatic herbicide (maximum 2 applications of granular BEE spaced 3 weeks apart at 42.75 kg a.e./ha). This use results in very high EECs because of the large concentrations of 2,4-D BEE required for the herbicide to be efficacious. The exposure scenario was the standard wetland, 1 ha in area and 7700 m^3 in volume, used to assess the risk to aquatic life.

2,4-D is frequently detected in rainfall monitoring studies in the prairies. The risk to aquatic life from this exposure was assessed against the highest concentrations detected in rainfall in Southern Alberta (0.053 mg a.e./L) (Hill et al. 2002a). The risk to terrestrial plants was assessed using the highest seasonal (cumulative) deposition rate (261 µg a.e./m^2) reported in monitoring studies in prairie rainfall (Hill et al. 2002a). This is a highly conservative scenario.

The PMRA classifies transformation products based on the proportions of transformation product detected relative to the parent concentrations. Major transformation products are those that occur in amounts greater than 10% of the initial parent concentration. In general, the PMRA considers only major transformation products in the review of pesticides. The only major transformation products identified in the review of 2,4-D are 2,4-DCP, chlorohydroquinone and carbon dioxide.

5.1 Environmental Fate

With respect to their behaviour in the environment, 2,4-D derivatives can be grouped into two main categories, the acid/amine group (acid, DMA, DEA, IPA, TIPA) and the ester group (EHE, BEE). Their behaviour in environmental media is different because their properties are different. 2,4-D acid and the amine forms are very soluble in water. The ester forms (EHE and BEE) are insoluble in water. The vapour pressure of 2,4-D acid and the amines is low, which indicates that they are non-volatile. 2,4-D acid and the amines are non-volatile from moist soil and water. The esters (EHE and BEE) have higher vapour pressures. Although they are classified as low or borderline low-intermediate volatile esters, the esters still volatilize in small amounts.

Field studies by several authors indicate that 2,4-D is the most frequently detected herbicide in prairie rainfall (in up to 93% of samples collected) (Hill et al. 2002a). Entry of 2,4-D to the atmosphere may be through entrainment of fine droplets during spray applications, incorporation of airborne dust containing 2,4-D into cloud forming processes or by volatilization of the esters during and after spray applications. The 2,4-D Industry Task Force II indicates that the forms used most frequently in agriculture are the esters (75% of the total), so volatilization may be one of the factors. Although they are classified as low or low-intermediate volatile esters, even low levels of volatilization may have an effect on regional atmospheric concentrations of 2,4-D vapour because of the widespread use of 2,4-D. The risks from 2,4-D in rainfall were assessed against the highest concentrations measured in rainfall (53 µg a.i./L) and the maximum seasonal (cumulative) deposition rates in rainfall (261 µg a.i./m^2). Donald et al. (2001) concluded from studies examining deposition rates of 2,4-D that the source of 2,4-D to prairie wetlands was atmospheric. The mean concentration of 2,4-D in observed wetlands was 0.26 µg a.e./L, which closely matches the predicted concentrations (0.29 µg a.e./L) in a typical prairie wetland (1-ha area and 77-cm deep).

The dissociation constant of 2,4-D is low (2.8), which indicates that it will be present in its ionic form under the pH conditions prevailing in most Canadian soils and water bodies (pH 4.5 to 8.5). The amines dissociate to the acid anion and a conjugate cation within a few minutes. Therefore, in the presence of water, the environmental behaviour of the amines can be considered to be the same as that of 2,4-D acid.

Laboratory data have shown that phototransformation is not a major route of transformation for 2,4-D and that hydrolysis is not an important route of transformation for 2,4-D acid or the amine forms. Under acidic or neutral pH levels (5 and 7), hydrolysis is not a significant route of transformation of the esters. However, it is an important route of transformation of the esters to the acid under alkaline pH conditions (pH 8 or 9), which might be expected to occur in alkaline prairie waters. The hydrolytic half-lives of EHE and BEE are 2 days and 0.07 day, respectively.

2,4-D acid and its derivatives are classified as non-persistent to slightly persistent in soil and water. Laboratory aerobic biotransformation half-lives range from 0.22 days to 31 days in soil and 0.25 to 29 days in water. Biotransformation of 2,4-D is not significant under anaerobic conditions. Under anaerobic conditions, 2,4-D is classified as persistent in soil and aquatic systems.

The log K_{ow} for 2,4-D acid and the amines is less than 2, which indicates that bioaccumulation is unlikely. However, for the EHE and the BEE forms, the log K_{ow} values are high (5.8 and 4.1, respectively), which indicates a potential to bioaccumulate. For 2,4-D acid, bioconcentration factors were 29 to 51 in bluegill sunfish, which indicates that bioaccumulation is not a concern. Studies of the EHE in the rat indicate that it is metabolized rapidly and is excreted rapidly in the urine. However, there are no data on the EHE ester in fish. Bioconcentration factors for fish for the EHE and BEE esters will be required to complete the risk assessment of the esters.

As 2,4-D adsorption to soil is very weak ($K_{oc} < 150$), it is not expected to partition significantly to soil or to sediments. Therefore, the potential for leaching of 2,4-D to groundwater is high, if the downward flow of water is rapid. Provided the rate of movement is slow, leaching will be attenuated by rapid biotransformation in the upper soil horizons and little residue will be found at depth owing to its relatively short half-life in soil (U.K. MAFF 1993). In a national survey of 68 000 wells throughout agricultural areas of the United States, 2,4-D was found to be the third most frequently detected pesticide. It was detected in 2.3% of samples collected (USEPA 1992, Wood and Anthony 1995).

In the field, 2,4-D has a relatively short half-life and is considered to be non-persistent in terrestrial and aerobic aquatic environments. However, it is persistent in anaerobic environments. The amines dissociate to the acid almost immediately in the presence of water, then the acid transforms further. The esters transform to the acid over the course of a few days. Aerobic biotransformation is the main route of transformation of 2,4-D. The ester transformation rate is similar to that of the amines. Hydrolysis is not significant except for the esters under alkaline conditions. In soil, the presence of moisture plays an important role in the microbial degradation of 2,4-D. The computed dissipation half-life from field studies on bare soil is 10 days for the acid and amines and 8 days for the esters (ester + 2,4-D acid residue). The half-life from studies on crops (wheat and corn) is 16 days for the acid and amines and 5 days for the esters (ester +

2,4-D acid residue). These values correspond to the upper 90th percentile of the half-lives from a large number of field studies including single and multiple applications. For aerobic aquatic environments, the maximum half-life is 10 days for the acid and amines, and 11 days for the esters (ester + 2,4-D acid residue). These values were used to predict the EECs for multiple applications. The maximum half-life in sediment is 26 days based on a study with the BEE form. However, 2,4-D is not expected to partition significantly to sediments because of its low adsorption properties. In anaerobic aquatic environments, 2,4-D is persistent. Measurable half-lives in anaerobic biotransformation studies vary from 41 days (2,4-D acid) to 1610 days (DMA).

A degradation diagram of 2,4-D was published in Re-evaluation Note REV2006-11, Appendix I, Section 10.16. As indicated in that publication, the major transformation products of 2,4-D (> 10% of initial parent concentration) identified in the aquatic biotransformation studies are 2,4-DCP (maximum of 22% of the parent concentration), chlorohydroquinone (maximum of 17% of the parent concentration) and carbon dioxide (71% of the parent concentration). The only major transformation product identified in the soil biotransformation studies was carbon dioxide (70% of the applied parent concentration). Several potential mechanisms for the degradation or removal of 2,4-DCP from water have been identified including, phototransformation, biotransformation, phototransformation, oxidation, catalysis at the silica surfaces and adsorption to sediment. 2,4-DCP is highly volatile, with a maximum half-life in air of about 9 days (European Chemicals Bureau 2002). However, in the aquatic environment, it is only slightly volatile because it is highly soluble in water. The p*K*a of 2,4-DCP is about 7.9, which indicates that it is likely to exist in its ionized state under alkaline conditions. In neutral or acidic soils it occurs in its volatile phenolic form rather than as a phenolate anion. Hydrolysis is not expected to be a significant mode of transformation. However, phototransformation is expected to be an important mode of transformation. 2,4-DCP is biodegradable in the presence of conditioned microflora. 4-chlorophenol (4-CP) is a major transformation product of 2,4-DCP under anaerobic transformation. In soil or sediment, it is classified as low to moderate mobility with K_{oc}s ranging from 368 to 1204 ml/g. 2,4-DCP is generally non-persistent in aerobic aquatic systems. Reported half-lives range from a few hours to 23 days. It can be persistent once it enters groundwater or sediment. Groundwater half-life varies from 133 to 1032 days. The half-life in sediment varies from 47 to 116 days (European Chemicals Bureau 2002).

The log K_{ow} of 2,4-DCP is 3.21 to 3.25 at 20°C, which indicates a potential for bioaccumulation. However, it is relatively short lived so bioaccumulation is not likely to be significant under environmental conditions. Bioconcentration factors for 2,4-DCP are low (1.5 to 69), which indicate that this is not a concern.

The second major transformation product of 2,4-D, chlorohydroquinone, is likely an intermediate transformation product. Results of aerobic aquatic transformation studies suggest it is relatively non-persistent. Additional data on its fate have been requested and are now under review.

5.2 Environmental Toxicology

5.2.1 Terrestrial

For terrestrial organisms, there was no distinct difference between the toxicity of the esters and that of 2,4-D acid and the amines. The most sensitive terrestrial organisms to 2,4-D, a herbicide, are plants.

2,4-D is phytotoxic to many non-target terrestrial plants, especially broadleaf plants. Based on the fresh weight, the lowest effect concentrations 25% (EC_{25}s) are ≤ 0.017 kg a.e./ha (mustard) for the acid and amines and 0.03 kg a.e./ha (mustard) for the esters. There are no fresh weight data for the BEE. With respect to vegetative vigour, the lowest EC_{25}s are 0.009 kg a.e./ha (soybean) for the acid and amines and 0.011 kg a.e./ha (tomato) for the esters. No seedling emergence and germination or vegetative vigour toxicity data are available for the IPA and TIPA forms. However, the PMRA regards toxicological data for terrestrial plants from the other amine forms as sufficient to support the environmental assessment of the IPA and TIPA forms. Therefore, data on the toxicological properties of these forms to terrestrial plants will not be required.

2,4-D has relatively low toxicity to terrestrial invertebrates including the honeybee and earthworms. The median lethal concentration (LC_{50}) of earthworms from 2,4-D exposure is 291 mg a.e./kg soil (DMA). No data are available for the other forms. The LC_{50} of the soil transformation product 2,4-DCP to the earthworm is 125 mg a.e./kg soil. The lethal doses 50% (LD_{50}s) of 2,4-D for the honeybee is > 83 µg a.e./bee (DMA) and > 68 µg a.e./bee (EHE).

For birds, the acute oral toxicity of the different forms of 2,4-D range from practically non-toxic to moderately toxic (median lethal dose [LD_{50}] > 3077 to 200 mg a.i./kg bw). The lowest LD_{50} amongst all the forms is 200 mg a.i./kg with the Chukar partridge (2,4-D acid). This value was used to estimate the acute LD_{50}s to small birds such as the American robin (146.4 mg a.i./kg bw) and the field sparrow (113.2 mg a.i./kg bw). For the bobwhite quail, the lowest LD_{50} is 217 mg a.e./kg bw (TIPA). For the mallard duck, the lowest LD_{50} is > 314 mg a.e./kg bw (IPA). These are classified as moderately toxic. These values are used in the acute risk assessment of larger birds.

2,4-D is less acutely toxic to birds on a dietary basis than when dosed orally. For both the bobwhite quail and the mallard duck, the lowest acute LC_{50} is > 3854 mg a.e./kg diet (DMA), which is classified as slightly toxic.

Avian reproductive data also indicate relatively low toxicity. The lowest no observed effect concentration (NOEC) is 962 mg a.i./kg diet with 2,4-D acid (bobwhite quail). Avian reproductive effects include cracked eggs and decrease in number of eggs laid.

For mammals, the acute oral toxicity of 2,4-D to the rat ranges from practically non-toxic to moderately toxic (LD_{50} = 1833 to 360 mg a.e./kg bw). For the rat, the lowest LD_{50} is 360 mg a.e./kg bw (DMA). Acute dietary toxicity for the risk assessment of mammals was computed from the acute oral toxicity data from the PMRA, the United Kingdom Ministry of

Agriculture, Forestry and Food (1993) and the WHO (1996) report. For the rat, the LC_{50} is 2100 mg a.i./kg diet (2,4-D acid). With respect to the reproductive (chronic) toxicity, the lowest NOEC for the rat is 85 mg a.i./kg diet (2,4-D acid). Reproductive effects include decreased body weight in the parental animals and renal tube alteration in the parental animals and offspring, increased gestation length and decreased pup weight.

With current available information, it is not possible to determine if reproductive effects in the birds and mammals tested are a possible indication of endocrinal disruption. At the present time, there are no test protocols to evaluate endocrine disrupting effects of pesticides. Test protocols that evaluate endocrine endpoints in environmental toxicity studies are currently being developed and validated. When the appropriate testing protocols have been developed, 2,4-D may be subject to additional screening and/or testing to better characterize any potential effects related to endocrine disruption. As stated in Re-evaluation Note REV2006-11, 2,4-D does not appear to be a true endocrine disrupter according to the weight-of-evidence from published and unpublished studies. Some animal studies showed effects such as decreased thyroid, adrenal and testicular weight, which may be why some groups have included 2,4-D in this category. However, these organ weight effects occurred at very high doses and are considered secondary to high-dose toxicity.

5.2.2 Aquatic

The most sensitive aquatic organisms to 2,4-D are aquatic plants, green algae and diatoms. The lowest NOECs are 0.07 mg a.e./L (*Lemna gibba*) for the acid amine group, 0.094 mg a.e./L (*Skeletonema costatum*) for EHE and 0.2 mg a.e./L *(L. gibba)* for BEE.

With respect to fauna, the 2,4-D ester forms are much more toxic (acute and chronic) to aquatic invertebrates and fish than 2,4-D acid or the amines. The toxicity of the acid and the different amines is quite similar to each other (same order of magnitude). However, the esters (EHE and BEE) showed distinctly different toxicities from each other. Chemical concentration of the technical esters was limited by their very low solubility to virtual insolubility in water.

For freshwater fish, the toxicity ranges from practically non-toxic to highly toxic (96-hour LC_{50}s = 2840 to 0.47 mg a.e./L. The lowest 96-hour LC_{50}s for cold water species (rainbow trout) are 240 mg a.e./L for 2,4-D acid and the amines, 7.2 mg a.e./L for EHE and 0.47 mg a.e./L (rainbow trout) for BEE. For warm water fish (bluegill sunfish), the lowest 96-hour LC_{50}s are 40 mg a.e./L for the 2,4-D acid and the amines, > 5.0 mg a.e./L for EHE and 0.61 mg a.e./L for BEE. The lowest chronic (embryo larval stage) NOECs are 17.1 mg a.e./L (fathead minnow) for the acid and amines, and 0.12 mg a.e./L (fathead minnow) for EHE. No chronic data are available for the BEE form or for cold water species. The toxicity of the technical esters to fish may have been limited by their very low solubility to virtual insolubility in water.

For estuarine/marine fish, the acute toxicity of 2,4-D derivatives ranges from practically non-toxic to highly toxic (LC_{50} > 560 to > 0.24 mg a.e./L). The lowest LC_{50}s are > 118 mg a.e./L (Atlantic silverside) for the acid amine group, 0.24 mg a.e./L (tidewater silverside) for EHE and 5.0 mg a.e./L (tidewater silverside) for BEE. The only chronic (embryo larval stage) NOEC available for estuarine/marine species is for BEE 0.056 mg a.e./L (sheepshead minnow).

The acute toxicity of 2,4-D to freshwater aquatic invertebrates ranges from practically non-toxic to highly toxic (LC_{50} = 748 to > 0.2). The lowest LC_{50}s are 8.72 mg a.i./L (*Cyclops vernalis*) for the acid and amines, > 0.2 mg a.e./L (*Daphnia magna*) for the EHE and 3.1 mg a.e./L (*Nitocra spinipes*) for BEE. The lowest chronic (21-day life-cycle) NOECs are 23.6 mg a.e./L (*D. magna*) for the acid and amines, 0.015 mg a.e./L (*D. magna*)for the EHE and 0.29 mg a.e./L (*D. magna*) for the BEE.

For estuarine/marine invertebrates, 2,4-D toxicity ranges from practically non-toxic to highly toxic (LC_{50} = 744 to > 0.014 mg a.e./L). The lowest LC_{50}s are 57 mg a.e./L (Eastern oyster) for the acid and amines, > 0.71 mg a.e./L (grass shrimp) for EHE and 5.6 mg a.e./L (brown shrimp) for BEE. No chronic (life-cycle) toxicity data are available for estuarine/marine invertebrates in any of the literature sources reviewed.

With respect to the major transformation product occurring in the aquatic environment (2,4-DCP), available data on the toxicity of 2,4-DCP indicate that the lowest chronic NOECs are 0.29 mg a.i./L for freshwater fish, 0.21 mg a.i./L for *D. magna* and 0.41 mg a.i./L for the macrophyte *L. gibba*.

5.3 Concentrations in Drinking Water

Estimates of the residues of 2,4-D in Canadian drinking water sources were obtained from large-scale surveys undertaken in the United States as well as smaller, localized data from various parts of Canada. Pesticide residues in source water and finished drinking water can be similar.

For this assessment, information was extracted from the available sources and sorted into three categories.

- Residues in municipal drinking water sources
- Residues in ambient water that may serve as a drinking water source
- Residues in farm dugouts and shallow wells that may supply private drinking water

The first group describes standard municipal drinking water resources obtained from groundwater and surface water sources. The second category encompasses bodies of surface water or groundwater resources that may be used as drinking water sources. The third category includes farm dugouts and shallow wells that are used as drinking water sources in rural areas. Table 5.3.1 provides a summary of 2,4-D detections in potential drinking water sources. Data from this table were used in the dietary risk assessment.

Table 5.3.1 Summary of 2,4-D Detections In Drinking Water Sources

Data Category	Detection Limit	Frequency of Detection (%)	Mode or Median Detection Value (µg/L)	Upper Detection Value (97.5 percentile) (µg/L)
Municipal	0.1 µg/L	20	0.3	50
Ambient	0.1 µg/L	20	0.3	50
Dugouts, wells	0.1 µg/L	30	0.6	50

5.4 Terrestrial Risk Assessment

There are potential risks to non-target terrestrial plants because 2,4-D is a herbicide. The risk assessment for terrestrial plants was carried out separately for the acid and amines as a group, and individually for each of the esters because of the widespread use of the esters in Canada.

The risk from the use of 2,4-D and its derivatives ranges from high to very high (RQ = 19 to 263) to seedling emergence of non-target terrestrial plants. The risk to vegetative vigour of non-target plants also ranges from high to very high risk (RQ = 14 to 553). There was negligible to low (RQ < 1) risk to seedling emergence and vegetative vigour from the maximum seasonal (cumulative) deposition rates of 2,4-D occurring in rainfall (261 µg a.e./m^2).

The risk assessment for the birds and mammals was carried out using the most sensitive toxicity endpoint from all of the forms because there were no distinct differences in toxicity between the forms of 2,4-D for birds and mammals.

The risk assessment for birds included large birds such as the mallard duck, as moderate-sized birds such as the bobwhite quail and small birds such as the American robin and the field sparrow. Data on the acute toxicity of 2,4-D to the robin and the sparrow were not available and were extrapolated from data for the Chukar partridge, which is the most sensitive species. The time taken to ingest 2,4-D in the diet equivalent to the NOEL for the mallard duck feeding on 2,4-D contaminated food sources was > 1 day, which is the threshold for risk. Therefore, there was no significant risk to the mallard duck. However, for the bobwhite quail, American robin and the field sparrow, the time taken to reach the NOEL is < 1 day, which indicates a potential risk to these birds. For the dietary risk assessment, the NOECs were estimated from $0.1 \times LC_{50}$ because there were no data on the dietary NOECs. The risk to the mallard from dietary consumption of food sources contaminated by 2,4-D derivatives ranges from negligible to low (RQ < 1). For small birds such as the American robin and the field sparrow, the dietary risk is moderate to high (RQ = 1.2 to 26). This is based on estimates of the NOECs for these birds and the assumption that birds are feeding entirely on a contaminated diet. The percentage of the diet contaminated with 2,4-D required to reach a risk quotient of 1 or less (low or negligible risk) ranges from 52% to 3.8% for the American robin and from 87 to 6.4% for the field sparrow.

Thus, even if 10% of the diet is contaminated, 2,4-D will still be a risk to small birds at the higher application rates (4.48 kg a.e./ha and 2 applications at 2.24 kg a.e./ha). There are no incidents of bird kills from 2,4-D use in Canada or the United States.

The available data indicate that the risk of reproductive effects to the bobwhite quail is negligible to low (RQ < 1).

The assessment indicated that there was a potential risk to small mammals, particularly at the higher use rates. For small mammals feeding on food sources contaminated with 2,4-D, the time taken to reach the NOEL is < 1 day at the higher use rates (2.24 kg a.e./ha and 4.48 kg a.e./ha), which indicates a potential risk. The risk of acute dietary effects ranges from low to high (RQ = 0.8 to 11). The risk of chronic (reproductive) effects to mammals from 2,4-D is moderate to high (RQ = 2.0 to 27). The assessment was based on the assumption that small mammals are feeding entirely on a contaminated diet. The percentage of the diet contaminated with 2,4-D required to reach a risk quotient of 1 or less (low or negligible risk) ranges from 51% to 3.9% for reproductive risk and from 15% to 9% for acute risk. Therefore, if 10% of the diet is contaminated, 2,4-D will still be a risk to small mammals at the higher application rates (4.48 kg a.e./ha and 2 applications at 2.24 kg a.e./ha). There are no incident reports of mortality in small mammals in any of the literature reviewed.

For terrestrial invertebrates 2,4-D use is not a concern. The risk to the earthworm from 2,4-D is negligible (RQ < 0.1). For the honeybee, the risk from 2,4-D ranges from negligible to low (RQ < 1). The risk from the soil transformation product 2,4-DCP to earthworms was not assessed because it is classified as a minor transformation product in soil. However, based on the relatively similar toxicities of 2,4-DCP and the 2,4-D form DMA to the earthworm, it would not be a significant risk to earthworms.

5.5 Aquatic Risk Assessment

The aquatic risk assessment was carried out for the acid and the amines as a group using the most sensitive toxicity endpoint from the group because the amines dissociate in minutes to 2,4-D acid in the presence of water. The esters are much more toxic than the amines. The risk assessment was carried out separately on each of the esters because of significant differences in the toxicity of the EHE and the BEE to aquatic life.

The assessment of risk to aquatic plants, green algae and diatoms from direct applications to water (overspray) indicated acute risks ranging from moderate to high (RQ = 1.6 to 21) from 2,4-D acid and the amines, low to moderate (RQ = 0.55 to 4.2) from BEE, and moderate to high (RQ = 1.2 to 16) from EHE. The risk to aquatic vegetation from runoff ranged from low to moderate (RQ = 0.13 to 4.9) for 2,4-D acid and the amines, negligible to moderate (RQ < 0.1 to 1.3) for the BEE, and negligible to moderate (RQ < 0.1 to 2.8) for the EHE. The risk from maximum concentrations of 2,4-D occurring in rainfall is low (RQ = 0.27 to 0.76) for the acid, amines and esters. Based on the observed wetland concentrations, the risk from 2,4-D in rainfall is negligible (RQ < 0.1).

No acute NOECs were available for freshwater fish. The acute risk quotients were calculated using 0.1 × LC_{50}. The assessment of risk from direct applications of 2,4-D to water (overspray) indicated that the acute and chronic risk to freshwater fish from 2,4-D acid and the amine forms ranged from negligible to low (RQ < 1). The acute risk ranged from low to moderate (RQ = 0.2 to 2.2) for EHE and moderate to high (RQ = 1.8 to 32) for BEE. The chronic risk is negligible (RQ < 0.1) for the acid and the amines, and low to high (RQ = 0.91 to 12) for the EHE. No chronic toxicity data are available for the BEE. With respect to 2,4-D in runoff, the acute risk to freshwater fish is negligible to low (RQ < 1) from 2,4-D acid and the amines and EHE, and low to moderate (RQ = 1.8 to 7.1) from BEE. The chronic risk (early life stage) from 2,4-D acid, the amines and the EHE is negligible (RQ < 0.1).

For the use of 2,4-D BEE as an aquatic herbicide, the risk of acute effects to freshwater fish is very high (RQ = 115 to 150). The chronic risk (early life stage) for freshwater fish from this use was assessed using the toxicity from EHE as a surrogate. The risk is high (RQ = 58).

The acute risk from the highest concentrations of 2,4-D measured in rainfall is negligible (RQ < 0.1) for the acid/amines, and negligible to low for EHE (RQ < 1) and low to moderate for BEE (RQ = 0.87 to 1.1). The risk of chronic effects is negligible (RQ < 0.1) for the acid and the amines and low (RQ = 0.4) for the EHE. Based on the observed concentrations in wetlands, the risk from 2,4-D in rainfall is negligible (RQ < 0.1).

For the estuarine/marine fish, the acute risk in the assessment of risk from direct applications to water (overspray) ranged from negligible to low (RQ < 1) for the acid and the amines, low to moderate (RQ = 0.22 to 3.0) for BEE, and moderate to high (RQ = 4.5 to 62) for EHE. For the embryo larval stage (chronic toxicity), the only toxicity data available were for the EHE. The chronic risk ranges from negligible to moderate (RQ < 0.1 to 1.4) for EHE. For 2,4-D in runoff, the acute risk was negligible (RQ < 0.1) from 2,4-D acid and the amines, negligible to low (RQ < 1) for BEE and negligible to high (RQ < 0.1 to 15) for EHE. For estuarine/marine fish, the chronic risk from runoff was negligible (RQ < 0.1) for EHE.

For the use of the BEE form as an aquatic herbicide, the risk of acute effects to estuarine/marine fish was high (RQ = 14). The chronic risk was assessed using the NOEC from EHE for estuarine/marine fish because a NOEC was not available for BEE. This was moderate (RQ = 6.4). The acute risk to estuarine/marine fish from the highest concentrations of 2,4-D occurring in rainfall was negligible (RQ < 0.1) for the acid and amines, low for BEE (RQ = 0.11) and moderate for EHE (RQ = 2.2). Based on the observed wetland concentrations, the risk from 2,4-D esters in rainfall is negligible (RQ < 0.1). The chronic risk from 2,4-D in rainfall was negligible (RQ < 0.1) for EHE.

For the assessment of risk to freshwater invertebrates from direct applications to water (overspray), the acute risk ranged from low to moderate (RQ = 0.13 to 1.7) for 2,4-D acid and the amines, low to moderate (RQ = 0.35 to 4.8) for BEE and moderate to high (RQ = 5.5 to 75) for EHE. The chronic risk to freshwater invertebrates was negligible (RQ < 0.1) for 2,4-D acid and the amines, and moderate to high (RQ = 7.2 to 99) for EHE. For 2,4-D in runoff the acute risk ranged from negligible to low (RQ < 1) for 2,4-D acid and the amines, negligible to moderate (RQ < 0.1 to 1.1) for BEE and low to high (RQ = 0.54 to 18) for EHE. The chronic (life-cycle) risk to freshwater invertebrates from runoff was negligible (RQ < 0.1) for 2,4-D acid and the amines, and negligible to low (RQ < 1) for EHE. For uses of the BEE form as an aquatic herbicide, the risk of acute effects to freshwater invertebrates was high (RQ = 23). The risk was assessed using the NOEC from the EHE as a surrogate because there are no chronic toxicity data for the BEE. The chronic risk was very high (RQ = 469). The acute risk to freshwater invertebrates from maximum concentrations of 2,4-D occurring in rainfall was negligible (RQ < 0.1) for the acid and amines, low (RQ = 0.17) for BEE and moderate (RQ = 2.7) for EHE. The chronic risk was negligible (RQ < 0.1) for the acid and amines, and moderate (RQ = 3.5) for the EHE. Based on the observed concentrations in wetlands, the risk from 2,4-D esters in rainfall is negligible (RQ < 0.1).

For the assessment of risks from direct applications to water (overspray) to the estuarine/marine invertebrates, the acute risk was low to moderate (RQ = 0.16 to 2.2) for 2,4-D acid and the amines, low to moderate (RQ = 0.19 to 2.7) for BEE and high for the EHE (RQ = 62 to 93). There are no toxicity data available to assess the chronic (life-cycle) risk to estuarine/marine invertebrates. The acute risk from 2,4-D in runoff ranged from negligible to low (RQ < 1) for 2,4-D acid, amines and BEE, and low to moderate (RQ = 0.67 to 22) for EHE. For the use of the BEE form to control aquatic vegetation, the acute risk is high (RQ = 13). The acute risk from maximum concentrations of 2,4-D occurring in rainfall was negligible (RQ < 0.1) for the acid, amines and BEE, and moderate (RQ = 3.3) for EHE. Based on the observed wetland concentrations, the risk from 2,4-D esters in rainfall is negligible (RQ < 0.1).

2,4-DCP is a major transformation product of 2,4-D found in aquatic environments. For freshwater fish and aquatic invertebrates, the acute risk from 2,4-DCP following direct application of 2,4-D to water, varies from low to moderate (RQ = 0.14 to 1.9 for fish; RQ = 0.17 to 2.4 for invertebrates). The chronic risk ranges from negligible or low to moderate (RQ = 0.08 to 1.1 for fish; RQ = 0.11 to 1.6 for invertebrates). The acute risk to freshwater fish and aquatic inverebrates from 2,4-DCP in a water body receiving runoff ranges from negligible risk to low risk (RQ = 0.01 to 0.5 for fish; RQ = 0.02 to 0.6 for invertebrates). The chronic risk is negligible (RQ < 0.1). For aquatic plants, the risk from 2,4-DCP following direct application of 2,4-D to water varies from low to moderate (RQ = 0.06 to 1.3). The risk to aquatic plants from 2,4-DCP in a water body receiving runoff is negligible (RQ < 0.1).

There was insufficient information available on the properties of the other major transformation product chlorohydroquinone, found in aquatic biotransformation studies, to assess the risk to the environment. Data on chlorohydroquinone has been requested in the data requirements for the continuing registration of 2,4-D for turf and lawn uses.

5.6 Environmental Assessment Conclusions

2,4-D is a relatively short lived chemical in the terrestrial and aquatic environment, with a half-life of less than two weeks. The exception is anaerobic environments where 2,4-D is persistent. It is a highly mobile chemical and, therefore, is susceptible to leaching and runoff from treated areas.

The assessment indicated that 2,4-D is not a risk to large birds such as the mallard duck. It is a potential acute dietary risk to smaller birds (bobwhite quail, American robin and field sparrow). This is based on the assumption that 100% of the diet is contaminated with 2,4-D. However, 2,4-D remains a risk to small birds at the higher use rates (4.48 kg a.e./ha and 2.24 kg a.e./ha), even if 10% of the diet is contaminated.

The assessment also indicated that 2,4-D is a potential acute dietary and reproductive risk to small mammals. 2,4-D remains a risk to small mammals from the higher use rates (4.48 kg a.e./ha and 2.24 kg a.e./ha), even if 10% of the diet is contaminated.

Being a herbicide, 2,4-D is highly toxic to terrestrial broadleafed plants, aquatic plants and algae, and there are risks from exposure at all application rates.

Runoff modelling indicates that there is negligible chronic risk to freshwater and estuarine/marine fish from the esters. Acute risks from runoff of the esters are moderate to freshwater and estuarine/marine fish. The use of the granular BEE form as an aquatic herbicide presents a moderate to very high risk to fish. With respect to 2,4-D in rainfall, the risks to fish from the acid, the amines and the esters, based on observed concentrations in wetlands, are not expected to be significant.

With respect to aquatic invertebrates, the concentrations occurring in runoff are not a significant risk except the estuarine/marine invertebrates, which are at risk from the EHE form. The use of the BEE form as an aquatic herbicide presents a moderate to very high risk to aquatic invertebrates. Based on the observed concentrations in wetlands, 2,4-D acid, amines and esters in rainfall are not expected to be a risk to aquatic invertebrates.

The risk to aquatic life in surface waters from the transformation product 2,4-DCP in runoff was negligible.

5.7 Environmental Risk Mitigation

5.7.1 Spray Drift

2,4-D can enter the aquatic or terrestrial habitats through spray drift. The observance of buffer zones, however, can effectively mitigate the risk to aquatic or terrestrial organisms. Pesticide spray drift from ground sprayers (boom and airblast) was predicted using the data of Wolf and Caldwell (2001), based on the maximum application rate for each type of spray equipment and the most sensitive aquatic or terrestrial species.

Currently, the buffer zones determined for ground applications are based on a standard set of assumptions for spray configuration and weather conditions, yet many variable conditions exist at a spray site. To allow for increased flexibility, the PMRA is developing, with the provinces, a proposal that would allow the applicator to factor in the actual values for spray characteristics, wind speed and the sensitivity of the habitat to be protected. Spray drift can be reduced by shrouds and cones. Consequently, individual applicators could reduce the size of the spray buffer zone if they use some of these measures to protect the habitat in question. Spray drift from field sprayers and aerial applications are substantially reduced by the use of American Society of Agricultural Engineers (ASAE) coarse droplet size (350 to 450 µm) instead of medium (250 to 350 µm). The PMRA is proposing to withdraw the use of medium spray droplet size and instead, use coarse droplet size for 2,4-D products, including coformulated and tank-mix products.

The calculated ground and aerial buffer zones for agricultural, non-cropland and forestry uses of 2,4-D are presented in Section 8.2.6.1. The buffer zone calculations for the ASAE coarse droplet size are based on standard scenarios for ground spray applications using a field sprayer (Wolf and Caldwell 2001). Aerial buffer zones were calculated using the AgDisp model (version 8.15) using coarse droplet size. The calculated aquatic buffer zones were determined based on the most sensitive aquatic organism for both freshwater and estuarine/marine environments for all of the 2,4-D forms (chronic NOEC for *D. magna* to EHE exposure = 0.015 mg a.e./L). The terrestrial buffer zones are based on the most sensitive plant species from all of the forms (i.e., 8.4 g a.i./ha based on vegetative vigour EC_{25} for tomato to 2,4-D acid exposure). Buffer zones are not required when spraying right-of-ways.

5.7.2 Surface Runoff/Leaching

Advisory statements must appear on product labels to minimize the risk of aquatic contamination from surface runoff. Similarly, to mitigate the downward movement of 2,4-D in soil and, thus, reduce contamination of groundwater, advisory statements should be included on 2,4-D product labels.

6.0 Use Data and Alternatives

6.1 Use Data Considered in Risk Assessments

6.1.1 Commercial and/or Restricted Class Products

Appendix II, Table 2, lists the use information considered in the PMRA’s risk assessments for uses of 2,4-D that have risk concerns. This information is divided by province and includes estimated percent crop treated, maximum single application rate of active ingredient applied to the crop, the maximum cumulative rate of active ingredient applied to the crop per year, maximum number of applications to the specific crop per year and the minimum number of days between applications.

6.1.2 Domestic Class Products

Domestic class products containing 2,4-D are only used on fine turf. These products are reviewed in a separate document, PACR2005-01, *Re-evaluation of the Lawn and Turf Uses of (2,4-Dichlorophenoxy)acetic Acid [2,4-D]).*

6.2 Alternatives to 2,4-D Use

Although the PMRA has searched information available for the control of aquatic weeds in aquatic sites and found one non-chemical measure of pest control involving mechanical removal of aquatic weeds, the effectiveness and extent of use of this non-chemical control measure is not verified.

The registered chemical alternatives for the supported uses of 2,4-D that have risk concerns are listed in Appendix II, Table 3. While the chemical control methods are registered, the PMRA has not commented on the availability and extent of use of these options.

The PMRA welcomes feedback on the availability and extent of use of the chemical alternatives to 2,4-D in Appendix II, Table 3. The Agency also invites further information regarding the availability, effectiveness and extent of use of non-chemical control methods for the site-pest combinations listed in that table.

7.0 Other Assessment Considerations

7.1 Toxic Substances Management Policy

During this review of the lawn and turf uses of 2,4-D, the PMRA took into account the federal Toxic Substances Management Policy[5] and followed its Regulatory Directive DIR99-03[6]. The technical grade active ingredient 2,4-D and its major transformation products do not meet the criteria for TSMP Track 1 substances.

The log *n*-octanol–water partition coefficient (log K_{ow}) for 2,4-D acid is less than 2.0, which is below the TSMP Track 1 cut-off criterion of log K_{ow} 5.0. The only form of 2,4-D that exceeds one of the TSMP Track 1 criteria is 2,4-D EHE, as it has a log K_{ow} of 5.8. However, 2,4-D EHE does not meet the persistence criterion. Esters such as EHE undergo rapid biotransformation (half-life of less than half a day) in natural water and soil; hence, their persistence is much less than the TSMP Track 1 cut-off criteria for water, sediment and soil (182 days in each medium).

7.2 Impurities, Byproducts and Contaminants

As indicated previously in REV2006-11, 2,3,7,8-TCDD or other dioxins and furans of concern may be present in 2,4-D only at levels below the regulatory limit of 1 ppb that was established in the early 1980s. Trace levels would not be detected above background levels following use of

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5 The federal Toxic Substances Management Policy is available through Environment Canada's website at www.ec.gc.ca/toxics.

6 Regulatory Directive DIR99-03, *The Pest Management Regulatory Agency's Strategy for Implementing the Toxic Substances Management Policy*, is available through the Pest Management Information Service. Phone: 1-800-267-6315 within Canada or 613-736-3799 outside Canada (long distance charges apply); fax: 613-736-3798; e-mail: pmra_infoserv@hc-sc.gc.ca; or through our website at www.pmra-arla.gc.ca.

2,4-D products and, therefore, would pose no additional health risk. As noted in Health Canada's *It's Your Health* publication found at www.hc-sc.gc.ca/iyh-vsv/environ/dioxin_e.html, the greatest sources of dioxins in the environment include the incineration of medical and municipal waste, the burning of fuel and wood, electrical power generation and tobacco smoke.

As 2,3,7,8-TCDD and other dioxins of concern are Track 1 substances and subject to virtual elimination under the federal Toxic Substance Management Policy, the PMRA requested the submission of data on dioxins in REV2006-11 using newer, more sensitive analytical methods.

7.3 Formulant Issues

Products containing 2,4-D are subject to all the requirements of the PMRA's Formulants Program presented in Regulatory Directive DIR2006-02, *Formulants Policy and Implementation Guidance Document*.

The PMRA indicated in Re-evaluation Note REV2006-11 that 2,4-D formulations containing DEA are no longer supported and have been discontinued (see Section 8.1.1).

DMA forms of 2,4-D may contain traces of N-nitrosodimethylamine (NDMA), usually at a concentration of less than 1 ppm. The PMRA will require registrants to quantify NDMA levels in any DMA used in manufacturing of 2,4-D products (see Section 9.1.2).

8.0 Proposed Regulatory Actions

In 2005, the PMRA proposed the continued registration of 2,4-D on residential, recreational and commercial turf (PACR2005-01. This document proposes that the use of 2,4-D in agricultural, forestry and industrial sites is acceptable for continued registration with the implementation of additional mitigation measures and label improvements to further protect workers and the environment. These mitigation measures include the phase-out of products containing the DEA form of 2,4-D and products for aquatic use, as indicated below.

8.1 Proposed Mitigation Measures

8.1.1 Phase-Out of the DEA Form

As indicated in Section 4.0, the PMRA has determined that the diethanolamine (DEA) form of 2,4-D is not toxicologically equivalent to other forms of 2,4-D. The following gaps were identified in the 2,4-D DEA toxicology database:

- metabolism studies;
- chronic/oncogenicity studies (rat and mouse); and
- a two-generation rat reproduction study.

In light of published studies on toxicological effects of DEA, and in the absence of a toxicological and exposure database with which to conduct a quantitative risk assessment, 2,4-D formulations containing DEA are no longer supported and have been discontinued (see REV2006-11).

8.1.2 Discontinuation of the Butyl Glycol Ester Form

As mentioned in Section 2.6, the butyl glycol ester form of 2,4-D was not included in this assessment because the only registered product was no longer available in the marketplace.

8.1.3 Discontinuation of Application to Aquatic Areas

Concerns were raised regarding applicator exposure and swimmer exposure following the use of granular products containing the BEE form of 2,4-D. Unless data are provided to refine this risk assessment, it is proposed this aquatic use of 2,4-D be phased out.

8.2 Label Recommendations and Improvements

8.2.1 Label Statements Related to the Guarantee

The guarantee statement on the labels of all products must be revised, when necessary, to specify the form of 2,4-D contained (i.e., one of the forms indicated in Section 2.4, Table 2.4.1) and the proportion of 2,4-D acid equivalents. For example, for the DMA form, the guarantee should read: "2,4-D, present as the dimethylamine salt... y % a.e." for solid products or "y g a.e./L" for liquid products where "y" is the equivalent concentration of 2,4-D as the acid. Note that the only form of isooctyl ester supported is the 2-ethylhexyl ester.

8.2.2 Label Statements Relating to Human Toxicology

The label of Commercial Class products containing 2,4-D must include the following text:

For products containing acid and amine forms

> **Toxicological Information**
>
> 2,4-D may cause severe irritation to the eyes.* Overexposure to 2,4-D may cause coughing, burning, dizziness or temporary loss of muscle coordination. Other possible effects of overexposure include fatigue, muscle weakness or nausea. Treat symptomatically.

* *This statement may be modified by product-specific data*.

For products containing the ester form

Toxicological Information

This product may cause mild irritation to the eyes.* Overexposure to 2,4-D may cause coughing, burning, dizziness or temporary loss of muscle coordination. Other possible effects of overexposure include fatigue, muscle weakness or nausea. Treat symptomatically.

* *This statement may be modified by product-specific data*.

8.2.3 Label Statements Relating to Occupational Exposure—Mixer/Loader/Applicator

8.2.3.1 Label Upgrades for Products Containing the Acid, DMA or EHE Forms

8.2.3.1.1 Mixing and Loading in All Scenarios (liquid formulations)

The following statements must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Mixers/loaders must wear coveralls over a long-sleeved shirt, long pants and chemical-resistant gloves.
- When handling more than 265 kg a.e. per day (approximately 120 ha at highest agricultural rate—2.24 kg a.e./ha), workers must also use a closed system.

For farmers applying using groundboom equipment, the MOEs are greater than the target MOE for open mixing/loading; however, for custom applicators, the target MOE is not met unless a closed system is put in place.

8.2.3.1.2 Mixing and Loading in All Scenarios (granular formulations)

The following statement must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Mixers/loaders must wear coveralls over a long-sleeved shirt, long pants and chemical-resistant gloves.

8.2.3.1.3 Application Using Groundboom Equipment (liquid formulations)

The following statement must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Applicators must wear coveralls over a long-sleeved shirt and long pants. Chemical-resistant gloves must also be worn during clean-up and repair activities.

8.2.3.1.4 Application Using Groundboom Equipment (soluble granule formulations)

The following statements must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Applicators must wear coveralls over a long-sleeved shirt and long pants. Chemical-resistant gloves must also be worn during clean-up and repair activities.
- When handling more than 300 kg a.e./day (approximately 135 ha at highest agricultural rate—2.24 kg a.e./ha), workers must also use a closed cab.

For farmers applying using groundboom equipment, the MOEs are greater than the target MOE for open cab; however, for custom applicators, the target MOE is not met unless a closed cab is put in to place.

8.2.3.1.5 Application Using Handheld Equipment (all formulations)

The following statements must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Applicators must wear coveralls over a long-sleeved shirt, long pants and chemical-resistant gloves.
- Applicators applying in non-cropland areas must also wear a respirator.
- Mixers/loaders/applicators must not handle more than 8 kg a.e. per day (approximately 180 L of spray at highest rate—0.0448 kg a.e./L).

The additional protection of a respirator is required because application in non-cropland areas is at higher rates.

8.2.3.1.6 Aerial Application in All Scenarios (all formulations)

The following statements must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Applicators must wear coveralls over a long-sleeved shirt and long pants. Chemical-resistant gloves must also be worn during clean-up and repair activities.
- No human flaggers are permitted.

8.2.3.1.7 Applicator Using Push Granular Spreaders (granular formulation)

The following statement must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Applicators must wear a long-sleeved shirt, long pants and chemical-resistant gloves.

8.2.3.1.8 Applicator Using Tractor-drawn Granular Spreaders (granular formulation)

The following statement must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Applicators must wear a long-sleeved shirt and long pants. Chemical-resistant gloves must also be worn during clean-up and repair activities.

8.2.3.1.9 Application in Non-Cropland Areas (granular formulation)

The following statement must be added to the **USE DIRECTIONS** section of the labels of the appropriate products:

- Do not apply granules by hand.

8.2.3.2 Label Upgrades for Products Containing the IPA, TIPA or BEE Forms

8.2.3.2.1 Mixing and Loading in All Scenarios (liquid formulations)

The following statements must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Closed mixing/loading systems are required.
- Mixers/loaders must wear coveralls over a long-sleeved shirt, long pants and chemical-resistant gloves.

Although calculated MOEs exceed target MOEs for some low acreage and/or low application rate scenarios, closed mixing/loading systems are still warranted for all ground and aerial applications.

8.2.3.2.2 Application Using Groundboom Equipment in All Scenarios (liquid formulations)

The following statements must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Applicators must wear coveralls over a long-sleeved shirt and long pants. Chemical-resistant gloves must also be worn during clean-up and repair activities.
- When handling more than 170 kg a.e. per day (approximately 75 ha at highest agricultural rate—2.24 kg a.e./ha), workers must also use a closed cab.

For farmer groundboom application, the MOEs are greater than the target MOE for open cab for most agricultural scenarios; however, for custom applicators, the target MOE is not met unless a closed cab is put in to place.

8.2.3.2.3 Aerial Application in All Scenarios (liquid formulations)

The following statements must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Applicators must wear coveralls over a long-sleeved shirt and long pants. Chemical-resistant gloves must also be worn during clean-up and repair activities.
- No human flaggers are permitted.

8.2.3.2.4 Application Using Handheld Equipment (liquid formulations)

The following statements must be added to the **PRECAUTIONS** section of the labels of the appropriate products:

- Applicators must wear coveralls over a long-sleeved shirt, long pants, respirator and chemical-resistant gloves.
- Mixers/loaders/applicators must not handle more than 2.7 kg a.e. per day (approximately 120 L of spray at highest rate—0.0224 kg a.e./L).
- Solutions for annual and broadleaf plant control must have a minimum dilution volume of 100 L/day.

The additional protection of a respirator is required because application in non-cropland areas is at higher rates.

8.2.3.2.5 Application in Non-Cropland

The following statement must be added to the **USE DIRECTIONS** section of the labels of the appropriate products:

- Maximum rate of application is 2.24 kg a.e./ha

Additional data must be provided to refine the assessment of applicator exposure and bystander postapplication exposure for woody plant control at rates above 2.24 kg a.e./ha

8.2.4 Label Statements Relating to Occupational Exposure—Restricted-Entry Intervals

8.2.4.1 Products Containing the Acid, DMA or EHE Forms

The following restricted-entry intervals must be added to the **USE DIRECTIONS** section of the labels of the appropriate products:

- All liquid products, all crops—12-hour REI
- Alfalfa stand removal (fall application)—3-day REI
- Corn (sweet)—14-day REI for hand detasseling and hand harvesting

8.2.4.2 Products Containing the IPA, TIPA or BEE Forms

The following restricted-entry intervals must be added to the **USE DIRECTIONS** section of the labels of the appropriate products:

- All liquid products, all crops—12-hour REI
- Alfalfa stand removal (fall application)—13 day REI
- Corn (field)—3-day REI
- Established grass pastures, rangeland, perennial grassland in agricultural production—3-day REI
- Grass grown for seed—2-day REI
- Fallow land and crop stubble—3-day REI
- Non-cropland (annual and perennial)—9 day-REI for scouting by foot

8.2.5 Label Statements Relating to Dietary Exposure Risk

The use on oats should be removed from all labels as per Note to CAPCO C94-08, *2,4-D Re-evaluation Update and Label Improvement Program*.

8.2.6 Label Statements Relating to the Environment

8.2.6.1 Spray Formulations

In addition to the statements already presented on the label, the following label statements must be included under **ENVIRONMENTAL HAZARDS**.

> **ENVIRONMENTAL HAZARDS**
>
> Toxic to small mammals, aquatic organisms and non-target terrestrial plants. Observe buffer zones specified under DIRECTIONS FOR USE.
>
> **LEACHING**
>
> The use of this chemical may result in contamination of groundwater particularly in areas where soils are permeable (e.g., sandy soil) and/or the depth to the water table is shallow.
>
> **RUNOFF**
>
> To reduce runoff from treated areas into aquatic habitats, avoid application to areas with a moderate to steep slope, bare soil, compacted soil, or clay.
>
> Avoid application of this product when heavy rain is forecast.

Contamination of aquatic areas as a result of runoff may be reduced by including a strip of untreated vegetation between the treated area and the edge of the water body.

The following label statements must be included under **DIRECTIONS FOR USE**.

DIRECTIONS FOR USE

DO NOT apply this product directly to freshwater habitats such as lakes, rivers, sloughs, ponds, prairie potholes, creeks, marshes, streams, reservoirs and wetlands, estuaries or marine habitats.

DO NOT contaminate irrigation/drinking water supplies or aquatic habitats by cleaning of equipment or disposal of wastes.

Field sprayer application: DO NOT apply during periods of dead calm. Avoid application of this product when winds are gusty. DO NOT apply with spray droplets smaller than the American Society of Agricultural Engineers (ASAE) coarse classification.

Aerial application: DO NOT apply during periods of dead calm. Avoid application of this product when winds are gusty. DO NOT apply when wind speed is greater than 16 km/h at flying height at the site of application. DO NOT apply with spray droplets smaller than the American Society of Agricultural Engineers (ASAE) coarse classification. DO NOT allow nozzle spacing to exceed 65% of boom length.

For application to rights-of-way, buffer zones for protection of sensitive terrestrial habitats are not required. However, the best available application strategies which minimize off-site spray drift, including meteorological conditions (e.g., wind direction, low wind speed) and spray equipment (e.g., coarse droplet size, minimizing height above canopy) should be used. Applicators must, however, observe the specified buffer zones for protection of sensitive aquatic habitats.

Buffer Zones:

The buffer zones specified in the tables below are required between the point of direct application and the closest downwind edge of sensitive terrestrial habitats, e.g., grasslands, forested areas, shelter belts, woodlots, hedgerows, pastures, rangelands and shrublands. When 2,4-D is used in forestry, any adjacent forested areas do not require buffer zones. Examples of sensitive freshwater habitats requiring buffer zones are lakes, rivers, sloughs, ponds, prairie potholes, creeks, marshes, streams, reservoirs, wetlands, and estuarine/marine habitats. Buffer zones for field sprayers can be reduced 70% with the use of shrouds and 30% with the use of cones.

Buffer Zones Required on the Label of Products Containing 2,4-D (ASAE coarse spray droplet size)

<table>
<tr><th rowspan="3">Method of Application</th><th rowspan="3" colspan="2">Crop</th><th colspan="4">Buffer Zone (metres) Required for the Protection of:</th></tr>
<tr><th colspan="3">Aquatic Habitat</th><th rowspan="2">Terrestrial Habitat</th></tr>
<tr><th>< 1 m</th><th>1–3 m</th><th>> 3 m</th></tr>
<tr><td rowspan="3">Field sprayer[1]</td><td colspan="2">Cereals, corn, alfalfa stand removal, sorghum, fruit trees, asparagus, strawberries, raspberries</td><td>1</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td colspan="2">Pastures, rangeland, grasslands, fallow land, crop stubble</td><td>1</td><td>0</td><td>0</td><td>5</td></tr>
<tr><td colspan="2">Non-cropland, forestry</td><td>2</td><td>1</td><td>0</td><td>10</td></tr>
<tr><td rowspan="8">Aerial</td><td rowspan="2">Cereal grain—postemergence and minimum tillage</td><td>Fixed wing</td><td>10</td><td>3</td><td>0</td><td>90</td></tr>
<tr><td>Rotary wing</td><td>10</td><td>0</td><td>0</td><td>70</td></tr>
<tr><td rowspan="2">Grain or forage sorghum</td><td>Fixed wing</td><td>10</td><td>0</td><td>0</td><td>60</td></tr>
<tr><td>Rotary wing</td><td>10</td><td>0</td><td>0</td><td>55</td></tr>
<tr><td rowspan="2">Corn, alfalfa</td><td>Fixed wing</td><td>15</td><td>5</td><td>0</td><td>125</td></tr>
<tr><td>Rotary wing</td><td>10</td><td>5</td><td>0</td><td>90</td></tr>
<tr><td rowspan="2">Pastures, rangeland, grasslands, fallow land, crop stubble</td><td>Fixed wing</td><td>30</td><td>10</td><td>3</td><td>200</td></tr>
<tr><td>Rotary wing</td><td>20</td><td>10</td><td>0</td><td>125</td></tr>
</table>

Aerial Buffer Zones for Non-Cropland and Forestry Uses Required on the Label of Products Containing 2,4-D (ASAE coarse spray droplet size)

Method of Application	Crop	Application Rate (kg a.e./ha)	Aircraft Type	Buffer Zone (metres) Required for the Protection of:			
				Aquatic Habitat			Terrestrial Habitat[1]
				< 1 m	1–3 m	> 3 m	
Aerial	Non-Cropland	2.24	Fixed wing	175	85	45	550
			Rotary wing	100	60	35	3501
		4.48	Fixed wing	300	125	70	750
			Rotary wing	175	80	50	525
	Forestry	2.4	Fixed wing	550	100	40	800
			Rotary wing	325	65	25	650
		3.1	Fixed wing	600	125	50	800
			Rotary wing	375	75	35	725
		4.48	Fixed wing	675	175	70	800
			Rotary wing	450	100	45	775

1 Buffer zones for protection of terrestrial habitats are not required for spraying of rights-of-way.

8.2.6.2 Granular Formulations

8.2.6.2.1 Soil Sterilant Uses of 2,4-D Acid

One product containing 2,4-D and bromacil is registered as a soil sterilant. This product will be assessed separately in a future review.

8.2.6.2.2 Aquatic Uses of 2,4-D BEE

Direct applications of 2,4-D BEE products to control aquatic vegetation in rivers, lakes and irrigation canals are designated RESTRICTED class as indicated in Regulatory Directive DIR93-12, *Pesticides for Aquatic Applications*. Therefore, should the data to support continued registration for this use be provided, products must have the following label statement:

> The aquatic use of this product is to be used only in the manner authorized; consult provincial pesticide regulatory authorities about use permits that may be required.

Disposal statements must conform with Regulatory Directive DIR99-04, *Disposal Statements For Control Product Labels*.

8.2.7 Proposed Measures Relating to Value

8.2.7.1 Lowering the Maximum Rate

As proposed by the 2,4-D Task Force, the maximum label rate will be lowered for some sites. Note that for the sites that are not listed in the following table, the existing maximum label rates remain unchanged.

Table 8.2.7.1.1 Sites for Which the 2,4-D Task Force Has Proposed a Reduced Maximum Rate

Site	Maximum Rate for a Single Application (g a.e. of 2,4-D/ha unless otherwise indicated)	Cumulative Maximum Rate per Season (g a.e. of 2,4-D/ha)	Maximum Number of Applications per Year	Comments
Use-Site Category 4—Forests and Woodlots				
Forest site preparation	4480	4480	2	
Use-Site Category 13—Terrestrial Feed Crops				
Grasses—established (forage/pastures/rangeland)	2240	4480	2	
Sorghum and millet (forage)	560	560	1	Current maximum label rate is 564 g a.e./ha
Use-Site Category 14—Terrestrial Food Crops				
Strawberries—postplantation	460	460	1	Rate for treatment at “dormance/after last picking” remains the same as current labels.

Site	Maximum Rate for a Single Application (g a.e. of 2,4-D/ha unless otherwise indicated)	Cumulative Maximum Rate per Season (g a.e. of 2,4-D/ha)	Maximum Number of Applications per Year	Comments
Raspberries— broadcast treatment	520	1040	2	
Raspberries—spot treatment	1250	—	—	Current labels do not specify a rate for spot treatments. 2,4-D Task force proposed 1250 g a.e./ha
Use-Site Category 13 and 14—Terrestrial Feed and Food Crops				
Barley, rye and wheat—postemergence treatment in conventional tillage	880	880	1	Rate for pre-emergence treatment in minimum tillage system remains the same as current labels.
Corn (field)—postemergence (except for Jerusalem artichoke control)	600	600	1	For Jerusalem artichoke control, 2 postemergence applications of 325 g a.e. of 2,4-D/ha are currently registered.
Fallow land and crop stubble	2240	4480	2	
Use-Site Category 16—Industrial and Domestic Non-Food Sites				
Non-crop land areas—annual and perennial weeds control	2240	4480	2	
Non-crop land areas—woody plants control	4480	4480	2	
Tree and brush control—basal spray/frill/cut surface–stumps	17 kg a.e. / 1000 L diluent	—	—	
Tree and brush control—injection	1.32–2.64 g a.e. / injection site	—	—	Current label rates are unclear.

For non-cropland areas, if the rate of 2,4-D is given in terms of g a.e./L, the label should also specify a spray volume per hectare such as the maximum allowable rate per hectare is not exceeded.

8.3 Proposals Pertaining To Food Residues

8.3.1 Residue of Concern Definition

Table 2, Division 15 of the Food and Drug Regulations currently defines 2,4-D as (2,4-dichlorophenoxy)acetic acid. Based on the available metabolism data, it is proposed that the residue of toxicological concern for crops and livestock maximum residue limits (MRLs) as well as for dietary risk assessments (food and water) be expanded to include the free and conjugated forms of 2,4-D, determined as the acid.

8.3.2 Maximum Residue Limits of 2,4-D in Food

In general, when the re-evaluation of a pesticide has been completed, the PMRA intends to update Canadian MRLs and to remove those that are no longer supported. The Agency recognizes, however, that interested parties may want to retain an MRL in the absence of a Canadian registration to allow legal importation of treated commodities into Canada. The PMRA requires similar chemistry and toxicology data for such import MRLs as those required to support Canadian food use registrations. In addition, the PMRA requires residue data that are representative of use conditions in exporting countries, in the same manner that representative residue data are required to support domestic use of the pesticide. These requirements are necessary so that the Agency may determine whether the requested MRLs are needed and to ensure they would not result in unacceptable health risks.

The supported food uses of 2,4-D are apple, apricot, asparagus, barley, cherry, corn, cranberry, peach, pear, plum, raspberry, rye, strawberry and wheat. Division 15, Table II, of the Food and Drug Regulations currently specifies MRLs for residues of 2,4-D on asparagus at 5 ppm, citrus fruits at 2 ppm, and on cranberries at 0.5 ppm. As 2,4-D is also registered for use on animal feed and forage crops, secondary residues of 2,4-D that may be transferred to animal commodities (such as meat and milk) are subject to regulation.

Residues in all agricultural commodities, including those approved for treatment in Canada but without a specified MRL (i.e., grain crops, beef and milk), must not exceed 0.1 ppm, a general MRL specified in subsection B.15.002(1) of the Food and Drug Regulations. Changes to this general MRL may be implemented in the future, as proposed in Discussion Document DIS2006-01, *Revocation of 0.1 ppm as a General Maximum Residue Limit for Food Pesticide Residues [Regulation B.15.002(1)]*.

Parties interested in supporting an import MRL for residues of 2,4-D on other commodities should contact the PMRA during the comment period of this document to discuss submitting the appropriate data.

9.0 Additional Data Requirements

The following data are required as a condition of continued registration under Section 12 of the *Pest Control Products Act*. The registrants of this active ingredient are required to provide these data or an acceptable scientific rationale within the timeline specified in a decision letter sent to the registrants when a final re-evaluation decision is made or as part of the implementation of interim measures.

9.1 Data Requirements Relating to Chemistry

9.1.1 Revised Specifications of Technical Grade Products

Previously, in REV2006-11, the PMRA requested that the most recent five batches of all technical products be analyzed using the most sensitive appropriate analytical methods for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF) and their respective higher substituted chlorinated congeners. Registrants were also requested to submit the data necessary to establish a nominal guarantee for technical grade products if they had not already done so.

9.1.2 Revised Specifications of Products Manufactured or Formulated by the Addition of DMA

An updated Statement Product Specification Form is required for all products to which DMA is added during manufacturing or formulation process. The form must identify the levels of NDMA present in the DMA that is used. The data on the Statement Product Specification Form must be supported by the results of the analysis for NDMA from five lots of the DMA. This requirement pertains only to products where DMA is added as part of the manufacturing or formulation process; it does not apply to products that are formulated from other registered products, as specifications for those products will be obtained directly from the formulators.

9.2 Data Requirements Relating to Toxicology

The PMRA has accounted for uncertainties associated with some studies considered in the risk assessment through safety factors. The following data were requested in PACR2005-01 to refine the risk assessment:

2,4-D Acid

- A developmental neurotoxicity study in rats using 2,4-D acid, complete with adequate histopathological examination of myelin deposition (Data Code [DACO] 4.5.14). This data requirement is based on evidence of neurotoxicity in guideline and published studies.
- A multigeneration reproduction study in rats using 2,4-D acid (DACO 4.5.1). Limitations in the existing reproduction study preclude a detailed assessment of potential sensitivity to the young.

9.3 Data Requirements Relating to the Occupational and Bystander Exposure

9.3.1 Data Requirements Relating to Selected Products

For granular products applied by hand, products used in aquatic sites, products used in non-croplands and applied using handheld equipment without a respirator as well as products used at daily quantities greater than what was specified in the label improvement section for mixing/loading, ground equipment and handheld equipment (Section 8.2):

- Mixer/loader/applicator exposure data representative of the application equipment and formulations applicable to the given use scenario and include not only mixing/loading/application, but equipment cleaning and maintenance activities (DACO 5.4 and/or 5.5).

9.3.2 Data Requirements Relating to REIs

For REIs greater than what was specified in the label improvement section for postapplication exposure (Section 8):

- Postapplication exposure data to confirm calculated REIs. (DACO 5.6, 5.7, 5.9 and 5.10).

9.3.3 Data Requirements Relating to Application Rates Higher Than Supported by the 2,4-D Task Force

For products used in non-crop areas at rates above 2.24 kg a.e./ha:

- Postapplication exposure data representative of bystanders in non-croplands (DACO 5.6 and/or 5.7).

9.3.4 Data Requirements Relating to Aquatic Sites

- Exposure data to adequately characterize exposure to swimmers. These data must include, but are not be limited to, chemical- and form-specific information such as dissociation of ester to free acid, skin permeability of specific areas of the body. Biomonitoring studies would also be accepted (DACO 5.7)

9.4 Additional Data Requirements Relating to Environmental Risks

- Bioconcentration factors for the EHE and the BEE esters in fish (DACO 9.5.6) are required to assess the potential for bioaccumulation.
- Data on the environmental fate of the intermediate transformation product chlorohydroquinone received in response to REV2006-11 are under review.

10.0 Proposed Re-evaluation Decision

After assessing the available information for 2,4-D, Health Canada's PMRA, under the authority of the *Pest Control Products Act*, is proposing continued registration of the use of 2,4-D and associated end-use products on terrestrial sites, provided that the mitigation measures for health and environment described in this document are implemented and the required data are provided. 2,4-D formulations containing DEA are no longer supported and have been discontinued (see REV2006-11). The PMRA is also proposing discontinuation of all products containing 2,4-D for use in aquatic sites unless additional data are submitted.

The PMRA will accept written comments on this proposal up to 60 days from the date of publication of this document to allow interested parties an opportunity to provide input into the proposed decision.

List of Abbreviations

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
2,3,7,8-TCDF	2,3,7,8-tetrachlorodibenzofuran
2,4-D	(2,4-dichlorophenoxy)acetic acid
2,4-DB	4-(2,4-dichlorophenoxy)butyric acid
2,4-DCP	2,4-dichlorophenol
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
4-CP	4-chlorophenol
ADI	acceptable daily intake
a.e.	acid equivalent
a.i.	active ingredient
AR	application rate
ARfD	acute reference dose
ARTF	Agricultural Reentry Task Force
ASAE	American Society of Agricultural Engineers
ATPD	area treated per day
BEE	butoxyethyl ester
bw	body weight
CAPCO	Canadian Association of Pesticide Control Officials
CAS	Chemical Abstracts Service
cm	centimetre
CML	canine malignant lymphoma
DACO	data code
DEA	diethanolamine
DFR	dislodgeable foliar residue
DMA	dimethylamine
DT_{50}	time for 50% decline
DWLOC	drinking water level of comparison
EC	European Commission (also known as European Union)
EC_{25}	effect concentration 25%
EEC	expected environmental concentration
EHE	2-ethylhexyl ester
EXAMS	Exposure Analysis Modeling System
F_1	first filial generation
F_{1a}	first litter of the first filial generation
FAO	Food and Agriculture Organization of the United Nations
ha	hectare
IPA	isopropylamine
IR-4	Interregional Research Project Number 4
IUPAC	International Union of Pure and Applied Chemistry
kg	kilogram
km	kilometre
K_{oc}	absorption quotient normalized for organic carbon
K_{ow}	*n*-octanol–water partition coefficient
*K*p	permeability coefficient
L	litre

LOAEL	lowest observed adverse effect level
LC_{50}	median lethal concentration
LD_{50}	median lethal dose
m	metre
MAFF	Ministry of Agriculture, Forestry and Food
MCPA	(4-chloro-2-methylphenoxy) acetic acid (CAS name)
MCPB	4-(4-chloro-2-methylphenoxy)butanoic acid (CAS name)
mg	milligram
MOE	margin of exposure
MRL	maximum residue limit
N/A	not applicable
NAFTA	North American Free Trade Agreement
NDMA	*N*-nitrosodimethylamine
ηm	nanometre
NOAEL	no observed adverse effect level
NOEC	no observed effect concentration
NTP	National Toxicology Program
Pa	Pascal
PACR	Proposed Acceptability for Continuing Registration
PDI	potential daily intake
PHED	Pesticide Handlers Exposure Database
p*K*a	dissociation constant
PMRA	Pest Management Regulatory Agency
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
PRZM	Pesticide Root Zone Model
RED	Reregistration Eligibility Document
REI	restricted-entry interval
RQ	risk quotient
SA	surface area
SF	safety factor
t½	half-time
TC	transfer coefficient
TIPA	triisopropanolamine
TSMP	Toxic Substances Management Policy
UF	uncertainty factor
U.K.	United Kingdom
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UV	ultraviolet
WHO	World Health Organization

Appendix I 2,4-D Products Registered as of 31 May 2005 (excluding discontinued products, products with a submission for discontinuation or products registered for use on fine turf only)

Registration Number	Marketing Class	Registrant	Product Name	Formulation Type	Form of 2,4-D[1]	Guarantee[2]
16981	Technical	Dow AgroSciences Canada Inc.	2,4-Dichlorophenoxyacetic Acid Flake Technical Herbicide	Solid	Acid	DXA 97%
16982	Technical	Dow AgroSciences Canada Inc.	Dow 2,4-D 2-ethylhexyl Ester	Emulsifiable concentrate or emulsion	EHE	DXF 63.9%
16990	Technical	Dow AgroSciences Canada Inc.	2,4-D Butoxy Ethanol Ester	Solution	BEE	DXF 65.8%
17007	Technical	GroWell Limited	GroWell 2,4-D Technical Acid	Liquid	Acid	DXA 98.5%
17012	Technical	GroWell Limited	GroWell 2,4-D Iso Octyl Ester Technical	Solution	EHE	DXF 64.7%
17013	Technical	GroWell Limited	GroWell 2,4-D Butyl Glycol Ester Technical	Solution	Butyl glycol ester	DXF 66.6%
17044	Technical	Nufarm Agriculture Inc.	Nufarm 2,4-D Technical Acid	Solid	Acid	DXA 98.5%
17045	Technical	Nufarm Agriculture Inc.	Nufarm 2,4-D Acid	Dust or powder	Acid	DXA 99.0%
17134	Technical	Nufarm Ltd.	2,4-D Dry Ppwder Acid Herbicide	Dust or powder	Acid	DXA 94%
17135	Technical	Nufarm Ltd.	Nufarm 2,4-D Liquid Iso Octyl Ester Herbicide	Solution	EHE	DXF 62.38%
17291	Technical	PBI/Gordon Corp.	2,4-Dichlorophenoxyacetic Acid Technical	Solid	Acid	DXA 98.20%
18611	Technical	Nufarm Ltd.	2,4-D Acid (Technical) Herbicide	Dust or powder	Acid	DXA 92%
19348	Technical	Nufarm Agriculture Inc.	2,4-D Iso octyl ester (Technical Grade Herbicide)	Solution	EHE	DXF 63%
24562	Technical	Nufarm Ltd.	Nufarm 2,4-D Technical Acid	Solid	Acid	DXA 96.0%
24836	Technical	Dow AgroSciences Canada Inc.	2,4-Dichlorophenoxyacetic Acid Molten State Technical Herbicide	Solution	Acid	DXA 74.8%
27263	Technical	Nufarm Agriculture Inc.	Nufarm 2,4-D 2-Ethylhexyl Ester Technical	Emulsifiable concentrate or emulsion	EHE	DXF 64.7%
27437	Technical	Albaugh Inc.	Albaugh 2,4-D Technical Acid Herbicide	Dust or powder	Acid	DXA 98.2%
16988	Manufacturing concentrate	Dow AgroSciences Canada Inc.	2,4-D DMA 720 Unsequestered Weed Killer	Solution	DMA	DXB 55.7%
17046	Manufacturing concentrate	Nufarm Agriculture Inc.	Nufarm 2,4-D Amine Salt	Solution	DMA	DXB 600 g/L
17107	Manufacturing concentrate	Dow AgroSciences Canada Inc.	2,4-D DMA 720 Sequestered Weed Killer	Solution	DMA	DXB 55.5%
17137	Manufacturing concentrate	Nufarm Agriculture Inc.	2,4-D Liquid Amine Sequestered Herbicide	Solution	DMA	DXB 53.1%
17138	Manufacturing concentrate	Nufarm Ltd.	2,4-D Liquid Amine Sequestered Herbicide	Solution	DMA	DXB 56.0%

Registration Number	Marketing Class	Registrant	Product Name	Formulation Type	Form of 2,4-D[1]	Guarantee[2]
17168	Manufacturing concentrate	GroWell Limited	GroWell 2,4-D Dimethylamine Salt 600 Formulation	Solution	DMA	DXB 600 g/L
17377	Manufacturing concentrate	GroWell Limited	GroWell 2,4-D Diethanolamine Salt 600 Formulation	Solution	DEA[4]	DXB 600 g/L
17401	Manufacturing concentrate	Nufarm Agriculture Inc.	BASF 2,4-D DMA	Solution	DMA	DXB 705 g/L
17699	Manufacturing concentrate	GroWell Limited	GroWell 2,4-D 2-Ethylhexyl Ester 600 g a.i./L Formulation	Emulsifiable concentrate or emulsion	EHE	DXF 600 g/L
18352	Manufacturing concentrate	GroWell Limited	GroWell 2,4-D Dimethylamine Salt 720 Formulation	Solution	DMA	DXB 720 g/L
18614	Manufacturing concentrate	Nufarm Ltd.	2,4-D Iso Octyl Ester Manufacturing Concentrate Low Volatile Ester	Solution	EHE	DXF 600 g/L
18620	Manufacturing concentrate	Nufarm Ltd.	2,4-D Amine 720 Liquid Herbicide	Solution	DMA	DXB 720 g/L
18819	Manufacturing concentrate	GroWell Limited	GroWell 2,4-D Dimethylamine Salt 500 Formulation	Solution	DMA	DXB 500 g/L
18823	Manufacturing concentrate	GroWell Limited	GroWell 2,4-D 2-Ethylhexyl Ester 564 g a.i./L Formulation	Emulsifiable concentrate or emulsion	EHE	DXF 564 g/L
18830	Manufacturing concentrate	GroWell Limited	GroWell 2,4-D Dimethylamine Salt 470 Formulation	Solution	DMA	DXB 470 g/L
19352	Manufacturing concentrate	Nufarm Agriculture Inc.	2,4-D Amine Manufacturing Concentrate Technical Grade Herbicide	Solution	DMA	DXB 720 g/L
19530	Manufacturing concentrate	Dow AgroSciences Canada Inc.	2,4-D Isopropylamine Salt	Solution	IPA	DXB 39.4%
20833	Manufacturing concentrate	Nufarm Agriculture Inc.	2,4-D 680 DEA Manufacturing Concentrate	Solution	DEA [4]	DXB 680 g/L
25394	Manufacturing concentrate	United Agri Products Canada Inc.	2,4-D Dry Manufacturing Concentrate	Soluble granules	DMA	DXB 80%
25783	Manufacturing concentrate	Dow AgroSciences Canada Inc.	Striker Manufacturing Concentrate	Wettable granules	Acid	FLM 9.3% DXA 50.0% DPI 25.0%
27165	Manufacturing concentrate	GroWell Limited	GroWell 2,4-D Dimethylamine Salt 683 Formulation	Solution	DMA	DXB 683 g/L
27709	Manufacturing concentrate	Yara Canada LP	Yara Canada L.P. Herbicide 523 Manufacturing Cconcentrate	Solution	DMA	MEZ 171 g/L DXB 342 g/L
27721	Manufacturing concentrate	Scotts Canada Ltd.	Killex 3X Manufacturing Concentrate II (Green Cross)	Solution	DMA	MEZ 157.5 g/L DXB 285 g/L DIC 27 g/L

Registration Number	Marketing Class	Registrant	Product Name	Formulation Type	Form of 2,4-D[1]	Guarantee[2]
27723	Manufacturing concentrate	Riverdale Chemical Co.	Riverdale Weedstroy Triamine (MO) Manufacturing Concentrate	Solution	DMA	MEC 78 g/L DXB 156 g/L DIG 156 g/L
27737	Manufacturing concentrate	Nufarm Agriculture Inc.	2,4-D/Mecoprop-p Manufacturing Concentrate	Solution	DMA	MEZ 180 g/L DXB 360 g/L
27738	Manufacturing concentrate	Nufarm Agriculture Inc.	CMPP-P/2,4-D Amine Manufacturing Concentrate	Solution	DMA	MEZ 180 g/L DXB 360 g/L
27808	Manufacturing concentrate	Interprovincial Cooperative Limited	IPCO 2,4-D/Mecoprop-p Formula 3 Manufacturing Grade Herbicide	Solution	DMA	MEZ 180 g/L DXB 360 g/L
27867	Manufacturing concentrate	United Agri Products Canada Inc.	Mecoprop-p + 2,4-D Manufacturing Concentrate	Solution	DMA	MEZ 180 g/L DXB 360 g/L
2687(28296)	Commercial	Dow AgroSciences Canada Inc.	Formula 40C Liquid Farm Weed Killer	Solution	DEA [3]	DXB 470 g/L
5931	Commercial	United Agri Products Canada Inc.	2,4-D Amine 600 Herbicide	Solution	DMA	DXB 564 g/L
6330	Commercial	Dow AgroSciences Canada Inc.	2,4-D BEE-4 Herbicide Weed Killer	Emulsifiable concentrate or emulsion	BEE	DXF 500 g/L
8885	Commercial	Syngenta Crop Protection Canada Inc.	Target DS Liquid Herbicide	Solution	DMA	MEC 80 g/L DXB 295 g/L DIC 110 g/L
9007	Commercial	Dow AgroSciences Canada Inc.	Tordon 101 Herbicide	Solution	TIPA	PID 65 g/L DXB 240 g/L
9342	Commercial	Nufarm Agriculture Inc.	Nufarm Calmix Pellets Weed Killer & Soil Sterilant	Pellets	Acid	DXA 5% BBU 3%
9528	Commercial	Dow AgroSciences Canada Inc.	2,4-D Amine 500 Liquid Farm Weed Killer	Solution	DMA	DXB 470 g/L
9547	Commercial	United Agri Products Canada Inc.	2,4-D Amine 500 Herbicide	Solution	DMA	DXB 470 g/L
9560	Commercial	Dow AgroSciences Canada Inc.	2,4-D LV-600 Emulsifiable Concentrate	Emulsifiable concentrate or emulsion	EHE	DXF 564 g/L
9606	Commercial	BASF Canada Inc.	Dyvel DS Liquid Herbicide	Solution	DMA	MEC 80 g/L DXB 295 g/L DIC1 10 g/L
11547	Commercial	Syngenta Crop Protection Canada Inc.	Dycleer 24 Liquid Herbicide	Solution	DMA	DXB 382 g/L DIC 200 g/L
11574	Commercial	Interprovincial Cooperative Limited	2,4-D Amine 600 Liquid Herbicide	Solution	DMA	DXB 560 g/L
13700	Commercial	Nufarm Agriculture Inc.	Nufarm WeeDone 100 2,4-D Ester LV500 Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 475 g/L
14167	Commercial	Dow AgroSciences Canada Inc.	Tordon 202C Liquid Herbicide Herbicide	Solution	TIPA	PID 12 g/L DXB 200 g/L
14623	Commercial	Nufarm Ltd.	Nufarm Estakil LV 700 2,4-D Low Volatile Liquid Herbicide Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 658 g/L

Registration Number	Marketing Class	Registrant	Product Name	Formulation Type	Form of 2,4-D[1]	Guarantee[2]
14722	Commercial	Nufarm Agriculture Inc.	Amine 500 2,4-D Liquid Herbicide	Solution	DMA	DXB 475 g/L
14723	Commercial	Nufarm Agriculture Inc.	AmKil 500 2,4-D Liquid Herbicide	Solution	DMA, DEA [4]	DXB 475 g/L
14725	Commercial	Nufarm Agriculture Inc.	Nufarm 2,4-D Amine 500 Liquid Herbicide	Solution	DMA	DXB 470 g/L
14726	Commercial	Nufarm Agriculture Inc.	AMSOL 2,4-D Amine 600 Liquid Herbicide	Solution	DMA	DXB 564 g/L
14803	Commercial	Nufarm Agriculture Inc.	Nufarm Estaprop Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 282 g/L DIH 300 g/L
15027	Commercial	Nufarm Agriculture Inc.	Desormone Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 330 g/L DIH 350 g/L
15707	Commercial	United Agri Products	Diphenoprop Plus	Emulsifiable concentrate or emulsion	EHE	DXF 339 g/L DIH 361 g/L
15730	Commercial	NU-Gro IP Inc.	Wilson 2,4-D Amine 500 Liquid Weed Killer	Solution	DMA	DXB 470 g/L
16532	Commercial	United Agri Products	Turboprop 600 Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 282 g/L DIH 300 g/L
16724	Commercial	United Agri Products	Diphenoprop BK 700 Herbicide	Emulsifiable concentrate or emulsion	BEE	DXF 329 g/L DIH 350 g/L
16994 (28295)	Commercial	Dow AgroSciences Canada Inc.	Dow AgroSciences Formula 40F Forestry Herbicide	Solution	DEA [3]	DXB 470 g/L
17511	Commercial	Interprovincial Cooperative Limited	IPCO 2,4-D Amine 600 Liquid Herbicide	Solution	DMA	DXB 560 g/L
19536	Commercial	Monsanto Canada Inc.	Rustler SummerFallow Herbicide	Solution	IPA	GPI 108 g/L DXB 182 g/L
19780	Commercial	Nufarm Agriculture Inc.	WeeDone CB Ready-to-Apply Basal Brushkiller	Solution	BEE	DXF 80 g/L DIH 80 g/L
20310	Commercial	Interprovincial Cooperative Limited	IPCO 2,4-D Ester 700 Low Volatile Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 660 g/L
20950	Commercial	Nufarm Agriculture Inc.	Nufarm Weedar 80 2,4-D Amine Liquid Herbicide	Solution	DMA	DXB 470 g/L
21022	Commercial	Sanex Agro Inc.	2,4-D LV 600 Emulsifiable Concentrate	Emulsifiable concentrate or emulsion	EHE	DXF 564 g/L
21717	Commercial	Interprovincial Cooperative Limited	IPCO Dichlorprop-D Liquid Herbicide Agricultural	Emulsifiable concentrate or emulsion	EHE	DXF 282 g/L DIH 300 g/L
22659	Commercial	Bayer Cropscience Inc.	Thumper Emulsifiable Selective Weedkiller	Emulsifiable concentrate or emulsion	EHE	DXF 280 g/L BRY 280 g/L
23192	Commercial	E.I. Du Pont Canada Company	DuPont 2,4-D Herbicide Low Volatile Ester (a component of Express Pack)	Emulsifiable concentrate or emulsion	EHE	DXF 660 g/L
23508	Commercial	Nufarm Agriculture Inc.	Nufarm 2,4-D Ester LV 700 Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF660 g/L
24608	Commercial	United Agri Products	Shotgun Flowable Herbicide	Suspension	EHE	DXF1 20 g/L ATR 272 (8) g/L

Registration Number	Marketing Class	Registrant	Product Name	Formulation Type	Form of 2,4-D[1]	Guarantee[2]
24669	Commercial	PBI/Gordon Corp	HI-DEP Broadleaf Herbicide	Solution	DMA, DEA [4]	DXB 460 g/L
24833	Commercial	Dow AgroSciences Canada Inc.	Attain B Herbicide (a component of Attain Herbicide Taml Mix)	Solution	EHE	DXF 564 g/L
25395	Commercial	United Agri Products	Savage Dry Soluble Herbicide	Soluble granules	DMA	DXB 80%
25898	Commercial	Monsanto Canada Inc.	Focus Water Soluble Herbicide Agricultural	Solution	IPA	GPS 132 g/L DXB 82 g/L
26156	Commercial	Interprovincial Cooperative Limited	WeedAway 2,4-D Ester 700 Low Volatile Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 660 g/L
26163	Commercial	Interprovincial Cooperative Limited	WeedAway 2,4-D Amine 600 Liquid Herbicide	Solution	DMA	DXB 560 g/L
26170	Commercial	Interprovincial Cooperative Limited	WeedAway Dichlorprop-D Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 282 g/L DIH 300 g/L
26247	Commercial	E.I. Du Pont Canada Company	MAX Herbicide (a component of Ultimax Herbicide Concept)	Wettable Granules	Acid	FLM 9.3% DXA 50.0% DPI 25.0%
26267	Commercial	Monsanto Canada Inc.	Anthem B Herbicide (a component of Anthem Herbicide Tank Mix)	Emulsifiable concentrate or emulsion	EHE	DXF 658 g/L
26649	Commercial	Dow AgroSciences Canada Inc.	Grazon Herbicide Solution	Solution	TIPA	PID 65 g/L DXB 240 g/L
27243	Commercial	Dow AgroSciences Canada Inc.	Frontline 2,4-D B EC Herbicide (a component of Frontline 2,4-D Herbicide Tank-Mix)	Suspension	EHE	DXF 564 g/L
27304	Commercial	Dow AgroSciences Canada Inc.	2,4-D Ester 700	Emulsifiable concentrate or emulsion	EHE	DXF 658 g/L
27634	Commercial	Dow AgroSciences Canada Inc.	Grazon P + D Herbicide Solution	Solution	TIPA (label front panel)	PIC 65 g/L DXA 240 g/L
27856	Commercial	BASF Canada Inc.	DYVEL DSP Liquid Herbicide	Solution	DMA	MEP 80 g/L DXB 295 g/L DIC 110 g/L
27857	Commercial	A.H. Marks and Company Limited	Marks 2,4-D DMA 470	Solution	DMA (label front panel)	DXA 470 g/L
27859	Commercial	A.H. Marks and Company Limited	Marks 2,4-D 2EH 564	Emulsifiable concentrate or emulsion	EHE	DXF 564 g/L
27879	Commercial	BASF Canada Inc.	Adrenalin SC Herbicide	Emulsifiable concentrate or emulsion	EHE	IMZ 20 g/L DXF 560 g/L
9561	Commercial + Restricted	United Agri Products	2,4-D Ester 600 Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF5 64 g/L
14739	Commercial + Restricted	Nufarm Agriculture Inc.	Nufarm 2,4-D Ester LV 600 Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 564 g/L

Registration Number	Marketing Class	Registrant	Product Name	Formulation Type	Form of 2,4-D[1]	Guarantee[2]
20956	Commercial + Restricted	Nufarm Agriculture Inc.	Nufarm WeeDone LV600 2,4-D Ester Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 564 g/L
20957	Commercial + Restricted	Nufarm Agriculture Inc.	2,4-D Ester (UFA) Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 564 g/L
23563	Commercial + Restricted	United Agri Products	2,4-D Ester 700 Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 658 g/L
27818	Commercial + Restricted	United Agri Products Canada Inc.	Salvo 2,4-D Ester 700	Emulsifiable concentrate or emulsion	EHE	DXF 660 g/L
27819	Commercial + Restricted	Interprovincial Cooperative Limited	IPCO 2,4-D Ester 700 Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 660 g/L
27820	Commercial + Restricted	Nufarm Agriculture Inc.	Nufarm 2,4-D Ester 700 Liquid Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 660 g/L
9907	Restricted	Nufarm Agriculture	Aqua-Kleen Granular 2,4-D Weed Killer For Aquatic Weeds	Granular	BEE	DXF 19%
15981	Restricted	Dow AgroSciences Canada Inc.	Esteron 600 Forestry Herbicide	Emulsifiable concentrate or emulsion	EHE	DXF 564 g/L

1 According to label front panels or electronic specification forms. Some information may not be accurate. EHE: 2-ethylhexyl ester; BEE: butoxyethyl ester; IPA: isopropylamine salt; TIPA: triisopropanolamine salt; DMA: dimethylamine salt; DEA: diethanolamine salt

2 ATR: atrazine; BBU: bromacil; BRY: bromoxynil; DIC: dicamba; DIG: dichlorprop amine; DIH: dichlorprop ester; DXA: 2,4-D present as acid; DXB: 2,4-D present as amine; DXF: 2,4-D present as ester; DPI: clopyralid; FLM: flumetsulam; GPI: glyphosate - ispropylamine salt; GPS: glyphosate acid; IMZ: imazamox; MEC: mecoprop amine; MEP: mecoprop d-isomer acid; MEZ: mecoprop d-isomer amine; PIC:picloram ; PID: picloram amine

3 This product has subsequently been reformulated.

4 Registrant sales of this product have subsequently been discontinued.

Appendix II Use Information

Table 1 Registered Canadian Uses of 2,4-D as of 31 May 2005

All uses are supported by the registrants.

Site(s)	Pests(s)	Marketing Class	Formulation Type	Application Methods and Equipment	Comments
Use-Site Category 1—Aquaculture					
Oyster farms	Marine eelgrass	Restricted	Granular	Boat granule spreader	Only one product is registered for that use (Registration Number 9907) and is not currently marketed.
Use-Site Category 2—Aquatic Non-Food Site					
Water (ponds, lakes, reservoirs, marshes, drainage, ditches, canals, rivers and streams that are quiescent or slow moving)	Water milfoil, water stargrass, bladderwort, white water lily, yellow water lily, water shield, marine eelgrass, coontail	Restricted	Granular	Boat granule spreader	Only one product is registered for that use (Registration Number 9907) and is not currently marketed.
Use-Site Category 4—Forests and Woodlots					
Conifer release	Broadleaf weeds	Restricted	Emulsifiable concentrate or emulsion	Air	
Forest site preparation	Broadleaf weeds	Restricted	Emulsifiable concentrate or emulsion	Air	
Use-Site Category 13—Terrestrial Feed Crops					
Alfalfa stand removal—minimum tillage system	Alfalfa stands	Commercial	Not specified, see comments	Ground (boom)	This use is stated on glyphosate labels only. Glyphosate labels allow for a tank mix of glyphosate with 2,4-D without mentioning specific 2,4-D products.

Site(s)	Pests(s)	Marketing Class	Formulation Type	Application Methods and Equipment	Comments
Grasses (seedlings/established) for forage or seed production	Broadleaf weeds	Commercial	Solution, soluble granules, emulsifiable concentrate or emulsion	Ground (boom) or air	
Pastures/Rangeland (established)	Broadleaf weeds	Commercial	Solution, soluble granules, emulsifiable concentrate or emulsion	Ground (boom), handwand sprayer, backpack or air	
Sorghum (forage)	Broadleaf weeds	Commercial	Solution	Ground (boom) or air	
Millet (forage)	Broadleaf weeds	Commercial	Solution	Ground (boom) or air	
Use-Site Category 14—Terrestrial Food Crops					
Bearing fruit trees (apple, peach, pear, plum, apricot, sweet and sour cherry)	Broadleaf weeds	Commercial	Solution	Ground (boom), handwand sprayer, backpack	
Strawberries	Broadleaf weeds	Commercial	Solution, soluble granules	Ground (boom)	
Cranberries	Broadleaf weeds	Commercial	Solution	Motorized wiper or hand wiper	Spot treatment only
Raspberries	Broadleaf weeds	Commercial	Solution, soluble granules	Ground (boom), handwand sprayer, backpack	
Asparagus	Broadleaf weeds	Commercial	Solution, soluble granules	Ground (boom)	
Sweet corn	Broadleaf weeds	Commercial	Solution	Ground (boom) or air	

Site(s)	Pests(s)	Marketing Class	Formulation Type	Application Methods and Equipment	Comments
Use-Site Categories 13 and 14—Terrestrial Feed and Food Crops					
Barley	Broadleaf weeds	Commercial	Solution, soluble granules, emulsifiable concentrate or emulsion	Ground (boom) or air	
Rye	Broadleaf weeds	Commercial	Solution, soluble granules, emulsifiable concentrate or emulsion	Ground (boom) or air	
Wheat	Broadleaf weeds	Commercial	Solution, soluble granules, suspension, emulsifiable concentrate or emulsion	Ground (boom) or air	
Oats	Broadleaf weeds	Commercial	Solution	Ground (boom) or air	
Field corn	Broadleaf weeds	Commercial	Wettable granules, solution, soluble granules, suspension, emulsifiable concentrate or emulsion	Ground (boom) or air	

Site(s)	Pests(s)	Marketing Class	Formulation Type	Application Methods and Equipment	Comments
Fallow land and crop stubble	Broadleaf weeds	Commercial	Solution, soluble granules, emulsifiable concentrate or emulsion	Ground (boom) or air	
Use-Site Category 16—Industrial and Domestic Non-Food Sites					
Non-cropland areas	Broadleaf weeds	Commercial, Restricted	Pellets, solution, soluble granules, emulsifiable concentrate or emulsion	Ground (boom), handwand sprayer, backpack or air Pellets: hand application or ground spreader	
Tree and brush control	Broadleaf weeds	Commercial, Restricted	Solution, soluble granules, emulsifiable concentrate or emulsion	Ground (boom), handwand sprayer, backpack or air	

Table 2 Crop Use Information for Restricted Class 2,4-D Uses That Are Supported by the Technical Registrant and Have Risk Concerns

Only one product is registered with these uses (Registration Number 9907) and it is not currently marketed in Canada.

Crop	Province	Estimated Percent of Crop Treated	Application Rate (g a.e./ha)		Maximum Number of Applications per Year	Minimum Number of Days Between Applications	Risk Assessment Concerns
			Maximum Single	Maximum Cumulative			
Use-Site Category 1—Aquaculture							
Oyster farm	British Columbia New Brunswick Nova Scotia Prince Edward Island	0[s] 0[s] 0[s] 0[s]	33 250	66 500	2	21	MOE below the target MOE for applicators.
Use-Site Category 2—Aquatic Non-Food Site							
Water (ponds, lakes, reservoirs, marshes, drainage, ditches, canals, rivers and streams that are quiescent or slow moving.)	All provinces	0	42 750	85 500	2	21	MOE below the target MOE for applicators and swimmers.

s Indicates survey data. All other values are from registrants.

Table 3 Alternative Registered Active Ingredients to 2,4-D for Those Site-Pest Combinations of Restricted Class Products for Which Concerns Have Been Identified in the Risk Assessment of Human Exposure

Site(s)	Pest	Pest Status / Incidence	Alternative Registered Active Ingredients (resistance management group no.)[1, 2]	Supported Use of 2,4-D?	Concerns From the Risk Assessments?	Risk Assessment Concerns
Use-Site Category 1—Aquaculture						
Oyster farm	Marine Eelgrass	Data not available	No alternatives	Yes	Yes	MOE below the target MOE for applicators.
Use-Site Category 2—Aquatic Non-Food Site						
Water (ponds, lakes, reservoirs, marshes, drainage, ditches, canals, rivers and streams that are quiescent or slow moving.)	Water stargrass, white water lily, yellow water lily, water shield, marine eelgrass	Data not available	No alternatives	Yes	Yes	MOE below the target MOE for applicators and swimmers.
	Bladderwort	Data not available	Group 7: diuron[3]			
	Water milfoil, coontail	Data not available	Group 22: diquat[3]			

1 This is a list of registered options only.
2 Herbicide Resistance Management Group Numbers: 7 = inhibitors of photosynthesis at photosystem II Site B (ureas or amide) and 22 = photo system I-electron diverters (bipyridyliums).
3 These active ingredients are under re-evaluation.

Appendix III Risk Assessment of Human Exposure

Table 1 Toxicological Endpoints Used in the 2,4-D Agricultural Risk Assessment

Exposure Scenario	2,4-D Acid, DMA, EHE			2,4-D BEE, IPA, TIPA		
	NOAEL (mg/kg bw/day)	Study	UF/SF or MOE	NOAEL (mg/kg bw/day)	Study	UF/SF or MOE
Acute dietary, females 13–50[1]	25	Skeletal variations (rat developmental)	300	Same as acid		
	ARfD = 0.08 mg/kg bw					
Acute dietary, general population	75	Ataxia (rat acute neurotoxicity)	300	Same as acid		
	ARfD = 0.25 mg/kg bw					
Chronic dietary[2]	5	Kidney effects (2-year rat)	300	Same as acid		
	ADI = 0.017 mg/kg bw/day					
> 1 day – 6 month dermal + inhalation, females 13–50[1]	30	Maternal mortality (rabbit developmental)	1000	10	Maternal mortality (rabbit developmental)	1000
> 1 day – 6 month dermal + inhalation, general population	12.5	Decreased female body-weight gain (rat developmental)	300	Same as acid		
Aggregate: 1–7 day						
Females 13-50[1]	30	Maternal mortality (rabbit developmental)	1000	10	Maternal mortality (rabbit developmental)	1000
General population	12.5	Decreased female body-weight gain (rat developmental)	300	Same as acid		

1 Females 13–50 (females of child-bearing age)

* The PMRA has revised the ADI set in the turf assessment, based on additional information submitted by the 2,4-D Task Force II.

Note: All endpoints were selected from studies with 2,4-D administered by the oral route. Dermal absorption is considered to be 10% of the oral dose and inhalation absorption is considered to be 100% (default value) of the oral dose.

Table 2 Margins of Exposure for Mixers/Loaders and Applicators Using 2,4-D: Acid, DMA, 2-EHE

Scenario	Formulation	Application Equipment	Application Rate (kg a.e. /ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal					Inhalation					Margin of Exposure[c]				
						Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
						Mix/Load	Apply	Total	Daily	Abrbd	Mix/Load	Apply	Total	Daily	Abrbd[b]					
Use-Site Category 4—Forests and Woodlands																				
Conifer release (annual broadleaf weeds, biennial and perennial broadleaf weeds, brush, early spring dormant oil spray [for British Columbia only])																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
A	Liquid	Aerial	3.100	375	1162.50		10.73	10.73	178.19	17.82		0.07	0.07	1.16	0.12	1684	258065	25 806	1580	1673
Engineering controls: closed M/L, closed cab; coveralls over single layer are worn																				
M/L	Liquid	Aerial	3.100	375	1162.50	9.61		9.61	159.59	15.96	0.11		0.11	1.83	0.18	1880	164 223	16 422	1687	1858
Forest site preparation (annual broadleaf weeds, biennial and perennial broadleaf weeds, brush)																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
A	Liquid	Aerial	4.480	375	1680.00		10.73	10.73	257.52	25.75		0.07	0.07	1.68	0.17	1165	178 571	17 857	1094	1157
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L	Liquid	Aerial	4.480	375	1680.00	9.61		9.61	230.64	23.06	0.11		0.11	2.64	0.26	1301	113 636	11 364	1167	1286
Use-Site Category 13—Terrestrial Feed Crops																				
Established grass pastures and forage, rangeland, perennial grasslands not in agricultural production																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	2.240	100	224.00	32.77	32.49	65.26	208.83	20.88	1.60	0.96	2.56	8.19	0.82	1437	36 621	3662	1032	1382
M/L/A	Liquid	Groundboom (custom)	2.240	100	224.00	32.77	32.49	65.26	208.83	20.88	1.60	0.96	2.56	8.19	0.82	1437	36 621	3662	1032	1382
M/L	Liquid	Aerial	2.240	200	448.00	32.77		32.77	209.73	20.97	1.60		1.60	10.24	1.02	1430	29 297	2930	961	1364
A	Liquid	Aerial	2.240	400	896.00		10.73	10.73	137.34	13.73		0.07	0.07	0.90	0.09	2184	334 821	33482	2051	2170
M/L/A	Soluble granule	Groundboom	2.24	100	224.00	6.86	32.49	39.35	125.92	12.59	2.20	0.96	3.16	10.11	1.01	2382	29668	2967	1321	2205
M/L/A	Soluble granule	Groundboom (custom)	2.240	100	224.00	6.86	32.49	39.35	125.92	12.59	2.20	0.96	3.16	10.11	1.01	2382	29668	2967	1321	2205
M/L	Soluble granule	Aerial	2.240	200	448.00	6.86		6.86	43.90	4.39	2.20		2.20	14.08	1.41	6833	21307	2131	1624	5174
A	Soluble granule	Aerial	2.240	400	896.00		10.73	10.73	137.34	13.73		0.07	0.07	0.90	0.09	2184	334821	33482	2051	2170
Forage sorghum																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.560	100	56.00	32.77	32.49	65.26	52.21	5.22	1.60	0.96	2.56	2.05	0.20	5746	146484	14648	4127	5529
M/L/A	Liquid	Groundboom (custom)	0.560	300	168.00	32.77	32.49	65.26	156.62	15.66	1.60	0.96	2.56	6.14	0.61	1915	48828	4883	1376	1843
M/L	Liquid	Aerial	0.560	400	224.00	32.77		32.77	104.86	10.49	1.60		1.60	5.12	0.51	2861	58594	5859	1922	2728
A	Liquid	Aerial	0.560	400	224.00		10.73	10.73	34.34	3.43		0.07	0.07	0.22	0.02	8737	1339286	133929	8202	8681
M/L/A	Soluble granule	Groundboom	0.560	100	56.00	6.86	32.49	39.35	31.48	3.15	2.20	0.96	3.16	2.53	0.25	9530	118671	11867	5285	8821
M/L/A	Soluble granule	Groundboom (custom)	0.560	300	168.00	6.86	32.49	39.35	94.44	9.44	2.20	0.96	3.16	7.58	0.76	3177	39557	3956	1762	2940
M/L	Soluble granule	Aerial	0.560	400	224.00	6.86		6.86	21.95	2.20	2.20		2.20	7.04	0.70	13666	42614	4261	3248	10348
A	Soluble granule	Aerial	0.560	400	224.00		10.73	10.73	34.34	3.43		0.07	0.07	0.22	0.02	8737	1339286	133929	8202	8681

Scenario	Formulation	Application Equipment	Application Rate (kg a.e. /ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal Unit Exposure (µg/ kg a.e.) Mix/Load	Dermal Unit Exposure (µg/ kg a.e.) Apply	Dermal Unit Exposure (µg/ kg a.e.) Total	Dermal Exposure (µg/kg bw/day)[a] Daily	Dermal Exposure (µg/kg bw/day)[a] Abrbd	Inhalation Unit Exposure (µg/ kg a.e.) Mix/Load	Inhalation Unit Exposure (µg/ kg a.e.) Apply	Inhalation Unit Exposure (µg/ kg a.e.) Total	Inhalation Exposure (µg/kg bw/day)[a] Daily	Inhalation Exposure (µg/kg bw/day)[a] Abrbd[b]	Margin of Exposure[c] Dermal	Margin of Exposure[c] Inh w/ resp	Margin of Exposure[c] Inh w/o resp	Margin of Exposure[c] Comb. w/o resp[d]	Margin of Exposure[c] Comb. w/ resp[d]
Forage millet, seedlings, grass grown for seed																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.564	100	56.40	32.77	32.49	65.26	52.58	5.26	1.60	0.96	2.56	2.06	0.21	5705	145445	14545	4098	5490
M/L/A	Liquid	Groundboom (custom)	0.564	300	169.20	32.77	32.49	65.26	157.74	15.77	1.60	0.96	2.56	6.19	0.62	1902	48482	4848	1366	1830
M/L	Liquid	Aerial	0.564	400	225.60	32.77		32.77	105.61	10.56	1.60		1.60	5.16	0.52	2841	58178	5818	1909	2708
A	Liquid	Aerial	0.564	400	225.60		10.73	10.73	34.58	3.46		0.07	0.07	0.23	0.02	8675	1329787	132979	8144	8619
M/L/A	Soluble granule	Groundboom	0.564	100	56.40	6.86	32.49	39.35	31.70	3.17	2.20	0.96	3.16	2.55	0.25	9462	117829	11783	5248	8759
M/L/A	Soluble granule	Groundboom (custom)	0.564	300	169.20	6.86	32.49	39.35	95.11	9.51	2.20	0.96	3.16	7.64	0.76	3154	39276	3928	1749	2920
M/L	Soluble granule	Aerial	0.564	400	225.60	6.86		6.86	22.11	2.21	2.20		2.20	7.09	0.71	13569	42311	4231	3225	10274
A	Soluble granule	Aerial	0.564	400	225.60		10.73	10.73	34.58	3.46		0.07	0.07	0.23	0.02	8675	1329787	132979	8144	8619
Fallow land and crop stubble																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	2.240	100	224.00	32.77	32.49	65.26	208.83	20.88	1.6	0.96	2.56	8.19	0.82	1437	36621	3662	1032	1382
M/L	Liquid	Aerial	2.240	200	448.00	32.77		32.77	209.73	20.97	1.60		1.60	10.24	1.02	1430	29297	2930	961	1364
A	Liquid	Aerial	2.240	400	896.00		10.73	10.73	137.34	13.73		0.07	0.07	0.90	0.09	2184	334821	33482	2051	2170
M/L/A	Soluble granule	Groundboom	2.240	100	224.00	6.86	32.49	39.35	125.92	12.59	2.20	0.96	3.16	10.11	1.01	2382	29668	2967	1321	2205
M/L	Soluble granule	Aerial	2.240	200	448.00	6.86		6.86	43.90	4.39	2.20		2.20	14.08	1.41	6833	21307	2131	1624	5174
A	Soluble granule	Aerial	2.240	400	896.00		10.73	10.73	137.34	13.73		0.07	0.07	0.90	0.09	2184	334821	33482	2051	2170
Partial engineering controls (A): closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	2.240	200	448.00	32.77	4.42	37.19	238.02	23.8	0.11	0.96	1.07	6.85	0.68	1260	43808	4381	979	1225
M/L/A	Soluble granule	Groundboom (custom)	2.24	200	448.00	6.86	4.42	11.28	72.19	7.22	2.2	0.06	2.26	14.46	1.45	4156	20741	2074	1384	3462
Use-Site Categories 13 and 14—Terrestrial Feed Crops/Terrestrial Food Crops																				
Cereal grains (wheat, barley, rye)—postemergence																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.880	100	88.00	32.77	32.49	65.26	82.04	8.20	1.60	0.96	2.56	3.22	0.32	3657	93 217	9322	2626	3519
M/L	Liquid	Aerial	0.880	400	352.00	32.77		32.77	164.79	16.48	1.60		1.60	8.05	0.80	1821	37 287	3729	1223	1736
A	Liquid	Aerial	0.880	400	352.00		10.73	10.73	53.96	5.40		0.07	0.07	0.35	0.04	5560	852 273	85 227	5220	5524
M/L/A	Soluble granule	Groundboom	0.880	100	88.00	6.86	32.49	39.35	49.47	4.95	2.20	0.96	3.16	3.97	0.40	6064	75 518	7552	3363	5614
M/L/A	Soluble granule	Groundboom (custom)	0.880	300	264.00	6.86	32.49	39.35	148.41	14.84	2.20	0.96	3.16	11.92	1.19	2021	25 173	2517	1121	1871
M/L	Soluble granule	Aerial	0.880	400	352.00	6.86		6.86	34.50	3.45	2.20		2.20	11.06	1.11	8697	27 118	2712	2067	6585
A	Soluble granule	Aerial	0.880	400	352.00		10.73	10.73	53.96	5.40		0.07	0.07	0.35	0.04	5560	852 273	85 227	5220	5524

Scenario	Formulation	Application Equipment	Application Rate (kg a.e. /ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal					Inhalation					Margin of Exposure[c]				
						Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
						Mix/Load	Apply	Total	Daily	Abrbd	Mix/Load	Apply	Total	Daily	Abrbd[b]					
Minimum: open M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	0.880	300	264.00	32.77	21.04	53.81	202.94	20.29	1.60	0.96	2.56	9.65	0.97	1478	31 072	3107	1002	1411
Cereal grains (wheat, barley, rye): prior to seeding or crop emergence, minimum tillage system																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.700	100	70.00	32.77	32.49	65.26	65.26	6.53	1.60	0.96	2.56	2.56	0.26	4597	117 188	11 719	3302	4423
M/L/A	Liquid	Groundboom (custom)	0.700	300	210.00	32.77	32.49	65.26	195.78	19.58	1.60	0.96	2.56	7.68	0.77	1532	39 063	3906	1101	1474
M/L	Liquid	Aerial	0.700	400	280.00	32.77		32.77	131.08	13.11	1.60		1.60	6.40	0.64	2289	46 875	4688	1538	2182
A	Liquid	Aerial	0.700	400	280.00		10.73	10.73	42.92	4.29		0.07	0.07	0.28	0.03	6990	1 071 429	107 143	6562	6944
M/L/A	Soluble granule	Groundboom	0.7	100	70.00	6.86	32.49	39.35	39.35	3.94	2.20	0.96	3.16	3.16	0.32	7624	94 937	9494	4228	7057
M/L/A	Soluble granule	Groundboom (custom)	0.700	300	210.00	6.86	32.49	39.35	118.05	11.81	2.20	0.96	3.16	9.48	0.95	2541	31 646	3165	1409	2352
M/L	Soluble granule	Aerial	0.700	400	280.00	6.86		6.86	27.44	2.74	2.20		2.20	8.80	0.88	10 933	34 091	3409	2599	8278
A	Soluble granule	Aerial	0.700	400	280.00		10.73	10.73	42.92	4.29		0.07	0.07	0.28	0.03	6990	1 071 429	107 143	6562	6944
Cereal grains (oats)—postemergence																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.285	100	28.50	32.77	32.49	65.26	26.57	2.66	1.60	0.96	2.56	1.04	0.10	11 291	287 829	28 783	8110	10 865
M/L/A	Liquid	Groundboom (custom)	0.285	300	85.50	32.77	32.49	65.26	79.71	7.97	1.60	0.96	2.56	3.13	0.31	3764	95 943	9594	2703	3622
M/L	Liquid	Aerial	0.285	400	114.00	32.77		32.77	53.37	5.34	1.60		1.60	2.61	0.26	5621	115 132	11 513	3777	5360
A	Liquid	Aerial	0.285	400	114.00		10.73	10.73	17.47	1.75		0.07	0.07	0.11	0.01	17 168	2 631 579	263 158	16 116	17 057
M/L/A	Soluble granule	Groundboom	0.285	100	28.50	6.86	32.49	39.35	16.02	1.60	2.20	0.96	3.16	1.29	0.13	18 725	233 178	23 318	10 385	17 333
M/L/A	Soluble granule	Groundboom (custom)	0.285	300	85.50	6.86	32.49	39.35	48.06	4.81	2.20	0.96	3.16	3.86	0.39	6242	77 726	7773	3462	5778
M/L	Soluble granule	Aerial	0.285	400	114.00	6.86		6.86	11.17	1.12	2.20		2.20	3.58	0.36	26 853	83 732	8373	6383	20 332
A	Soluble granule	Aerial	0.285	400	114.00		10.73	10.73	17.47	1.75		0.07	0.07	0.11	0.01	17 168	2 631 579	263 158	16 116	17 057

Scenario	Formulation	Application Equipment	Application Rate (kg a.e./ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal					Inhalation					Margin of Exposure[c]				
						Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
						Mix/Load	Apply	Total	Daily	Abrbd	Mix/Load	Apply	Total	Daily	Abrbd[b]					
Corn (field)—postemergence																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.600	100	60.00	32.77	32.49	65.26	55.94	5.59	1.60	0.96	2.56	2.19	0.22	5363	136 719	13 672	3852	5161
M/L/A	Liquid	Groundboom (custom)	0.600	140	84.00	32.77	32.49	65.26	78.31	7.83	1.60	0.96	2.56	3.07	0.31	3831	97 656	9766	2751	3686
M/L	Liquid	Aerial	0.600	400	240.00	32.77		32.77	112.35	11.24	1.60		1.60	5.49	0.55	2670	54 688	5469	1794	2546
A	Liquid	Aerial	0.600	400	240.00		10.73	10.73	36.79	3.68		0.07	0.07	0.24	0.02	8155	1 250 000	125 000	7655	8102
M/L/A	Soluble granule	Groundboom	0.600	100	60	6.86	32.49	39.35	33.73	3.37	2.20	0.96	3.16	2.71	0.27	8895	110 759	11 076	4933	8233
M/L/A	Soluble granule	Groundboom (custom)	0.600	140	84.00	6.86	32.49	39.35	47.22	4.72	2.20	0.96	3.16	3.79	0.38	6353	79 114	7911	3524	5881
M/L	Soluble granule	Aerial	0.600	400	240.00	6.86		6.86	23.52	2.35	2.20		2.20	7.54	0.75	12 755	39 773	3977	3032	9658
A	Soluble granule	Aerial	0.600	400	240.00		10.73	10.73	36.79	3.68		0.07	0.07	0.24	0.02	8155	1 250 000	125 000	7655	8102
Corn (sweet): postemergence																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.325	100	32.50	32.77	32.49	65.26	30.30	3.03	1.60	0.96	2.56	1.19	0.12	9901	252404	25240	7112	9527
M/L/A	Liquid	Groundboom (custom)	0.325	140	45.50	32.77	32.49	65.26	42.42	4.24	1.60	0.96	2.56	1.66	0.17	7072	180288	18029	5080	6805
M/L/A	Soluble granule	Groundboom	0.325	100	32.5	6.86	32.49	39.35	18.27	1.83	2.20	0.96	3.16	1.47	0.15	16421	204479	20448	9107	15200
M/L/A	Soluble granule	Groundboom (custom)	0.325	140	45.50	6.86	32.49	39.35	25.58	2.56	2.20	0.96	3.16	2.05	0.21	11729	146056	14606	6505	10857
Alfalfa stand removal—minimum tillage system: fall application																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	1.200	100	120.00	32.77	32.49	65.26	111.87	11.19	1.60	0.96	2.56	4.39	0.44	2682	68359	6836	1926	2580
M/L	Liquid	Aerial	1.2	150	180.00	32.77		32.77	84.27	8.43	1.60		1.60	4.11	0.41	3560	72917	7292	2392	3394
A	Liquid	Aerial	1.200	150	180.00		10.73	10.73	27.59	2.76		0.07	0.07	0.18	0.02	10873	1666667	166667	10207	10802
M/L/A	Soluble granule	Groundboom	1.200	100	120.00	6.86	32.49	39.35	67.46	6.75	2.20	0.96	3.16	5.42	0.54	4447	55380	5538	2467	4117
M/L	Soluble granule	Aerial	1.200	150	180.00	6.86		6.86	17.64	1.76	2.20		2.20	5.66	0.57	17007	53030	5303	4043	12877
A	Soluble granule	Aerial	1.200	150	180.00		10.73	10.73	27.59	2.76		0.07	0.07	0.18	0.02	10873	1666667	166667	10207	10802
Minimum: open M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Soluble granule	Groundboom (custom)	1.2	300	360.00	6.86	21.04	27.90	143.49	14.35	2.20	0.96	3.16	16.25	1.63	2091	18460	1846	980	1878
Partial engineering controls (A): closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	1.2	300	360.00	32.77	4.42	37.19	191.26	19.13	1.6	0.06	1.66	8.54	0.85	1569	35141	3514	1084	1502
Alfalfa stand removal—minimum tillage system: spring application																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.600	70	42.00	32.77	32.49	65.26	39.16	3.92	1.60	0.96	2.56	1.54	0.15	7662	195313	19531	5503	7372
M/L/A	Liquid	Groundboom (custom)	0.600	300	180.00	32.77	32.49	65.26	167.81	16.78	1.60	0.96	2.56	6.58	0.66	1788	45573	4557	1284	1720
M/L	Liquid	Aerial	0.600	400	240.00	32.77		32.77	112.35	11.24	1.60		1.60	5.49	0.55	2670	54688	5469	1794	2546

Scenario	Formulation	Application Equipment	Application Rate (kg a.e. /ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal					Inhalation					Margin of Exposure[c]				
						Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
						Mix/Load	Apply	Total	Daily	Abrbd	Mix/Load	Apply	Total	Daily	Abrbd[b]					
A	Liquid	Aerial	0.600	400	240.00		10.73	10.73	36.79	3.68		0.07	0.07	0.24	0.02	8155	1250000	125000	7655	8102
M/L/A	Soluble granule	Groundboom	0.600	70	42.00	6.86	32.49	39.35	23.61	2.36	2.20	0.96	3.16	1.90	0.19	12706	158228	15823	7047	11762
M/L/A	Soluble granule	Groundboom (custom)	0.600	300	180.00	6.86	32.49	39.35	101.19	10.12	2.20	0.96	3.16	8.13	0.81	2965	36920	3692	1644	2744
M/L	Soluble granule	Aerial	0.600	400	240.00	6.86		6.86	23.52	2.35	2.20		2.20	7.54	0.75	12755	39773	3977	3032	9658
A	Soluble granule	Aerial	0.600	400	240.00		10.73	10.73	36.79	3.68		0.07	0.07	0.24	0.02	8155	1250000	125000	7655	8102
Use-Site Category 14—Terrestrial Food Crops																				
Bearing fruit trees (apple, peach, pear, plum, apricot, sweet and sour cherry)																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.952	16	15.23	32.77	32.49	65.26	14.20	1.42	1.60	0.96	2.56	0.56	0.06	21126	538545	53855	15174	20328
M/L/A	Liquid	Groundboom (custom)	0.952	16	15.23	32.77	32.49	65.26	14.20	1.42	1.60	0.96	2.56	0.56	0.06	21126	538545	53855	15174	20328
M/L/A	Liquid	Backpack	0.024	150	3.57		5445.85	5445.85	277.74	27.77		39.10	39.10	1.99	0.20	1080	150444	15044	1008	1072
M/L/A	Liquid	Low-pressure handwand	0.024	150	3.57		943.37	943.37	48.11	4.81		45.20	45.20	2.31	0.23	6235	130141	13014	4216	5950
M/L/A	Soluble granule	Groundboom	0.952	16	15.23	6.86	32.49	39.35	8.56	0.86	2.20	0.96	3.16	0.69	0.07	35036	436290	43629	19432	32432
M/L/A	Soluble granule	Groundboom (custom)	0.952	16	15.23	6.86	32.49	39.35	8.56	0.86	2.20	0.96	3.16	0.69	0.07	35036	436290	43629	19432	32432
M/L/A	Soluble granule	Backpack	0.024	150	3.57		5445.85	5445.85	277.74	27.77		39.10	39.10	1.99	0.20	1080	150444	15044	1008	1072
M/L/A	Soluble granule	Low-pressure handwand	0.024	150	3.57		943.37	943.37	48.11	4.81		45.20	45.20	2.31	0.23	6235	130141	13014	4216	5950
Maximum: open M/L, open or no cab (e.g., handheld); chemical-resistant coveralls over a single layer, chemical-resistant gloves are worn																				
M/L/A	Liquid	High-pressure handwand	0.010	3750	35.70		1827.13	1827.13	931.84	93.18		151.00	151.00	77.01	7.70	322	3896	390	176	297
M/L/A	Liquid	High-pressure handwand	0.010	3750	35.7		1827.13	1827.13	931.84	93.18		151.00	151.00	77.01	7.70	322	3896	390	176	297
Asparagus—after cutting and end of season																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	1.650	30	49.50	32.77	32.49	65.26	46.15	4.61	1.6	0.96	2.56	1.81	0.18	6501	165720	16572	4669	6255
M/L/A	Liquid	Groundboom (custom)	1.650	80	132.00	32.77	32.49	65.26	123.06	12.31	1.60	0.96	2.56	4.83	0.48	2438	62145	6214	1751	2346
M/L/A	Soluble granule	Groundboom	1.650	30	49.50	6.86	32.49	39.35	27.83	2.78	2.20	0.96	3.16	2.23	0.22	10781	134254	13425	5979	9980
M/L/A	Soluble granule	Groundboom (custom)	1.650	80	132.00	6.86	32.49	39.35	74.20	7.42	2.20	0.96	3.16	5.96	0.60	4043	50345	5035	2242	3742

Scenario	Formulation	Application Equipment	Application Rate (kg a.e. /ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal					Inhalation					Margin of Exposure[c]				
						Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
						Mix/Load	Apply	Total	Daily	Abrbd	Mix/Load	Apply	Total	Daily	Abrbd[b]					
Strawberries (eastern Canada only)—postplant																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.460	32	14.72	32.77	32.49	65.26	13.72	1.37	1.60	0.96	2.56	0.54	0.05	21861	557278	55728	15701	21036
M/L/A	Liquid	Groundboom (custom)	0.460	80	36.80	32.77	32.49	65.26	34.31	3.43	1.60	0.96	2.56	1.35	0.13	8744	222911	22291	6281	8414
M/L/A	Soluble granule	Groundboom	0.460	32	14.72	6.86	32.49	39.35	8.27	0.83	2.20	0.96	3.16	0.66	0.07	36255	451465	45147	20108	33560
M/L/A	Soluble granule	Groundboom (custom)	0.460	80	36.80	6.86	32.49	39.35	20.69	2.07	2.20	0.96	3.16	1.66	0.17	14502	180586	18059	8043	13424
Strawberries (eastern Canada only)—dormant or following last picking																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.959	32	30.69	32.77	32.49	65.26	28.61	2.86	1.6	0.96	2.56	1.12	0.11	10486	267307	26731	7531	10090
M/L/A	Liquid	Groundboom (custom)	0.959	80	76.72	32.77	32.49	65.26	71.52	7.15	1.60	0.96	2.56	2.81	0.28	4194	106923	10692	3013	4036
M/L/A	Soluble granule	Groundboom	0.959	32	30.69	6.86	32.49	39.35	17.25	1.73	2.20	0.96	3.16	1.39	0.14	17390	216553	21655	9645	16098
M/L/A	Soluble granule	Groundboom (custom)	0.959	80	76.72	6.86	32.49	39.35	43.13	4.31	2.20	0.96	3.16	3.46	0.35	6956	86621	8662	3858	6439
Cranberry																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom (wipe)	0.235	4	0.94	32.77	32.49	65.26	0.88	0.09	1.60	0.96	2.56	0.03	0.00	342330	8726729	872673	245877	329408
M/L/A	Liquid	Backpack	0.235	6	1.41		5445.85	5445.85	109.69	10.97		62.10	62.10	1.25	0.13	2735	239833	23983	2455	2704
M/L/A	Liquid	Low-pressure handwand	0.235	6	1.41		943.37	943.37	19.00	1.90		45.20	45.20	0.91	0.09	15788	329505	32950	10674	15066
M/L/A	Soluble granule	Groundboom (wipe)	0.235	4	0.94	6.86	32.49	39.35	0.53	0.05	2.20	0.96	3.16	0.04	0.00	567736	7069755	706975	314876	525533
M/L/A	Soluble granule	Backpack	0.235	6	1.41		5445.85	5445.85	109.69	10.97		62.10	62.10	1.25	0.13	2735	239833	23983	2455	2704
M/L/A	Soluble granule	Low-pressure handwand	0.235	6	1.41		943.37	943.37	19.00	1.90		45.20	45.20	0.91	0.09	15788	329505	32950	10674	15066
Raspberries (eastern Canada only)—postemergence																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.520	32	16.64	32.77	32.49	65.26	15.51	1.55	1.60	0.96	2.56	0.61	0.06	19338	492976	49298	13890	18608
M/L/A	Liquid	Groundboom (custom)	0.520	80	41.60	32.77	32.49	65.26	38.78	3.88	1.60	0.96	2.56	1.52	0.15	7735	197191	19719	5556	7443
M/L/A	Liquid	Backpack	0.017	150	2.60		5445.85	5445.85	202.27	20.23		62.10	62.10	2.31	0.23	1483	130063	13006	1331	1466
M/L/A	Liquid	Low-pressure handwand	0.017	150	2.60		943.37	943.37	35.04	3.50		45.20	45.20	1.68	0.17	8562	178693	17869	5788	8170
M/L/A	Soluble granule	Groundboom	0.520	32	16.64	6.86	32.49	39.35	9.35	0.94	2.20	0.96	3.16	0.75	0.08	32072	399373	39937	17787	29688
M/L/A	Soluble granule	Groundboom (custom)	0.520	80	41.60	6.86	32.49	39.35	23.39	2.34	2.20	0.96	3.16	1.88	0.19	12829	159749	15975	7115	11875
M/L/A	Soluble granule	Backpack	0.013	150	1.95		5445.85	5445.85	151.71	15.17		62.10	62.10	1.73	0.17	1978	173418	17342	1775	1955
M/L/A	Soluble granule	Low-pressure handwand	0.013	150	1.95		943.37	943.37	26.28	2.63		45.20	45.20	1.26	0.13	11416	238257	23826	7718	10894

Scenario	Formulation	Application Equipment	Application Rate (kg a.e. /ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal					Inhalation					Margin of Exposure[c]				
						Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
						Mix/Load	Apply	Total	Daily	Abrbd	Mix/Load	Apply	Total	Daily	Abrbd[b]					
Minimum: open M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Backpack	0.005	150	0.78		2597.09	2597.09	28.94	2.89		39.10	39.10	0.44	0.04	10367	688570	68857	9010	10213
M/L/A	Liquid	Low-pressure handwand	0.005	150	0.78		735.22	735.22	8.19	0.82		45.20	45.20	0.50	0.05	36619	595643	59564	22677	34498
M/L/A	Soluble granule	Backpack	0.005	150	0.78		2597.09	2597.09	28.94	2.89		39.10	39.10	0.44	0.04	10367	688570	68857	9010	10213
M/L/A	Soluble granule	Low-pressure handwand	0.005	150	0.78		735.22	735.22	8.19	0.82		45.20	45.20	0.50	0.05	36619	595643	59564	22677	34498
Raspberries (eastern Canada only)—postemergence: spot-treatment																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Backpack	0.023	150	3.41		5445.85	5445.85	265.22	26.52		62.10	62.10	3.02	0.30	1131	99195	9919	1015	1118
M/L/A	Liquid	Low-pressure handwand	0.023	150	3.41		943.37	943.37	45.94	4.59		45.20	45.20	2.20	0.22	6530	136283	13628	4415	6231
M/L/A	Soluble granule	Backpack	0.023	150	3.41		5445.85	5445.85	265.22	26.52		62.10	62.10	3.02	0.30	1131	99195	9919	1015	1118
M/L/A	Soluble granule	Low-pressure handwand	0.023	150	3.41		943.37	943.37	45.94	4.59		45.20	45.20	2.20	0.22	6530	136283	13628	4415	6231
Minimum: open M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Backpack	0.013	150	1.88		2597.09	2597.09	69.56	6.96		39.10	39.10	1.05	0.10	4313	286445	28645	3748	4249
M/L/A	Liquid	Low-pressure handwand	0.013	150	1.88		735.22	735.22	19.69	1.97		45.20	45.20	1.21	0.12	15234	247788	24779	9434	14351
M/L/A	Soluble granule	Backpack	0.013	150	1.88		2597.09	2597.09	69.56	6.96		39.10	39.10	1.05	0.10	4313	286445	28645	3748	4249
M/L/A	Soluble granule	Low-pressure handwand	0.013	150	1.88		735.22	735.22	19.69	1.97		45.20	45.20	1.21	0.12	15234	247788	24779	9434	14351
Use-Site Category 16—Industrial and Domestic Vegetation Control Non-Food Sites																				
Non-cropland: postemergence (woody plants)—fence rows, roadsides, rights of ways, powerlines, railroads, industrial sites and other non-crop areas including broadcast application for tree and brush control																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Low-pressure handwand	4.480	2	7.17		943.37	943.37	96.60	9.66		45.20	45.20	4.63	0.46	3106	64816	6482	2100	2964
M/L/A	Liquid	Right-of-way sprayer	0.004	3750	16.80	32.77	852.54	885.31	212.47	21.25	1.60	5.00	6.60	1.58	0.16	1412	189394	18939	1314	1401
M/L	Liquid	Aerial	4.480	100	448.00	32.77		32.77	209.73	20.97	1.60		1.60	10.24	1.02	1430	29297	2930	961	1364
A	Liquid	Aerial	4.480	100	448.00		10.73	10.73	68.67	6.87		0.07	0.07	0.45	0.04	4369	669643	66964	4101	4340
M/L/A	Soluble granule	Low-pressure handwand	4.480	2	7.17		943.37	943.37	96.60	9.66		45.20	45.20	4.63	0.46	3106	64816	6482	2100	2964
M/L/A	Soluble granule	Right-of-way sprayer	0.004	3750	16.80	6.86	852.54	859.40	206.26	20.63	2.20	5.00	7.20	1.73	0.17	1455	173611	17361	1342	1442
M/L	Soluble granule	Aerial	4.480	100	448.00	6.86		6.86	43.90	4.39	2.20		2.20	14.08	1.41	6833	21307	2131	1624	5174
A	Soluble granule	Aerial	4.480	100	448.00		10.73	10.73	68.67	6.87		0.07	0.07	0.45	0.04	4369	669643	66964	4101	4340
M/L/A	Granule	Solid broadcast spreader	4.48	80	358.40	6.86	15.89	22.75	116.48	11.65	2.20	1.60	3.80	19.46	1.95	2576	15419	1542	965	2207
M/L/A	Granule	Push rotary spreader	4.480	2	8.96		474.00	474.00	60.67	6.07		16.50	16.50	2.11	0.21	4945	142045	14205	3668	4778

Scenario	Formulation	Application Equipment	Application Rate (kg a.e. /ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal Unit Exposure (µg/ kg a.e.)			Dermal Exposure (µg/kg bw/day)[a]		Inhalation Unit Exposure (µg/ kg a.e.)			Inhalation Exposure (µg/kg bw/day)[a]		Margin of Exposure[c]				
						Mix/Load	Apply	Total	Daily	Abrbd	Mix/Load	Apply	Total	Daily	Abrbd[b]	Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
Maximum: open M/L, open or no cab (e.g., handheld); chemical-resistant coveralls over a single layer, chemical-resistant gloves are worn																				
M/L/A	Liquid	Backpack	4.480	2	7.17		2027.34	2027.34	207.60	20.76		62.10	62.10	6.36	0.64	1445	47177	4718	1106	1402
M/L/A	Liquid	High-pressure handwand	0.004	3750	16.80		1827.13	1827.13	438.51	43.85		151.00	151.00	36.24	3.62	684	8278	828	375	632
M/L/A	Soluble granule	Backpack	4.480	2	7.17		2027.34	2027.34	207.60	20.76		62.10	62.10	6.36	0.64	1445	47177	4718	1106	1402
M/L/A	Soluble granule	High-pressure handwand	0.004	3750	16.80		1827.13	1827.13	438.51	43.85		151.00	151.00	36.24	3.62	684	8278	828	375	632
M/L/A	Granule	Granules by hand	4.48	2	8.96	6.86	34191.8	34198.6	3501.94	350.19	2.2	605	607.2	62.18	6.218	86	4825	483	73	84
Partial engineering controls (M/A): closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom	4.480	70	313.60	32.77	4.42	37.19	166.61	16.66	1.6	0.06	1.66	7.44	0.74	1808	40341	4034	1245	1724
Non-cropland: postemergence (annual and perennial weeds)—fence rows, roadsides, rights of ways, powerlines, railroads, industrial sites and other non-crop areas																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Backpack	2.240	2	3.58		5445.85	5445.85	278.83	27.88		62.10	62.10	3.18	0.32	1076	94354	9435	966	1064
M/L/A	Liquid	Low-pressure handwand	2.240	2	3.58		943.37	943.37	48.30	4.83		45.20	45.20	2.31	0.23	6211	129632	12963	4199	5927
M/L/A	Liquid	Groundboom	2.240	70	156.80	32.77	32.49	65.26	146.18	14.62	1.60	0.96	2.56	5.73	0.57	2052	52316	5232	1474	1975
M/L/A	Liquid	Right-of-way sprayer	0.002	3750	8.40	32.77	852.54	885.31	106.24	10.62	1.60	5.00	6.60	0.79	0.08	2824	378788	37879	2628	2803
M/L	Liquid	Aerial	2.240	100	224.00	32.77		32.77	104.86	10.49	1.60		1.60	5.12	0.51	2861	58594	5859	1922	2728
A	Liquid	Aerial	2.240	100	224.00		10.73	10.73	34.34	3.43		0.07	0.07	0.22	0.02	8737	1339286	133929	8202	8681
M/L/A	Soluble granule	Backpack	2.240	2	3.58		5445.85	5445.85	278.83	27.88		62.10	62.10	3.18	0.32	1076	94354	9435	966	1064
M/L/A	Soluble granule	Low-pressure handwand	2.240	2	3.58		943.37	943.37	48.30	4.83		45.20	45.20	2.31	0.23	6211	129632	12963	4199	5927
M/L/A	Soluble granule	Groundboom	2.240	70	156.80	6.86	32.49	39.35	88.14	8.81	2.20	0.96	3.16	7.08	0.71	3404	42382	4238	1888	3151
M/L/A	Soluble granule	Right-of-way sprayer	0.002	3750	8.40	6.86	852.54	859.40	103.13	10.31	2.20	5.00	7.20	0.86	0.09	2909	347222	34722	2684	2885
M/L	Soluble granule	Aerial	2.240	100	224.00	6.86		6.86	21.95	2.20	2.20		2.20	7.04	0.70	13666	42614	4261	3248	10348
A	Soluble granule	Aerial	2.240	100	224.00		10.73	10.73	34.34	3.43		0.07	0.07	0.22	0.02	8737	1339286	133929	8202	8681
M/L/A	Granule	Solid broadcast spreader	2.240	80	179.2	6.86	15.89	22.75	58.24	5.82	2.20	1.60	3.80	9.73	0.97	5151	30839	3084	1929	4414
M/L/A	Granule	Push rotary spreader	2.240	2	4.48		474.00	474.00	30.34	3.03		16.50	16.50	1.06	0.11	9889	284091	28409	7336	9557
Maximum: open M/L, open or no cab (e.g., handheld); chemical-resistant coveralls over a single layer, chemical-resistant gloves are worn																				
M/L/A	Liquid	High-pressure handwand	0.002	3750	8.40		1827.13	1827.13	219.26	21.93		151.00	151.00	18.12	1.81	1368	16556	1656	749	1264
M/L/A	Soluble granule	High-pressure handwand	0.002	3750	8.40		1827.13	1827.13	219.26	21.93		151.00	151.00	18.12	1.81	1368	16556	1656	749	1264

Scenario	Formulation	Application Equipment	Application Rate (kg a.e. /ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal					Inhalation					Margin of Exposure[c]				
						Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
						Mix/Load	Apply	Total	Daily	Abrbd	Mix/Load	Apply	Total	Daily	Abrbd[b]					
M/L/A	Granule	Granules by hand	2.24	2	3.58	6.86	34191.8	34198.6	1750.97	175.1	2.2	605	607.2	31.09	3.109	171	9650	965	146	168
Tree and brush control—non-broadcast application (basal spray, cut surface-stump, frill)																				
Minimum: open M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Backpack	0.017	150	2.55		2597.09	2597.09	94.61	9.46		62.10	62.1	2.26	0.23	3171	132613	13261	2559	3097
M/L/A	Liquid	Low-pressure handwand	0.017	150	2.55		735.22	735.22	26.78	2.68		45.20	45.20	1.65	0.16	11201	182197	18220	6937	10552
M/L/A	Soluble granule	Backpack	0.017	150	2.55		2597.09	2597.09	94.61	9.46		62.10	62.10	2.26	0.23	3171	132613	13261	2559	3097
M/L/A	Soluble granule	Low-pressure handwand	0.017	150	2.55		735.22	735.22	26.78	2.68		45.20	45.20	1.65	0.16	11201	182197	18220	6937	10552
Maximum: open M/L, open or no cab (e.g., handheld); chemical-resistant coveralls over a single layer, chemical-resistant gloves are worn																				
M/L/A	Liquid	High-pressure handwand	0.017	3750	63.75		1827.13	1827.13	1663.99	166.40		151.00	151.00	137.52	13.75	180	2182	218	99	167
M/L/A	Soluble granule	High-pressure handwand	0.017	3750	63.75		1827.13	1827.13	1663.99	166.40		151.00	151.00	137.52	13.75	180	2182	218	99	167

Shaded cells indicate MOEs that are less than the target MOE

Resp = respirator; ATPD = area treated per day; M/L = mix/load; A = application; Absb = absorbed

[a] Where dermal/inhalation exposure µg/kg/day = (unit exposure × volume handled × use rate [g/L])/70 kg bw.

[b] This includes the 90% protection factor for respirator use. For engineering controls, the respirator only applies to the mixing and loading, not the application.

[c] Dermal and inhalation exposure based on an oral NOAEL of 30 mg/kg bw/day; target MOE is 1000.

[d] Calculated using the following equation: combined MOE = 1/[1/dermal MOE + 1/inhalation MOE].

Table 3 Margins of Exposure (MOEs) for Mixers/Loaders and Applicators Using 2,4-D: BEE, IPA, TIPA

Scenario	Formulation	Application Equipment	Application Rate (kg a.e. /ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal					Inhalation					Margin of Exposure[c]				
						Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
						Mix/ Load	Apply	Total	Daily	Abrbd	Mix/ Load	Apply	Total	Daily	Abrbd[b]					
Use-Site Category 1—Aquaculture																				
Oyster farms																				
Maximum: open M/L, open or no cab (e.g., handheld); chemical-resistant coveralls over a single layer, chemical-resistant gloves are worn																				
M/L/A	Granular	Solid broadcast spreader (boat)	33.250	20	665.00	4.02	3.90	7.92	75.24	7.52	2.20	1.60	3.80	36.10	3.61	1329	2770	277	229	N/A[e]
Use-Site Category 2—Aquatic Non-Food Sites																				
Aquatic weeds (water milfoil, and slightly to moderately resistant weeds) in ponds, lakes, reservoirs, marshes, drainage ditches, canals, rivers, and streams that are quiescent or slow moving																				
Maximum: open M/L, open or no cab (e.g., handheld); chemical-resistant coveralls over a single layer, chemical-resistant gloves are worn																				
M/L/A	Granular	Solid broadcast spreader (boat)	42.750	20	855.00	4.02	3.90	7.92	96.74	9.67	2.20	1.60	3.80	46.41	4.64	1034	2155	215	178	N/A[e]
Use-Site Category 13—Terrestrial Feed Crops																				
Established grass pastures, rangeland, perennial grasslands not in agricultural production																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
A	Liquid	Aerial	2.24	200	448.00		10.73	10.73	68.67	6.87		0.07	0.07	0.45	0.04	1456	223214	22321	1367	1447
Partial engineering controls (M/L): closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom	2.240	50	112.00	9.61	21.04	30.65	49.04	4.90	0.11	0.96	1.07	1.71	0.17	2039	58411	5841	1511	1970
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	2.240	100	224.00	9.61	4.42	14.03	44.90	4.49	0.11	0.06	0.17	0.54	0.23	2227	44014	18382	1987	2120
M/L	Liquid	Aerial	2.240	200	448.00	9.61		9.61	61.50	6.15	0.11		0.11	0.70	0.07	1626	142045	14205	1459	1608
Grass grown for seed																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.564	100	56.40	32.77	32.49	65.26	52.58	5.26	1.60	0.96	2.56	2.06	0.21	1902	48 482	4848	1366	1830
A	Liquid	Aerial	0.564	400	225.60		10.73	10.73	34.58	3.46		0.07	0.07	0.23	0.02	2892	443 262	44 326	2715	2873
Partial engineering controls (M/L): closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	0.564	300	169.20	9.61	21.04	30.65	74.09	7.41	0.11	0.96	1.07	2.59	0.26	1350	38 665	3866	1001	1304
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L	Liquid	Aerial	0.564	400	225.60	9.61		9.61	30.97	3.10	0.11		0.11	0.35	0.04	3229	282 076	28 208	2897	3192
Fallow land and crop stubble																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
A	Liquid (soluble concentrate)	Aerial	2.240	200	448.00		10.73	10.73	68.67	6.87		0.07	0.07	0.45	0.04	1456	223214	22321	1367	1447
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	2.24	200	448.00	9.61	4.42	14.03	89.79	8.98	0.11	0.06	0.17	1.09	0.45	1114	22007	9191	993	1060
M/L	Liquid	Aerial	2.240	200	448.00	9.61		9.61	61.50	6.15	0.11		0.11	0.70	0.07	1626	142 045	14 205	1459	1608
Use-Site Category 13/14—Terrestrial Feed Crops/Terrestrial Food Crops																				
Cereal grains (wheat, barley, rye)—postemergence																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.880	80	70.40	32.77	32.49	65.26	65.63	6.56	1.60	0.96	2.56	2.57	0.26	1524	38 841	3884	1094	1466
A	Liquid	Aerial	0.880	200	176.00		10.73	10.73	26.98	2.70		0.07	0.07	0.18	0.02	3707	568 182	56 818	3480	3683

Scenario	Formulation	Application Equipment	Application Rate (kg a.e./ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal Unit Exposure (µg/ kg a.e.)			Dermal Exposure (µg/kg bw/day)[a]		Inhalation Unit Exposure (µg/ kg a.e.)			Inhalation Exposure (µg/kg bw/day)[a]		Margin of Exposure[c]				
						Mix/ Load	Apply	Total	Daily	Abrbd	Mix/ Load	Apply	Total	Daily	Abrbd[b]	Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	0.880	280	246.40	9.61	4.42	14.03	49.39	4.94	0.11	0.06	0.17	0.60	0.25	2025	40 013	16 711	1806	1927
M/L	Liquid	Aerial	0.880	200	176.00	9.61		9.61	24.16	2.42	0.11		0.11	0.28	0.03	4139	361 570	36 157	3714	4092
Cereal grains (wheat, barley, rye): prior to seeding or crop emergence, minimum tillage system																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.700	100.00	70.00	32.77	32.49	65.26	65.26	6.53	1.60	0.96	2.56	2.56	0.26	1532	39 063	3906	1101	1474
M/L	Liquid	Aerial	0.700	200.00	140.00	32.77		32.77	65.54	6.55	1.60		1.60	3.20	0.32	1526	31 250	3125	1025	1455
A	Liquid	Aerial	0.700	200.00	140.00		10.73	10.73	21.46	2.15		0.07	0.07	0.14	0.01	4660	714 286	71 429	4374	4630
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	0.700	280.00	196.00	9.61	4.42	14.03	39.28	3.93	0.11	0.06	0.17	0.48	0.20	2546	50 302	21008	2270	2423
Cereal grains (oats)—postemergence																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.285	100.00	28.50	32.77	32.49	65.26	26.57	2.66	1.60	0.96	2.56	1.04	0.10	3764	95 943	9594	2703	3622
M/L	Liquid	Aerial	0.285	200.00	57.00	32.77		32.77	26.68	2.67	1.60		1.60	1.30	0.13	3748	76 754	7675	2518	3573
A	Liquid	Aerial	0.285	200.00	57.00		10.73	10.73	8.74	0.87		0.07	0.07	0.06	0.01	11 445	1 754 386	175 439	10 744	11371
Minimum: open M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	0.285	300.00	85.50	32.77	21.04	53.81	65.73	6.57	1.60	0.96	2.56	3.13	0.31	1521	31 981	3198	1031	1452
Cereal grains (oats)—postemergence																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.418	100.00	41.80	32.77	32.49	65.26	38.97	3.90	1.60	0.96	2.56	1.53	0.15	2566	65 416	6542	1843	2469
M/L	Liquid	Aerial	0.418	200.00	83.60	32.77		32.77	39.14	3.91	1.60		1.60	1.91	0.19	2555	52333	5233	1717	2436
A	Liquid	Aerial	0.418	200.00	83.60		10.73	10.73	12.81	1.28		0.07	0.07	0.08	0.01	7804	1 196 172	119 617	7326	7753
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	0.418	300.00	125.40	9.61	21.04	30.65	54.91	5.49	0.11	0.96	1.07	1.92	0.19	1821	52 170	5217	1350	1760
Corn (field)																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.600	100	60.00	32.77	32.49	65.26	55.94	5.59	1.60	0.96	2.56	2.19	0.22	1788	45 573	4557	1284	1720
M/L/A	Liquid	Groundboom (custom)	0.600	140	84.00	32.77	32.49	65.26	78.31	7.83	1.60	0.96	2.56	3.07	0.31	1277	32 552	3255	917	1229
M/L	Liquid	Aerial	0.600	220	132.00	32.77		32.77	61.79	6.18	1.60		1.60	3.02	0.30	1618	33 144	3314	1087	1543
A	Liquid	Aerial	0.600	220	132.00		10.73	10.73	20.23	2.02		0.07	0.07	0.13	0.01	4942	757 576	75 758	4640	4910
Alfalfa stand removal—minimum tillage system: fall application																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
A	Liquid	Aerial	1.200	150.00	180.00		10.73	10.73	27.59	2.76		0.07	0.07	0.18	0.02	3624	555 556	55 556	3402	3601
Minimum: open M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom	1.200	70.00	84.00	32.77	21.04	53.81	64.57	6.46	1.60	0.96	2.56	3.07	0.31	1549	32 552	3255	1049	1478
Partial engineering controls (M/L): closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	1.200	300.00	360.00	9.61	21.04	30.65	157.63	15.76	0.11	0.96	1.07	5.50	0.55	634	18 172	1817	470	613
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L	Liquid	Aerial	1.200	150.00	180.00	9.61		9.61	24.71	2.47	0.11		0.11	0.28	0.03	4047	353 535	35 354	3631	4001

Scenario	Formulation	Application Equipment	Application Rate (kg a.e./ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal					Inhalation					Margin of Exposure[c]				
						Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
						Mix/ Load	Apply	Total	Daily	Abrbd	Mix/ Load	Apply	Total	Daily	Abrbd[b]					
Alfalfa stand removal—minimum tillage system: spring application																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Groundboom	0.600	70.00	42.00	32.77	32.49	65.26	39.16	3.92	1.60	0.96	2.56	1.54	0.15	2554	65 104	6510	1834	2457
M/L	Liquid	Aerial	0.600	150.00	90.00	32.77		32.77	42.13	4.21	1.60		1.60	2.06	0.21	2373	48 611	4861	1595	2263
A	Liquid	Aerial	0.600	15.00	9.00		10.73	10.73	1.38	0.14		0.07	0.07	0.01	0.00	72 486	1111111	1 111 111	68047	72016
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom (custom)	0.600	300.00	180.00	9.61	4.42	14.03	36.08	3.61	0.11	0.06	0.17	0.44	0.18	2772	54 773	22 876	2472	2638
Use-Site Category 16—Industrial and Domestic Vegetation Control Non-Food Sites																				
Non-cropland: postemergence (woody plants)—fence rows, roadsides, rights of ways, powerlines, railroads, industrial sites and other non-crop areas including broadcast application for tree and brush control																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
A	Liquid	Aerial	4.480	100	448.00		10.73	10.73	68.67	6.87		0.07	0.07	0.45	0.04	1456	223 214	22 321	1367	1447
Maximum: open M/L, open or no cab (e.g., handheld); chemical-resistant coveralls over a single layer, chemical-resistant gloves are worn																				
M/L/A	Liquid	Backpack	4.48	2	7.17		2027.34	2027.34	207.60	20.76		62.10	62.10	6.36	0.64	482	15 726	1573	369	467
M/L/A	Liquid	Low-pressure handwand	4.480	2	7.17		693.59	693.59	71.02	7.10		45.20	45.20	4.63	0.46	1408	21 605	2161	852	1322
M/L/A	Liquid	High-pressure handwand	0.004	3750	16.80		1827.13	1827.13	438.51	43.85		151.00	151.00	36.24	3.62	228	2759	276	125	211
Partial engineering controls (M/L): closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Right-of-way sprayer	0.004	3750	16.80	9.61	524.07	533.68	128.08	12.81	0.11	5.00	5.11	1.23	0.12	781	81 539	8154	713	773
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom	4.480	70	313.60	9.61	4.42	14.03	62.85	6.29	0.11	0.06	0.17	0.76	0.32	1591	31 439	13 130	1419	1514
M/L	Liquid	Aerial	4.480	100	448.00	9.61		9.61	61.50	6.15	0.11		0.11	0.70	0.07	1626	142 045	14 205	1459	1608
Non-cropland: postemergence (annual and perennial weeds)—fence rows, roadsides, rights of ways, powerlines, railroads, industrial sites and other non-crop areas																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Low-pressure handwand	2.240	2	3.58		943.37	943.37	48.30	4.83		45.20	45.20	2.31	0.23	2070	43 211	4321	1400	1976
A	Liquid	Aerial	2.240	100	224.00		10.73	10.73	34.34	3.43		0.07	0.07	0.22	0.02	2912	446 429	44 643	2734	2894
Minimum: open M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Right-of-way sprayer	0.002	3750	8.40	32.77	524.07	556.84	66.82	6.68	1.60	5.00	6.60	0.79	0.08	1497	126 263	12 626	1338	1479
Maximum: open M/L, open or no cab (e.g., handheld); chemical-resistant coveralls over a single layer, chemical-resistant gloves are worn																				
M/L/A	Liquid	Backpack	2.240	2	3.58		2027.34	2027.34	103.80	10.38		62.10	62.10	3.18	0.32	963	31 451	3145	737	935
M/L/A	Liquid	High-pressure handwand	0.002	3750	8.4		1827.13	1827.13	219.26	21.93		151.00	151.00	18.12	1.81	456	5519	552	250	421
Partial engineering controls (M/L): closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L/A	Liquid	Groundboom	2.240	70	156.80	9.61	21.04	30.65	68.66	6.87	0.11	0.96	1.07	2.40	0.24	1457	41722	4172	1080	1407
Engineering controls: closed M/L, open cab; coveralls over single layer and chemical-resistant gloves are worn																				
M/L	Liquid	Aerial	2.240	100	224.00	9.61		9.61	30.75	3.08	0.11		0.11	0.35	0.04	3252	284 091	28 409	2918	3215
Non-cropland: tree and brush control—non-broadcast application (basal spray, cut surface-stump, frill)																				
Baseline: open M/L wearing coveralls over single layer, chemical-resistant gloves; open or no cab (e.g., handheld) wearing a long-sleeved shirt, long pants, chemical-resistant gloves (gloves not required for groundboom)																				
M/L/A	Liquid	Low-pressure handwand	0.017	150	2.55		943.37	943.37	34.37	3.44		45.20	45.20	1.65	0.16	2910	60 732	6073	1967	2777

Scenario	Formulation	Application Equipment	Appli-cation Rate (kg a.e. /ha)	ATPD (ha or L)	a.e. handled per day (kg)	Dermal					Inhalation					Margin of Exposure[c]				
						Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Unit Exposure (µg/ kg a.e.)			Exposure (µg/kg bw/day)[a]		Dermal	Inh w/ resp	Inh w/o resp	Comb. w/o resp[d]	Comb. w/ resp[d]
						Mix/ Load	Apply	Total	Daily	Abrbd	Mix/ Load	Apply	Total	Daily	Abrbd[b]					
Maximum: open M/L, open or no cab (e.g., handheld); chemical-resistant coveralls over a single layer, chemical-resistant gloves are worn																				
M/L/A	Liquid	Backpack	0.017	150	2.55		2027.34	2027.34	73.85	7.39		62.10	62.10	2.26	0.23	1354	44 204	4420	1037	1314
M/L/A	Liquid	High-pressure handwand	0.017	3750	63.75		1827.13	1827.13	1663.99	166.40		151.00	151.00	137.52	13.75	60	727	73	33	56

Shaded cells indicate MOEs that are less than the target MOE.

Resp = respirator; ATPD = area treated per day; M/L = mix/load; A = application; Absb = absorbed

[a] Where dermal/inhalation exposure µg/kg/day = (unit exposure × volume handled × use rate [g/L])/70 kg bw.

[b] This includes the 90% protection factor for respirator use. For engineering controls, the respirator only applies to the mixing and loading, not the application.

[c] Dermal and inhalation exposure based on an oral NOAEL of 30 mg/kg bw/day; target MOE is 1000.

[d] Calculated using the following equation: Combined MOE = 1/[1/dermal MOE + 1/inhalation MOE]

[e] A respirator in combination with maximum PPE was not considered to be feasible as there were thought to be safety issues regarding mobility of an applicator in a boat with full PPE, lifevest as well as a respirator.

Table 4 Restricted-Entry Interval for Commercial Postapplication Activities for 2,4-D: Acid, DMA, 2-EHE

Activity	Transfer Coefficient (cm^2/hour)[a]	Rate[b] (kg a.e./ha)	Acceptable Residue Limit[c]	MOE (day 0)	REI[d]
Use-Site Category 4—Forests and Woodlands					
Conifer release and forest site preparation					
No postapplication exposure is expected. Survey of usage of 2,4-D in forestry indicated that applicators are unlikely to re-enter treated areas, and that warning signs are posted to prohibit other people from entering the treated area..					
Use-Site Category 13—Terrestrial Feed Crops					
Established grass pastures and forage, rangeland, perennial grasslands not in agricultural production					
Scouting[e]	500	2.240	5.250	1172	**0**
Harvest—mechanical[f]	0	N/A			
Forage sorghum					
Scouting	1000	0.560	2.625	2344	**0**
Harvest—mechanical	0	N/A			
Forage millet, seedlings, grass grown for seed					
Scouting, irrigating[g]	1000	0.564	2.625	2327	**0**
Harvest—mechanical	0	N/A			
Fallow land and crop stubble					
Scouting[e]	500	2.240	5.250	1172	**0**
Harvest—mechanical[f]	0	N/A			

Activity	Transfer Coefficient (cm²/hour)[a]	Rate[b] (kg a.e./ha)	Acceptable Residue Limit[c]	MOE (day 0)	REI[d]
Use-Site Category 13/14—Terrestrial Feed Crops/Terrestrial Food Crops					
Cereal grains (wheat, barley, rye)					
Scouting, irrigation (low foliage)	100	0.880	26.250	14915	**0**
Harvest—mechanical	0	N/A			
Cereal grains (oats)					
Scouting, irrigation (low foliage)	100	0.285	26.250	46053	**0**
Harvest—mechanical	0	N/A			
Corn (field): postemergence					
Scouting, irrigation (tall, full foliage)	1000	0.600	2.625	2188	**0**
Scouting (low, minimum foliage)	400	0.600	6.563	5469	**0**
Harvest—mechanical	0	N/A			
Corn (sweet): postemergence					
Hand detasseling, hand harvesting	17000	0.325	0.154	238	**14**
Scouting, irrigation, hand weeding (tall, full foliage)	1000	0.325	2.625	4038	**0**
Scouting (low/high, minimum foliage)	400	0.325	6.563	10096	**0**
Hand weeding (low, minimum foliage)	100	0.325	26.250	40385	**0**
Harvest—mechanical	0	N/A			

Activity	Transfer Coefficient (cm²/hour)[a]	Rate[b] (kg a.e./ha)	Acceptable Residue Limit[c]	MOE (day 0)	REI[d]
Corn (field and sweet): postemergence (Jerusalem artichoke control)[h]					
Hand detasseling	17000	0.325	0.154	238	**30**
Scouting, irrigation (tall, full foliage)	1000	0.325	2.625	4038	**0**
Scouting (low, minimum foliage)	400	0.325	6.563	10096	**0**
Harvest—mechanical	0	N/A			
Alfalfa stand removal—minimum tillage system: fall application					
Scouting	1500	1.200	1.750	729	**3**
Alfalfa stand removal—minimum tillage system: spring application					
Scouting	100	0.600	26.250	21875	**0**
Use-Site Category 14 — Terrestrial Food Crops					
Asparagus—after cutting and end of season					
2,4-D is applied before the spears emerge and after harvesting, so it is unlikely that any postapplication exposure would occur from residues					
Bearing fruit trees (apple, peach, pear, plum, apricot, sweet and sour cherry)					
Scouting[i]	500	0.952	5.250	2757	**0**
Cranberry					
Scouting, thinning, hand weeding[j]	400	0.418	6.563	7850	**0**

Activity	Transfer Coefficient (cm²/hour)[a]	Rate[b] (kg a.e./ha)	Acceptable Residue Limit[c]	MOE (day 0)	REI[d]
Raspberries (eastern Canada only)[k]					
Hand harvest, hand pruning, thinning, training (full foliage); tying (any foliage)	5000	0.520	0.525	505	**6**
Scouting (full foliage)	1000	1.250	2.625	1050	**0**
Hand weeding (any foliage level)	500	1.250	5.250	2100	**0**
Scouting (minimum foliage)	500	1.250	5.250	2100	**0**
Strawberries (eastern Canada only)—postplant					
Irrigation, hand pruning, scouting, hand weeding (all foliage levels)	400	0.460	6.563	7133	**0**
Transplanting	Out of scope				
Strawberries (eastern Canada only)—dormant or last picking					
Irrigation, hand pruning, scouting, hand weeding (all foliage levels)	400	1.680	6.563	1953	**0**
Use-Site Category 16—Industrial and Domestic Vegetation Control Non-Food Sites					
Non-Cropland: postemergence (woody plants)—fence rows, roadsides, rights-of-ways, powerlines, railroads, industrial sites and other non-crop areas including broadcast application for tree and brush control					
Scouting[l]	500	4.48	10.500	1172	**0**
Non-Cropland: Postemergence (annual and perennial weeds): fence rows, roadsides, rights-of-ways, powerlines, railroads, industrial sites, and other non-crop areas					
Scouting[l]	500	2.24	10.500	2344	**0**

Activity	Transfer Coefficient (cm²/hour)[a]	Rate[b] (kg a.e./ha)	Acceptable Residue Limit[c]	MOE (day 0)	REI[d]
Tree and brush control—non-broadcast application (basal spray, cut surface-stump, frill)					
2,4-D is applied to the trunk of the tree using these application methods; given there should be little to no residue on foliage, scouting or bystander exposure should be negligible.					

Shaded cells indicate MOEs that are less than target.

a Rates are from the ARTF.

b Maximum rate.

c Based on an oral NOAEL of 30 mg/kg bw/day, target is 1000; duration of 8 hours for commercial postapplication activities; body weights of 70 kg.

d REI = restricted-entry interval; day at which the residues are low enough for the target MOE to be reached.
The REI is the length of time that it takes for the dissipation to reach the acceptable residue limit, which is calculated using the following equation:

$$\text{Acceptable Residue Limit } (\mu g/cm^2) = \frac{\text{NOAEL } (\mu g/kg) \times \text{bw (kg)}}{\text{TC } (cm^2/\text{hour}) \times \text{exposure time (hours)} \times \text{safety factor (unitless)}}$$

e Transfer coefficient is the same as scouting TC for turf, Christmas trees, orchard crops in the ARTF data. As there was no scenario for pastures, fallow land, and crop stubble, it was thought that this TC would be representative. The exposure calculated is thought to be conservative because it seems unlikely that farmers would spend 8 hours scouting these areas.

f TC from field row crops. There were no TCs for pastures, rangeland, etc. for cutting forage for hay. This is the same TC for mechanical harvesting in many/most other field row crops, so it is unlikely to be an underestimate.

g Sorghum TCs.

h Two applications of 325 g a.e./ha, 10–14 days apart are permitted for control of Jerusalem artichoke. In this assessment, the 14-day interval was used as it resulted in the longest REI. Label instructions specified that only the plant below the point where the first leaf meets the stem was to be treated; while worker contact with foliage is potentially high during detasseling, the proportion of treated foliage is low (less than 20%); therefore, exposure is expected to be minimal and mitigated by the general 14-day REI for detasseling.

i TC from scouting treated turf/sod was used to represent walking along/scouting the grass on orchard floors because there was no TC for this activity for orchards

j Applicators using handheld wick equipment used 0.3 L of 2,4-D/acre (0.741 L/ha) (guarantee of 564 g/L) and could treat 20 acres/day (9 ha/day).

k There are two rates for raspberries. The highest rate (used for spot treatment) was used to calculate REIs.

l TC is the same as scouting for turf, orchard crops, Christmas trees in the ARTF data. This scenario is expected to be representative of a person walking or scouting along non-crop areas. Used a duration of 4 hours because it was thought that most of the day would be spent in the car travelling to sites, or driving in the sites, with spot-scouting.

Table 5 Restricted-Entry Interval for Commercial Postapplication Activities for 2,4-D: IPA, TIPA, BEE

Activity	Transfer Coefficient (cm^2/hour)[a]	Rate[b] (kg a.e./ha)	Acceptable Residue Limit[c]	MOE (day 0)	REI[d]
Use-Site Category 1/2—Aquaculture/Aquatic Non-Food Sites					
Postapplication exposure following application of 2,4-D to lakes, ponds, etc. is expected to be minimal because no occupational postapplication activities are expected. Based on a survey of usage, it seems that 2,4-D is not used in oyster production; no postapplication exposure is expected for this use.					
Use-Site Category 4—Forests and Woodlands					
Conifer Release and Forest site preparation					
No postapplication exposure is expected. Survey of usage of 2,4-D in forestry indicated that applicators are unlikely to re-enter treated areas, and that warning signs are posted to prohibit other people from entering the treated area.					
Use-Site Category 13—Terrestrial Feed Crops					
Established grass pastures, rangeland, perennial grasslands not in agricultural production					
Scouting[e]	500	2.240	1.750	391	**3**
Harvest—mechanical[f]	0	N/A			
Grass grown for seed					
Scouting	1000	0.560	0.875	781	**2**
Harvest—mechanical	0	N/A			
Fallow land and crop stubble					
Scouting[e]	500	2.240	1.750	391	**3**
Harvest—mechanical[f]	0	N/A			

Activity	Transfer Coefficient (cm^2/hour)[a]	Rate[b] (kg a.e./ha)	Acceptable Residue Limit[c]	MOE (day 0)	REI[d]
Use-Site Category 13/14—Terrestrial Feed Crops/Terrestrial Food Crops					
Cereal grains (wheat, barley, rye)					
Scouting, irrigation (low foliage)	100	0.880	8.750	4972	**0**
Harvest—mechanical	0	N/A			
Cereal grains (oats): postemergence[g]					
Scouting, irrigation (low foliage)	100	0.285	8.750	15351	**0**
Harvest—mechanical	0	N/A			
Corn (field): postemergence					
Scouting, irrigation (tall, full foliage)	1000	0.600	0.875	729	**3**
Scouting (low, min foliage)	400	0.600	2.188	1823	**0**
Harvest—mechanical	0	N/A			
Alfalfa stand removal—fall application					
Scouting	1500	1.200	0.583	243	**13**
Alfalfa stand removal—spring application					
Scouting	100	0.600	8.750	7292	**0**
Use-Site Category 16—Industrial and Domestic Vegetation Control Non-Food Sites					
Non-cropland: postemergence (woody plants)—fence rows, roadsides, rights-of-ways, powerlines, railroads, industrial sites and other non-crop areas					
Scouting[h]	500	4.480	3.500	391	**9**
Bystander—adult[i]	500	4.480	7.000	781	**2**
Bystander—youth[ij]	500	4.480	16.250	544	**0**

Activity	Transfer Coefficient (cm^2/hour)[a]	Rate[b] (kg a.e./ha)	Acceptable Residue Limit[c]	MOE (day 0)	REI[d]
Non-Cropland: postemergence (annual and perennial weeds)—fence rows, roadsides, rights-of-ways, powerlines, railroads, industrial sites and other non-crop areas					
Scouting[h]	500	2.240	3.500	781	**2**
Bystander—adult[i]	500	2.240	7.000	1563	**0**
Bystander—youth[ij]	500	2.240	16.250	1088	**0**

Shaded cells indicate MOEs that are less than target.

[a] Rates are from the ARTF.

[b] Maximum rate.

[c] Based on an oral NOAEL of 10 mg/kg bw/day, target is 1000; duration of 8 hours for commercial postapplication activities; body weights of 70 kg.

[d] REI= restricted-entry interval; day at which the residues are low enough for the target MOE to be reached.
The REI is the length of time that it takes for the dissipation to reach the acceptable residue limit, which is calculated using the following equation:

$$\text{Acceptable Residue Limit } (\mu g/cm^2) = \frac{\text{NOAEL } (\mu g/kg) \times \text{bw (kg)}}{\text{TC } (cm^2/\text{hour}) \times \text{exposure time (hours)} \times \text{safety factor (unitless)}}$$

[e] Transfer coefficient is the same as scouting TC for turf, Christmas trees, orchard crops in the ARTF data. As there was no scenario for pastures, fallow land and crop stubble, it was thought that this TC would be representative. Used a duration of 4 hours because it was thought that most of the day would be spent in the car travelling to sites or driving in the sites, with spot-scouting.

[f] TC from field row crops. There were no TCs for pastures, rangeland, etc. for cutting forage for hay. This is the same TC for mechanical harvesting in many/most other field row crops, so it is unlikely to be an underestimate.

[g] Exposure to residues on oats is not expected following the “prior-to-seeding” application because no foliage is present

[h] TC is the same as scouting for turf, orchard crops, Christmas trees in the ARTF data. This scenario is expected to be representative of a person walking or scouting along non-crop areas. Used a duration of 4 hours because it was thought that most of the day would be spent in the car travelling to sites, or driving in the sites, with spot-scouting.

[i] As an REI would be required for workers and many of these treated areas are closed to the public (such as parks, etc.), postapplication exposure to bystanders was assessed. Duration of 2 hours was assumed.

[j] Oral NOAEL of 12.5 mg/kg bw/day, dermal absorption of 10%, target MOE of 300 and body weight of 39 kg.

Table 6 Residential Postapplication Short- to Intermediate-Term (> 1 day to 6 months) Dermal and Oral Exposure Estimates for Swimming in Treated Bodies of Water[a]

Surface Area[b] (cm^2)	Concentration (a.e.) in water (mg/L)[c]	Exposure Time (hour/day)[d]	Permeability Coefficient[e] (cm/hour)	Dermal Exposure[f] (mg/kg bw/day)	Ingestion Rate (L/hour)[g]	Potential Dose Rate[h]	Ingestion Exposure[i] (mg/kg bw/day)
Adults							
BEE form							
18440	4	1.5	1.70×10^{-2}	**2.69×10^{-2}**	0.05	0.3	**4.29×10^{-3}**
18440	0.68	1.5	1.70×10^{-2}	**4.58×10^{-3}**	0.05	0.051	**7.29×10^{-4}**
Acid form							
18440	4	1.5	1.47×10^{-4}	**2.32×10^{-4}**	0.05	0.3	**4.29×10^{-3}**
Children							
BEE form							
8545	4	1.5	1.70×10^{-2}	**5.83×10^{-2}**	0.1	0.6	**4.00×10^{-2}**
8545	0.68	1.5	1.70×10^{-2}	**9.91×10^{-3}**	0.1	0.102	**6.80×10^{-3}**
Acid form							
8545	4	1.5	1.47×10^{-4}	**5.01×10^{-4}**	0.1	0.6	**4.00×10^{-2}**

[a] Exposure calculation is from the USEPA's SWIMODEL.

[b] Central descriptor surface area of adults and children (6 years) is from the North American Free Trade Agreement (NAFTA) Regulatory Capacity Building Subcommittee.

[c] BEE of 0.68 ppm was from Hoeppel and Westerdahl (1983) and is thought to underestimate the BEE concentration that would be found under Canadian conditions. 4 ppm for the acid and BEE forms was determined from the maximum application rate of 42.75 kg a.e./ha.

[d] Exposure time was from the USEPA (1997b).

[e] Skin permeability coefficient, calculated using the following equation: log Kp (cm/hour) = -2.72 + 0.71 × log K_{ow} -0.0061 × molecular weight
For acid, log K_{ow} = 0.33 (pH 5), molecular weight = 221. For BEE, log K_{ow} = 4.10 (estimated), molecular weight = 312.2. As this value was based on molecular weights and could not be verified using dermal absorption studies, there is low confidence in this parameter.

[f] Dermal exposure was calculated with the following equation: (concentration in water) × (body surface area) × (exposure time) × (1 L/1000 cm^3) × (log Kp) / (body weight). Body weights used were 70 kg for adults and 15 kg for children.

g Ingestion rate is a default from the USEPA (1997c).

h Potential dose rate = (concentration in water) × (exposure time) × (ingestion rate)

i Incidental non-dietary ingestion exposure was calculated with the following equation: potential dose rate/body weight. Body weights used were 70 kg for adult, 15 kg for children.

Table 7 Residential Postapplication Short- to Intermediate-Term (> 1 day to 6 months) Inhalation Exposure Estimates for Swimming in Treated Bodies of Water

Surface Area[a] (cm^2)	Concentration (a.e.) in Water (mg/L)[b]	Exposure Time (hr/day)[c]	Molecular Weight (g/mol)	Vapour Pressure[d] (mm Hg)	Solubility[e] (mg/L)	Temp (K)	Henry's Law Constant[f]	Vapour Concentration[g] (mg/m^3)	Inhalation Rate (m^3/hour)	Inhalation Exposure[h] (mg/kg bw/day)
Adults										
BEE form										
18440	4	1.5	321.2	4.50×10^{-6}	12	288	6.72×10^{-3}	2.69×10^{-2}	1.7	**9.79×10^{-4}**
18440	0.68	1.5	321.2	4.50×10^{-6}	12	288	6.72×10^{-3}	4.57×10^{-3}	1.7	**1.66×10^{-4}**
Acid form										
18440	4	1.5	221	1.42×10^{-7}	20031	288	8.74×10^{-8}	3.50×10^{-7}	1.7	**1.273×10^{-8}**
Children										
BEE form										
8545	4	1.5	321.2	4.50×10^{-6}	12	288	6.72×10^{-3}	2.69×10^{-2}	1.7	**4.57×10^{-3}**
8545	0.68	1.5	321.2	4.50×10^{-6}	12	288	6.72×10^{-3}	4.57×10^{-3}	1.7	**7.77×10^{-4}**
Acid form										
8545	4	1.5	221	1.42×10^{-7}	20031	288	8.74×10^{-8}	3.50×10^{-7}	1.7	**5.94×10^{-8}**

a Central descriptor surface area of adults and children (6 years) is from the NAFTA Regulatory Capacity Building Subcommittee.

b BEE of 0.68 ppm was from Hoeppel and Westerdahl (1983) and is thought to underestimate the BEE concentration that would be found under Canadian conditions. The 4 ppm value for the acid and BEE forms was determined from the maximum application rate of 42.75 kg a.e./ha.

c Exposure time was from the USEPA (1997b).

d Vapour pressure at 25°C.

[e] Water solubility at 25°C, and pH 5 for the acid form.
[f] Unitless Henry's law constant. It was calculated using the following equation:
Henry's law constant = [(vapour pressure) × (molecular weight) × (1000)] / [(0.062) × (solubility) × (ambient air temp)]
[g] Vapour concentration of a.i. in air. Calculated using the following equation:
Cvp = (unitless Henry's law constant) × (concentration in water) × 1000
[h] Inhalation exposure calculated using the following equation: (vapour concentration) × (inhalation rate) × (exposure time) / body weight. Body weights used were 70 kg for adult and 15 kg for children.

Table 8 Residential Postapplication Short- to Intermediate-Term (> 1 day to 6 months) Aural Exposure Estimates for Swimming in Treated Bodies of Water

Ear Surface Area[a] (cm^2)	Log Kow[b]	Permeability Coefficient[c] (cm/hour)	Aural Exposure (mg/kg/day)[d]
Adults			
BEE form			
4	4.1	1.70×10^{-2}	**2.40×10^{-2}**
4	4.1	1.70×10^{-2}	**1.20×10^{-2}**
4	4.1	1.70×10^{-2}	**4.07×10^{-3}**
Acid form			
4	2.83	1.47×10^{-4}	**1.42×10^{-4}**
4	2.83	1.47×10^{-4}	**7.11×10^{-5}**
Children			
BEE form			
4	4.1	1.70×10^{-2}	**1.12×10^{-1}**
4	4.1	1.70×10^{-2}	**5.59×10^{-2}**
4	4.1	1.70×10^{-2}	**4.07×10^{-3}**
Acid form			
4	4.1	1.47×10^{-4}	**9.62×10^{-4}**

[a] From the USEPA's SWIMODEL. Central estimate.
[b] Log K_{ow} for BEE was an estimate from the USDA (1999).
[c] Aural exposure was calculated using the following equation:
(concentration in water) × (exposure time) × (ear SA) × (log Kow) × (skin permeability coefficient) / body weight
Body weights used were 70 kg for adult and 15 kg for children
[d] Taken from the USEPA's SWIMODEL. Rates from non-competitive swimmers

Table 9 Residential Postapplication Short- to Intermediate-Term (> 1 day to 6 months) Buccal/Sublingual Exposure Estimates for Swimming in Treated Bodies of Water

Concentration (a.e.) in Water (mg/L)	Exposure Time (hour/day)[a]	Water Intake (L/hour)[b]	Absorption Factor	Buccal/ Subbuccal Dose[c]
Adults				
BEE form				
4	1.5	1.25	0.01	**1.07×10^{-3}**
2	1.5	1.25	0.01	**5.36×10^{-4}**
0.68	1.5	1.25	0.01	**1.82×10^{-4}**
Acid form				
4	1.5	1.25	0.01	**1.07×10^{-3}**
2	1.5	1.25	0.01	**5.36×10^{-4}**
Children				
BEE form				
4	1.5	2.5	0.01	**1.00×10^{-2}**
2	1.5	2.5	0.01	**5.00×10^{-3}**
0.68	1.5	2.5	0.01	**1.70×10^{-3}**
Acid form				
4	1.5	2.5	0.01	**1.00×10^{-2}**

[a] Exposure time was from the USEPA (1997b).

[b] Default sublingual absorption factor of 0.01, based on the rate of sublingual absorption of nitroglycerine. The absorption of 2,4-D was thought to be lower, but as there was no information available to determine a more appropriate value, the default was used.

[c] Buccal/sublingual exposure is calculated using the following equation:
Exposure = [(concentration in water) × (exposure time) × (water intake) × (sublingual absorption factor)] / (body weight).
Body weights used were 70 kg for adult, 15 kg for children.

Table 10 Residential Postapplication Short to Intermediate-Term (> 1 day to 6 months) Total Exposure Estimates for Swimming in Treated Bodies of Water

Concentration (a.e.) in Water (mg/L)	Dermal Dose	Ingestion Dose	Inhalation Dose	Aural Dose	Buccal/ Subuccal Dose	Orbital/ Nasal Dose[a]	Sexual Organs[b]	Total Dose[c]	Total MOE[d]	Combined MOE[e]
Adults										
BEE form										
4	2.69×10^{-2}	4.29×10^{-3}	9.79×10^{-4}	2.40×10^{-2}	1.07×10^{-3}	1.07×10^{-3}	No data	5.83×10^{-2}	**171**	
0.68	4.58×10^{-3}	7.29×10^{-4}	1.66×10^{-4}	4.07×10^{-3}	1.82×10^{-4}	1.82×10^{-4}	No data	9.91×10^{-3}	**1000**	**821**
Acid form										
4	2.32×10^{-4}	4.29×10^{-3}	1.27×10^{-8}	1.42×10^{-4}	1.07×10^{-3}	1.07×10^{-3}	No data	6.80×10^{-3}	**4410**	
Children										
BEE form										
4	5.83×10^{-2}	4.00×10^{-2}	4.57×10^{-3}	1.12×10^{-1}	1.00×10^{-2}	1.00×10^{-2}	No data	2.35×10^{-1}	**53**	
0.68	9.91×10^{-3}	6.80×10^{-3}	7.77×10^{-4}	4.07×10^{-3}	1.70×10^{-3}	1.70×10^{-3}	No data	2.50×10^{-2}	**500**	**145**
Acid form										
4	5.01×10^{-4}	4.00×10^{-2}	5.94×10^{-8}	9.62×10^{-4}	1.00×10^{-2}	1.00×10^{-2}	No data	6.15×10^{-2}	**200**	

Shaded cells indicate MOEs that are less than target.

[a] Orbital/nasal exposure is considered to be equivalent to buccal/sublingual exposure (USEPA SWIMODEL).

[b] Exposure via sexual organs cannot be estimated because no chemical-specific absorption rate of male swimmer scrotal contact is available. As exposure by this route is considered to be significant for males, lacking this exposure from the total exposure could result in an underestimate of exposure for male swimmers.

[c] Total exposure = dermal exposure + ingestion exposure + inhalation exposure + aural exposure + buccal/sublingual exposure + orbital/nasal exposure

[d] In adults, based on an oral NOAEL of 10 mg/kg bw/day for BEE; target MOE is 1000. Based on an oral NOAEL of 12.5 mg/kg bw/day for acid; target MOE is 1000.

In children, based on an oral NOAEL of 12.5 mg/kg bw/day for acid and BEE; target MOE is 300.

[e] As the acid (4 ppm) and BEE (0.68 ppm) are both considered to be in the water while a person may be swimming in alkaline waters, their MOEs were combined.

References

A list of additional information regarding 2,4-D is included below. This is limited to a subset of published studies including review articles and international regulatory documents. It is not an exhaustive listing of all published studies on 2,4-D. Other relevant information referenced within each of the published reviews and international documents were also considered in this re-evaluation, and these documents may be consulted for further reference listings. This list does not include references to the unpublished proprietary data used in this assessment. A complete list of references used in the evaluation of 2,4-D will be available when a final decision for all uses of 2,4-D is published.

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