SERA TR-056-06-02b-App

Appendices 1, 2, and 3 to the Reassessment of Worker Exposure Rates

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NOTE

These appendices are released with SERA TR 056-06-02b, Reassessment of Worker Exposure Rates, FINAL REPORT.

Appendix 1: Summary and Disposition of Studies Consulted

Note: Studies recommended during peer review are included at the end of this table.

N	Citation	General Topic	Notes
1	Abbott et al. 1987	Ground Spray	Gives only dermal deposition. May be useful for variability as well as relative rates for backpack vs ground boom. See Table IV, p. 172 which gives dermal exp as ug/g handled.
2	Abdelghani 1995	Ground Herbicides	2,4-D, glyphosate, and triclopyr. Inhalation insignificant. Cannot get rates. Amount handled is not provided.
3	Adamis et al. 1985	OPs	No excretion data. Potential dermal >> inhalation by factors of 870 to 7000.
4	Ahn et al. 2011	Forestry	Mean excretion in Table 4 for groups not individuals for PBA. This is a harvesting and not an application study. Not directly useful.
5	Aprea et al. 2002	Review	This is a review of analytical methods. It contains no data from which rates can be derived.
6	Bell et al. 2006	Review	This is a review of "high pesticide exposure events" in applicators and spouses. It focuses on signs of toxicity and has no data from which rates can be derived.
7	Bouchard et al. 2003	PBPK	This is a malathion PBPK model. No data on applicator exposure.
8	Bouvier et al. 2006	Greenhouse	This involves general exposures of greenhouse and other workers and members of the general public to OPs. No specific information on applications that can be used to derive rates.
9	Branson and Sweeney 1991	PPE	Review: This is a general and non-quantitative review of PPE. No efficacy summaries.
10	Brouwer et al. 1992a	Greenhouse	This is a re-entry study and not an application study. Cannot get rates.
11	Brouwer et al. 1992b	Greenhouse	This has dermal and inhalation potential exposure (deposition, Table II) but no biomonitoring. Inhalation << dermal in Table III.
12	Brouwer et al. 1992c	Greenhouse	This is a re-entry study and not an application study. Focus on air exposures. Cannot get rates.
13	Brouwer et al. 1992d	Greenhouse	This is a greenhouse study with a focus on foliar residues. No applicator exposures.
14	Brouwer et al. 1993	Greenhouse	This has biomonitoring but only for workers harvesting flowers in greenhouse (Table I, p. 598). No applicator monitoring.
15	Byers et al. 1992	Ground Ag	This has mixer-loader deposition data (Table 1, p. 63) but no biomonitoring.
16	Canning et al. 1998	PPE	Discusses deficiencies in polyvinyl chloride and nitrile butadiene rubber gloves.
17	Cessna and Grover 2002	Ground	See Table 8 for urinary excretion of bromoxynil. Includes impact of gloves. Will need urinary excretion data. Not covered in 1998 report.
18	Chester et al. 1992	Ground	Cypermethrin. Pakistan. Covered in 1998 report.
19	Cocker et al. 2002	OPs	This study has biomonitoring but the data are not associated with amounts handled.

Appendix 1: Summary and Disposition of Studies Consulted *(continued)*

N	Citation	General Topic	Notes
20	Corsini et al. 2006	Ground	This is an abstract. Focused on impacts of propanil on immune function.
21	Cowell et al. 1987	Ground	See Table 4 (p. 331). Not included in 1998 report. Alachlor, soil incorporation.
22	Cowell et al. 1991	Ground	Lawn care workers, dithiopyr. See Tables 2 and 3 of paper. Included in 1998 report (Table A-8).
23	Creely and Cherrie 2001	PPE	Efficacy of gloves. Gives protection factors for 'tidy' and 'messy' workers. Good study. Include,.
24	Cruz Márquez et al. 2001	Greenhouse	This study is discussed in the Malathion RA.
25	Damalas and Eleftherohorinos 2011	Review	Very general review of pesticide exposure. May not be worth citing.
26	Davies et al. 1982	PPE	Citrus grove workers. May be able to get PPE factor for overalls. Not very detailed.
27	Davis et al. 1983	PPE	May be able to get PPE for minimal vs normal clothing but this will not do us much good.
28	de Cock et al. 1998	Ground Fruit	Mostly focused on reentry with dermal deposition and inhalation exposures.
29	de Raat et al. 1997	Review	No original data. General review of pesticide worker exposure. Not very technical.
30	de Vreede et al. 1998	Ground Spray	Deposition study. Does show Dermal >>> Inhalation. Clean data in Tables 1 and 2.
31	Desi et al. 1986	Greenhouse	Has some biomonitoring but not associated with specific exposures. Focus on effects.
32	Dosemeci et al. 2002	Ground Ag	This is a 'scoring' algorithm related to deposition based measurements a al PHED.
33	Draper and Street 1982	Ground	See Table 4 (p. 334) for excretion. Also see Table 5. Not used quantitatively in 1998 report. Be careful in reanalysis in getting amount handled.
34	Drexler 2003	Review	Very general discussion of dermal exposure. No real data.
35	Driver et al. 2007	PPE	Good PPE analysis in context of deposition. No biomonitoring.
36	Dubelman and Cowell 1989	Ground	See Table IV (p. 247). Footnote gives amount handled. Very good discussion of biomonitoring vs deposition measures. Not covered in 1998 assessment.
37	Duggan et al. 2003	OPs	Good summary of biomonitoring but not associated with specific applications.
38	Durham and Wolfe 1962	Methods	Deposition based. See Table 4 (p. 87) for dermal >>> inhalation.
39	Easter and Nigg 1992	PPE	Very general review of PPE.
40	Edmiston et al. 2004	Ground	The only biomonitoring with detectable levels (simazine) did not yield validated results. This study is not used quantitatively to derive rates.
41	Elfman et al. 2009	Effects	Health survey of planters handling conifer seedlings. No rates.

Appendix 1: Summary and Disposition of Studies Consulted *(continued)*

N	Citation	General Topic	Notes
42	Elovaara et al. 1995	Other	This involves exposure to creosote in workers in an industrial plant. Irrelevant.
43	Faustman 2006	OPs	Discusses both applicators and farm workers but no biomonitoring associated with specific applications.
44	Fenske 1988	Malathion	See Table II (p. 440) and discussion on field conditions (p. 439). This is not covered in 1998 report or malathion RA.
45	Fenske 1990	General	This is a deposition study. No biomonitoring.
46	Fenske 1997	Review	General review. No biomonitoring data.
47	Fenske 2005	Review	Review of methods for assessing worker exposure. No useful data for deriving rates.
48	Fenske et al. 1987	Greenhouse	Deposition data only.
49	Feldmann and Maibach 1974	Dermal absorption	Absorption paper. Will probably cite but cannot be used to get rates.
50	Flack et al. 2006	Ground Ag	Deposition data only.
51	Frank et al. 1985	Aerial Forestry	This was not handled in 1998 assessment. No urinary data on pilot. Cannot determine the amount of 2,4-D handled by mixer/loaders. Not used in current analysis.
52	Franklin et al. 1981	Ground	Cited in 1998 assessment but not used to derive rates. See Table 4 (p. 725). It may be possible to derive rates in conjunction with the application data in Table 1. Also has rubberized vs non-rubberized clothing.
53	Garreyn et al. 2003	Review	No biomonitoring data.
54	Garry et al. 2001	Ground Forestry	Gives concentrations in urine and amount applied (Table 1) but I am not sure if we can get amount excreted. Does not appear to give application rates or amount handled.
55	Gee et al. 1995	Methods	Data on concentrations in urine but not for specific applications.
56	Geer et al. 2004	OPs	See Table 1 for amount handled. See Fig. 1 and for chlorpyrifos dose. It may be possible to estimate group but not individual rates.
57	Gilbert 1987	Statistics	Just a statistics reference. May not use.
58	Gold et al. 1984	OPs	Reviewed for but not cited in 1998 report. Cannot get rates. May want to cite for clothing protection factor.
59	Gosselin et al. 2005	Ground	Can get rates for backpack and ground boom workers. Covered in Triclopry RA (Table 16).
60	Grover et al. 1986	Ground	See Tables 5 and 6 of publication. It appears that exposure rates can be derived. Not cited in 1998 assessment. Must have been missed.
61	Hakkert 2001	Review	Methods review. No new data.

Appendix 1: Summary and Disposition of Studies Consulted *(continued)*

N	Citation	General Topic	Notes
62	Hardt and Angerer 2003	Pyrethroids	Very nice biomonitoring data but the amount of pesticide handled is not specified.
63	Harris and Solomon 1992a	Bystanders	This is the turf study used in Durkin et al. paper on dermal absorption. No applicator data.
64	Harris and Solomon 1992b	Dermal absorption	Dermal absorption of 2,4-D. No applicator data.
65	Harris et al. 1992	Ground	See Table II, p. 31. May be able to get some useful data but only very small amounts applied.
66	Harris et al. 2001	Methods	No new data.
67	Harris et al. 2005	Ground turf	See Table II for amounts handled. The field study data are taken from Solomon et al. 1993. No new data here.
68	Harris et al. 2010	Ground	This is a very extensive paper but the absorbed doses cannot be associated with the amount handled. Nonetheless, this study may be worth re-reviewing after the initial analysis.
69	He 1999	Review	General review of biomonitoring studies.
70	Hines et al. 2008	Ground orchard	See p. 163 for average amount of captan handled. See Table 2 for 24-h absorbed dose. Looks tenuous. At best, we can get average for group but not for individuals.
71	Hoekstra et al. 1996	Ground nursery	Benomyl, Nursery workers. Some biomonitoring (Fig 1) but cannot associate with amount applied.
72	Hoppin 2005	Review	Brief review. Marginal.
73	Hughes et al. 2006	Ground	Deposition only.
74	Hughes et al. 2008	Ground	Deposition only.
75	Jauhiainen et al. 1991	Ground Forestry	Glyphosate. Covered in 1998 paper and glyphosate RA.
76	Jauhiainen et al. 1992	Greenhouse	Measures AChE activity as index of exposure. Cannot derive rates.
77	Julien 2004	Methods	Only an abstract of a symposium. No data.
78	Kangas et al. 1993	Greenhouse	Mevinphos. Deposition, air concentrations, and DFR. No biomonitoring.
79	Karr et al. 1992	OPs	Deposition and AChE activity only.
80	Keeble et al. 1988	PPE	Can get good protection factors for different types of suits vs work cloths (Table 11, p. 581).
81	Kezic and Nielsen 2009	Dermal absorption	Impact of abraded skin. Good paper.
82	Klein-Szanto et al. 1991	Std	Chapter on skin from Handbook of Toxicologic Pathology.
83	Knarr et al. 1985	Aerial	Good deposition data on different job categories (Tables 2 and 3) but no absorbed doses.
84	Kolmodin-Hedman et al. 1995	Health effects	Signs of toxicity/irritancy in workers handling plants treated with permethrin. No exposure data.

Appendix 1: Summary and Disposition of Studies Consulted *(continued)*

N	Citation	General Topic	Notes
85	Korpalski et al. 2005	Foliar residue	Only data on lognormal distribution of DFR measurements.
86	Krieger 1995	Review	Good but general review.
87	Krieger et al. 1990	Ground Ag	Only estimates based on passive (deposition) dosimetry.
88	Kummer and Van Sittert 1986	OPs	Exposure estimates based on AChE. I had reviewed this for the 1998 assessment.
89	Lander and Hinke 1992	PPE	AChE measurements with no protection, apron, and full body suit. No internal dose rates.
90	Lander et al. 1992	PPE	AChE measurements with and without gloves. No internal dose rates.
91	Lavy and Mattice 1985	Ground	Covered in 1998 report. This is a review with information on relative rates in pilots and flagmen as well as other info that appears to be from Lavy et al. 1982 and some earlier studies. May cite but it does not appear to contain new information.
92	Lavy et al. 1980	Ground Forestry	Reviewed but not used in 1998 report. Good urinary data but cannot relate to amount handled. Good comparative data on job categories. Keep this in studies to process for second tier.
93	Lavy et al. 1982	Aerial Forestry	Handled in 1998 report.
94	Lavy et al. 1987	Ground Forestry	This is the classic. Talked to Paul about issue with leather gloves. Handled in 1998 report.
95	Lavy et al. 1992	Ground nursery	Glyphosate. Not covered in 1998 paper. In the 2011 glyphosate RA.
96	Lavy et al. 1993	Ground nursery	See Table 15. Previous tables give amount handled. Not used in 1998 report.
97	Leng et al. 1982	Review	See Table V (p. 139) for total exposure based on 24 hour urine samples. Data not otherwise published. Cannot get amount of pesticide handled.
98	Leighton and Nielsen 1995	Std/PHED	Just PHED documentation.
99	Libich et al. 1984	Ground	Handled in 1998 report.
100	Lunchick and Selman 1982	Review/ Methods	PHED database application.
101	Lunchick et al. 2005	Review /Methods	Ethoprop. See Table 1 (p. 86). Also see summary in Table 2 (p. 87).
102	Lyubimov et al. 2000	Ground	This is a good 2,4-D immunoassay method validation but cannot get amounts handled.
103	Machera et al. 2002	Greenhouse	Tracer study. No absorbed doses.
104	Maizlish et al. 1987	OPs	Urinary excretion data but no information on amounts handled.
105	Manugistics 1997	Statistics	Standard reference but I may not cite. Will use different statistical methods.

Appendix 1: Summary and Disposition of Studies Consulted *(continued)*

N	Citation	General Topic	Notes
106	Marín et al. 2004	Greenhouse	Some urine data (Fig. 5) but could not accurately read. Could estimate amount handled from description on p. 271.
107	Maroni et al. 2000	Review	Good review but no new/unpublished data.
108	Mestres et al. 1985	Greenhouse	Deposition assessment only.
109	Methner and Fenske 1996	Greenhouse	Tracer study. No absorbed doses.
110	Middendorf 1992a	Ground	Detailed in 2011 triclopyr RA.
111	Middendorf 1992b	Ground	Detailed in 2011 triclopyr RA.
112	Middendorf et al. 1992	Ground	Detailed in 2011 triclopyr RA. NOTE: This has useful data but it is a summary of Middendorf 1992b, which is the full study. This will not be included as a separate item in Appendix of used studies but the relationship to Middendorf 1992b will be noted.
113	Moody et al. 1990	Dermal absorption	Will cite for absorption data on acid and esters.
114	Moody et al. 1992	Dermal absorption	May cite for general discussion of differential absorption in different body regions.
115	Nash et al. 1982	Ground Ag	Covered in 1998 report.
116	Newton and Norris 1981	Ground	Cannot get rate but have data on relative rates for mixer-loaders and flaggers
117	Nigg and Stamper 1983a	Aquatic	This is the only study that gives us aquatic rates. Re-review and use. Covered in aquatic risk assessments.
118	Nigg and Stamper 1983b	Ground	Some PPE data but cannot get rates. Worth another read if time permits.
119	Nigg et al. 1986	Ground	Deposition only. No urine data.
120	Nigg et al. 1990	Ground	Deposition only. No urine data.
121	Nigg et al. 1992	PPE	Penetration factors for different fabrics. No absorbed doses.
122	Nigg et al. 1993	PPE	Penetration factors for different fabrics. No absorbed doses.
123	Norris 1985	Ground Forestry	Involves arsenic. This cannot be used for organic pesticides.
124	Nuyttens et al. 2004	Greenhouse	Depositon only.
125	Obendorf et al. 2003	Dermal absorption	This is a really interesting paper if we ever update dermal absorption methods. Not useful for worker exp.
126	Osterloh and Feldman 1993	Ground	Methods paper. No applicator data.
127	Piperakis et al. 2003	Greenhouse	Biomonitoring based on on Comet Assay. Also, no applicator data.
128	Putnam et al. 1983	Ground PPE	Deposition only. No urine data.
129	Ramirez 2009	Statistics	SAS statistists reference. Will use.

Appendix 1: Summary and Disposition of Studies Consulted *(continued)*

N	Citation	General Topic	Notes
130	Richter et al. 1980	Aerial	Incidence of parathion induced decreases in pilots and ground crews. No data for rates.
131	Robinson 1991	Ground	A nice MS thesis but no internal/urine excretion dose data.
132	Ross et al. 2000	Review	Good review but no new/unpublished data.
133	Ross et al. 2001	Review	Similar to 2000 review. No rate data.
134	Ross et al. 2006	Review	Focus on re-entry issue. No useful data on applicator exposure.
135	Ross et al. 2008	Review	Very nice review comparing passive dosimetry with biomonitoring. **Cannot use for rate but should cite.**
136	Rutz and Krieger 1992	Review	Another nice review but no data for rates based on biomonitoring.
137	Salvatore et al. 2008	Other	Focus on behavior modification. No internal dose data.
138	Salvatore et al. 2009	Other	Similar to 2008 publication. No internal dose data.
139	Samples et al. 2009	Other	Focus on worker training. No internal dose data.
140	Samuel et al. 1991	Forestry	Covered in hexazinone 2005 RA. Study does not report the amounts of hexazinone applied by each worker.
141	Samuel et al. 1992	Forestry	Covered in hexazinone 2005 RA. Study does not report the amounts of hexazinone applied by each worker.
142	Savolainen et al. 1989	Ground	Provides metabolite data in urine which could be useful but cannot get the amount handled.
143	Senior and Lavers 1992	Ground	Deposition only. No urine data.
144	Simpson 1965	Ground	Inhalation and deposition but no urine data.
145	Siqueria and Fernicola 1981	Other	Just analytical methods for pentachlorophenol.
146	Solomon et al. 1993	Ground	Lawn care workers applying 2,4-D and mecoprop. May be able to get rates. See Harris et al. 2001.
147	Spear et al. 1975	Ground	More of an epidemiology study for effects with some data on DFR. No data for rates.
148	Spencer et al. 1997	Ground	The 1996 version is covered in the 1998 report. Now have final 1997 version.
149	Spencer et al. 2000	Ground	Covered in Triclopry RA. Can get rates
150	Staiff et al. 1975	OPs	Deposition only. No urine data.
151	Stamper et al. 1988	Greenhouse	Deposition and air sampling only. No urine data.
152	Stamper et al. 1989a	Greenhouse	Similar to 1988 paper -- i.e., deposition and air sampling only. No urine data.

Appendix 1: Summary and Disposition of Studies Consulted *(continued)*

N	Citation	General Topic	Notes
153	Stamper et al. 1989b	Greenhouse	As with 1989a and 1988 paper, no urine data, only deposition and air sampling.
154	Tasker et al. 1982	Ground	Pretty good urine data (Table 5, p. 589) but cannot get the amount handled (see p. 587).
155	Tharr 1997	PPE	Paraquat, only air concentration. No good PPE factors.
156	Thomas et al. 2010	Ground	This gives only pre-application and post-application concentrations of 2,4-D and TCP (from chlorpyrifos) in urine. Cannot get data on total excretion. Also cannot get amounts handled.
157	van der Jagt et al. 2004	PPE	Chlorpyrifox with urine assays for TCP. Authors approximate the internal dose but no information on the amount handled. Also, the time course of urinary TCP is odd (see diescussion on pp. 360-361) possibly due to prior exposures of workers to chlorpyrifos. Even if we had amounts handled, the results could not be used.
158	van Hemmen 1992	Review	Our standard review for dermal vs inhalation. I will cite but no new data for rates.
159	Waldron 1985	Review	This is a review of work practices of farmers. No data for getting rates.
160	Weisskopf et al. 1988	OPs	Diazinon with monitoring of urinary metabolite. Specifies application rate but cannot get amount handled. Fig 8 dose should good correlation between estimated (deposition) exposure and urinary metabolites. May cite but cannot get rates.
161	Wester et al. 1984	Dermal absorption	Paraquat dermal absorption kinetics. Could be useful if the first-order dermal absorption rate method is updated but cannot be used to get worker exposure rates.
162	Whitmyre et al. 2004	DFR	Focus on DFR kinetics and post-application dermal exposure. No rates for applicators
163	Williams et al. 2003	Bystanders	This is similar to the Harris and Solomon study on uptake from turf. No rates for applicators.
164	Williams et al. 2004	Bystanders	Similar to above with emphasis on the impact of sweating. Sweating increases exposure. May want to cite but cannot get rates.
165	Wojeck et al. 1981	Ground	Ethion. We can approximate amount handled (p.726). Some urine data (Table 4, p. 731) as mean daily dialkyl phosphate excretion. This would tenuous but we may want to look at trying to get a crude rate. Probably would not incorporate into derivation of rates. Data are weak.
166	Wojeck et al. 1982	Ground	Arsenic. Cannot use data on inorganic compounds in current analysis.
167	Wolf et al. 1999	Inhalation	Focus on inhalation exposure. Another reference for inhalation <<< dermal.
168	Wolfe et al. 1966	Ground	Deposition and inhalation only. No internal dose. Inhalation <<<< dermal.
169	Wolfe et al. 1967	Ground/ Review	Good review but deposition and inhalation only. No internal dose. Inhalation <<<< dermal.

Appendix 1: Summary and Disposition of Studies Consulted *(continued)*

N	Citation	General Topic	Notes
170	Wolfe et al. 1970	Ground	Parathion and DDT. Might be able to get amount handled (p. 712). Have urinary excretion data for p-nitrophenol and DDA.
171	Wolff et al. 1992	Ground	Dermal exposures only. No urine data. Study involves formulators not applicators.
172	Yeary 1986	Ground	Covered in 1998 report.
173	Young et al. 2004	Review/ Methods	No estimates of absorbed dose. Semi-quantitative "exposure scores".
174	Zhang et al. 2011	Ground	This is the publication of the Krieger et al. (2005) report to the Forest Service for backpack applications of a mixture of 2,4-D and triclopyr esters.
175	Lavy et al. (1990a,b)	Nursery	This is the Forest Service technical report for Lavy et al. 1993. Individual applicator exposures are estimated for benomyl (Table 60), bifenox (Table 61), and carbaryl (Table 62) but the amounts handled by the individual workers are not specified. The study focus on year long exposures rather than individual applications. Individual exposure rates cannot be derived from this study.
176	Maddy et al. 1980	Ground	Dermal deposition and inhalation only. No urine data.
177	Maddy et al. 1981a	Ground	Dermal deposition and inhalation only. No urine data.
178	Maddy et al. 1982a	Aerial	Dermal deposition and inhalation only. No urine data.
179	Maddy et al. 1982b	Aerial	Dermal deposition and inhalation only. No urine data.
180	Vadal et al. 2002	Greenhouse	Dermal deposition analysis. No urine data.
181	Vanderlinden et al. 2002	Review	Review that covers the studies by Harris and Solomon 1992a,b and Harris et al. 1992. See entries 64-66 above. These studies focus on exposures to members of the general public and does not include data on exposure rates for applicators.
182	U.S. EPA/OPP 2012	Review/ Methods	This is essentially an update to Keigwin (1998). The document consists of a table giving dermal deposition and inhalation exposure rates for various scenarios. This document in incorporated into
183	Chester and Hart 1986	Ground	Involves backpack and ground vehicle sprays. This study provides excellent data on both deposition and absorption methods but does not provide information on the amount of the pesticide applied. Thus, it cannot be used to derive worker exposure rates.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Note On Formatting

Summaries of the studies are given in the following tables, one table for each study. Standard Times-Roman Font indicates that the information is taken either verbatim or with only minor editorial changes from the study. **Working notes are given Courier Bold Font. The working notes are either commentary on the study or other information relevant to the assessment or analysis of the study.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Cessna and Grover 2002**
Application Method:	Ground Broadcast. tractor-drawn ground rigs, consisting of trailer-mounted spray tanks equipped with booms at the rear. Nine of the 14 exposures involved tractors were equipped with cabs. 9/14 cabs were closed. Seven of the exposures involved cabs fitted with air filters (two charcoal and five dust filters). Spray height ranged from 12 to 57 cm.
Worker Groups:	Applicators
Pesticide(s):	Bromoxynil (1:1 mixture of bromoxynil butyrate and bromoxynil octanoate)
Location(s):	Regina, Saskatchewan, Canada
Terrain/Field:	Farm fields
Vegetative Cover/Crop:	Cereal crops (wheat, barley, and oats). Crop height at application varied from 4 to 38 cm depending on the leaf stage of the crop at application.
Protective Clothing:	Wool socks, cotton work pants, a short-sleeve cotton T-shirt, and a long sleeve cotton coverall of heavy material. Knee-high rubber boots and a plastic hard hat completed the protective gear worn during nine of the exposures. For the remaining five exposures, gauntlet-style neoprene gloves (0.56-mm thickness; Safety Supply Canada) were also worn. Seven of the exposures involved cabs fitted with air filters (two charcoal and five dust filters).
Application Rates:	Application rates specified in Table 1 (p. 374) of paper ranged from about 0.25 kg/ha to 0.3 kg/ha. Total amount of bromoxynil applied given as 9 kg (phenol equivalent, p.e.)
Kinetic Considerations:	The urinary excretion pattern for these exposures indicates that the amounts of bromoxynil excreted daily increased over the first few days after application and then, instead of continuously declining, tended to remain relatively constant during the remainder of the sampling period. This pattern of urinary excretion of bromoxynil may indicate that the herbicide may have a longer residence time in the body than generally expected, based on urinary excretion patterns of other herbicides, such as the phenoxy herbicides. **Authors do not discuss or correct for the proportion of bromoxynil that is excreted in the urine. U.S. EPA/OPP (1998a) indicated that about 75 to 90% excretion in the urine of rats.** **The Agency estimates a dermal absorption factor of 10.32% for bromoxynil phenol and 1.92% for bromoxynil. Used a rate of 10% for exposure assessment.**
Biomonitoring:	Composite 24-h urine samples were collected by each farmer beginning 1 day before the spraying operation and for 10 days after the spraying operation. Group rather than individual data are presented. Absorbed doses assayed as phenol equivalents. See Table 8 (p.) of paper.
Other monitoring:	Also measured levels of compound in air, deposition on clothing, and hand wipe samples. Group rather than individual data are presented.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Cessna and Grover 2002**
Notes:	Enclosed tractor cabs reduced inhalation and dermal exposure by factors of eight and two, respectively. There were no significant correlations between amount excreted and any of the operational parameters (duration of exposure, number of tank fills, area sprayed, amount applied) with the exception of duration of exposure for those exposures involving cabs. The exposure rates calculated by the authors are in Table 8 of the paper (p. 378). The calculated exposure rates from this study are in the EXCEL workbook that accompanies this report. Based on Figure 1 of study, workers not using glove were still excreting the pesticide in significant amounts (comparable to Day 4) at Day 10. Thus, absorbed doses could be underestimated.

Study:	**Chester et al. 1987**
Application Method:	Aerial, fixed-wing, Ultra Low Volume.
Worker Groups:	Pilots (2), professional mixer-loaders (2), volunteer mixer-loader (1)
Pesticide(s):	Cypermethrin (Cymbush 3E formulation)
Location(s):	Greenwood, Mississippi
Terrain/Field:	Farms
Vegetative Cover/Crop:	Cotton
Protective Clothing:	Professional workers: a long-sleeved shirt, trousers, boots, and socks. During application wore Tyvek overalls with attached hoods, cotton gloves, and acrylic-nylon socks. Volunteer mixer-loaders: similar clothing, with the exception of the wearing of short-sleeved shirts. All mixer-loaders wore protective equipment consisting of calf length rubber boots, coated rubber gloves, and an ankle-length rubber apron, and a full face shield.
Application Rates:	0.06 lb/acre. For each application - sometime referred to as replicates in this publication - the mixer loader handled 4 gallons of Cymbush 3E, which is equivalent to 5.44 kg (≈12 lb) of cypermethrin. Each mixer-loader mixed 3 replicates. Thus, each mixer-loader handed about 36 lbs.
Kinetic Considerations:	Authors note that approximately 50% of orally administered cypermethrin is excreted in the feces of rats. Authors assumed that 50% of the absorbed dose is excreted in the urine of the workers and used this correction factor in estimating the dose (p. 76 of study).

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Chester et al. 1987**
Biomonitoring:	Measurement of the cypermethrin urinary metabolites. Total urine collection (24 hour composites) for six days after application.
Other monitoring:	Measured residue on clothing
Notes:	Although it was not possible to obtain measurements of absorption of cypermethrin for the pilots, it is considered that the likely levels of absorption would be lower than those for the mixer-loaders. Exposures as mg/kg bw per kg applied for pilots is given in Table 3 of publication. Urinary excretion for mixer-loaders in Table 6 of publication. **For estimating the total absorbed dose, Chester et al. (1987) assumed that 50% of the cypermethrin metabolites are eliminated in the urine. For the three mixer-loaders on which urinary elimination data were obtained, the absorbed dose estimates were 46, 59, and 78 µg/day (Chester et al. 1987, Table 6, pp. 76-77). These data are used to calculate rates based on a 70 kg bw. See EXCEL workbook for details.**

Study:	**Cowell et al. 1987**
Application Method:	Soil incorporation
Worker Groups:	Applicators (n=4) and mixer-loaders (n=12)
Pesticide(s):	Alachlor, emulsifiable concentration (EC) and micro-encapsulated (MT) formulations
Location(s):	St. Louis County and St. Charles County, Missouri.
Terrain/Field:	Farms
Vegetative Cover/Crop:	Soybeans
Protective Clothing:	Normal clothing a “protective clothing recommended on label”. Not otherwise described in paper.
Application Rates:	4 lb/acre.
Kinetic Considerations	Authors state that about 88% of absorbed alachlor is excreted in the urine. It does not appear that this **correction factor for urinary excretion was used.**
Biomonitoring:	Complete urine collection up to 5 days after exposure.
Other monitoring:	Gauze patches on clothing.
Notes:	**See study Table 4 for details of individual measurement. Only one mixer/loader/applicator evidenced any detectable concentration of pesticide in the urine. Cannot get meaningful statistics. The mixing/loading devices were closed system. This study is not used to derive rates.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Cowell et al. 1991**
Application Method:	Ground broadcast
Worker Groups:	Applicator/Mixer-Loaders (workers did both), n=18
Pesticide(s):	Dithiopyr as Dimension Emulsifiable Concentrate formulation.
Location(s):	Atlanta, GA; Cincinnati, OH; and Cleveland, OH.
Terrain/Field:	Lawns
Vegetative Cover/Crop:	Grass
Protective Clothing:	long pants and boots during spray treatments and there was a mixture of short-sleeve shirts, long-sleeved shirts or jackets depending upon the temperature. Two of 18 workers wore gloves **(not otherwise described).**
Application Rates:	1 lb/acre
Kinetic Considerations:	The results of the IV study (Couch 1990a) indicate that dithiopyr is rapidly metabolized and cleared (>94%) from the body within a 72 hour period. Dithiopyr is excreted primarily in the urine (64.8%) as one major metabolite, the dicarbothioic acid, and the remainder (29.4%) in the feces. From the dermal application study, it was observed that the majority of the dose was washed off after the 12 hour exposure period. The skin was excised from the application site and analyzed. No significant residue was found in the skin.
Biomonitoring:	Urine collections for 72 hours after exposure. Assayed for dithiopyr and metabolites with metabolites converted to dithiopyr equivalents (Table 2 of study).
Other monitoring:	Cotton gauze patches, air monitoring, and hand washes.
Notes:	Mixing and loading done in closed system (trucks). Individual doses normalized for mg/kg bw per lb applied given in Table 3 of study. These values are corrected for recovery and can be used directly in analysis. See EXCEL workbook.

Study:	**Cruz Márquez et al. 2001**
Application Method:	Foliar spray, high volume (4 L/min)
Worker Groups:	Applicators (3)
Pesticide(s):	Malathion, Malathion 90 (malathion 90%, w/v, EL, Lainco, Barcelona, Spain)
Location(s):	Almeria, Spain.
Terrain/Field:	Greenhouse study (directed foliar)
Vegetative Cover/Crop:	Green beans, tomatoes, and cucumbers
Protective Clothing:	Latex gloves, disposable coveralls (65% cotton, 35% polyester purchased from Iturri, Sevilla, Spain) and protective masks (3M Model 4251). Applicator 1 did not use PPE>
Application Rates:	1 kg/ha (0.892 lb/acre). As detailed in SERA (2008a), each worker handled = 1.12 lb a.i.
Kinetic Considerations:	None explicit in publication. The absorbed dose is estimated from the total excretion of malathion monocarboxylic acid (MMA). **Based on study by Krieger and Dinoff (2000, Table 1, p. 547), the proportion of MMA excreted in urine after oral exposure to malathion is about 0.36. This factor is used in the EXCEL workbook to estimate absorbed dose as malathion equivalents.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Cruz Márquez et al. 2001**
Biomonitoring:	Clothing and glove samples as well as air samples
Other monitoring:	Urine samples up to 24 hours after application for parent and metabolites.
Notes:	**It is not clear that an additional correction for the 24 hour urine sampling is need. The underestimate of exposure would be minor. See kinetic analysis in Forest Service risk assessment (SERA 2008a).** **Authors give only a range of MMA excretion, 133.75 to 671.42 μg/worker. The highest value is for the worker that did not use PPE. Based on Figure 5 of paper, the total absorption for Worker 2 and 3 can be estimated but this would not add substantially to the analysis because only 2 workers were involved. Body weights are not given. A default of 70 kg is used.** **This study involved 3 applicators (see Table 5 and Figure 5 of study).** **This study is in EXCEL workbook but only two rates (PPE and no PPE are derived).**

Study:	**Draper and Street 1982**
Application Method:	Ground broadcast, boom spry or (in impassible areas) hand guns fed from trucks.
Worker Groups:	Applicators: Drivers and sprayers in boom spray. Workers mixed, loaded, and applied. Group A: Applied pesticides only once. Group B: Applied pesticides daily.
Pesticide(s):	2,4-D (dimethylamine salt) and Dicamba (dimethylamine salt)
Location(s):	Utah, northern
Terrain/Field:	Pasture, 42 acres
Vegetative Cover/Crop:	Grass
Protective Clothing:	No protective clothing. Workers did not wear gloves.
Application Rates:	Not clearly stated in paper.
Kinetic Considerations:	Paper discussed rapid urinary excretion of both 2,4-D and dicamba.
Biomonitoring:	Urine samples up to 72 hours after spraying.
Other monitoring:	Clothing and hand wash
Notes:	Pre-spray residues from Sprayer and Driver in Group B were associated with previous applications. **Note: Reliable worker exposure rates cannot be derived from this paper. This study was used to derive relative exposure rates in the 1998 analysis but not for absolute rates.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Dubelman and Cowell 1989**
Application Method:	Three groups: Indiana Closed-Tractor (soil incorporation), Canada, Open tractor (surface application), Closed Tractor (Missouri, NOS)
Worker Groups:	3 groups of applicators (see above)
Pesticide(s):	Alachlor
Location(s):	Indiana, Missouri, and Canada
Terrain/Field:	Agricultural field.
Vegetative Cover/Crop:	Not clearly specified.
Protective Clothing:	Gloves and goggles specified. Other clothing appears to be normal.
Application Rates:	4 lb/acre
Kinetic Considerations:	Detailed kinetic discussion in study with worker doses corrected for urinary excretion based on pharmacokinetic studies in monkeys.
Biomonitoring:	5 day urine collections.
Other monitoring:	Gauze patches.
Notes:	**See detailed individual exposure rates (µg/kg bw per lb handled) in Table VI, p. 247) of publication. While some key details are not well described, this appears to be a very good study.** **The Missouri workers may be from Cowell et al. 1987, summarized above, but this is not clear.** **Some workers were involved in only mixing-loading. These are not captured in the workbook.** **This study is included in EXCEL workbook, one worksheet per group.** **This study was not handled in the 1998 report.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Edmiston et al. 2004**
Application Method:	Foliar spray (various) or spot treatments (see Appendix 1).
Worker Groups:	Mixers/Loaders/Applicators. 113 worker-days.
Pesticide(s):	Bromacil (dispersible granule), diuron (dispersible granule), glyphosate (Roundup) , oryzalin (liquid), oxyfluorfen (emulsifiable liquid) and simazine (water dispersible granule and flowable liquid).
Location(s):	Various locations in California
Terrain/Field:	Not clear but appear to be highly variable (several sites)
Vegetative Cover/Crop:	Not clear but appear to be highly variable (several sites)
Protective Clothing:	No attempt was made to alter the normal clothing worn, personal protective equipment (PPE) used or work habits of the workers prior to or during exposure monitoring. In general, workers wore clean clothing to start each work day. Most workers wore eye protection and Tyvek® coveralls over their normal clothing during mixing/loading and application; the exception being workers #3 and #10 who wore the coveralls only during mixing/loading. Workers also usually wore chemical resistant boots and gloves while mixing and loading and during all hand-wand applications. Respiratory protection was used only while actually pouring the formulated herbicide product into the tank.
Application Rates:	Variable. See Appendix 1 of study for details.
Kinetic Considerations:	For deposition, used the following dermal absorption rates: bromacil - 1%, diuron - 5%, glyphosate - 2.2%, oryzalin - 1.9%, oxyfluorfen - 22%, and simazine 32.1%. Actual worker weights were used to calculate absorbed dosage in mg/kg.
Biomonitoring:	24-hour urine samples were collected following diuron and simazine exposure to measure absorbed dosage. For diuron, none of the urine samples contained detectable levels of parent or metabolite. Simazine urine data are in Table 10. It should be possible to combine these with Appendix 1 of the Edmiston report to get at least crude worker exposure rates.
Other monitoring:	Full-body dermal dosimetry, hand wipes, face/neck wipes and breathing zone samples
Notes:	Not clear that application methods can be directly associated with exposure estimates. See p. 8 for a listing of all application methods that were studied. The only biomonitoring with detectable levels (simazine) did not yield validated results. This study is not used quantitatively to derive rates.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Fenske 1988**
Application Method:	High volume spray (50 gal/min)
Worker Groups:	**Mixers**: Each loaded eight 1892 L (500 gal.) tanks with 5.6 kg (15 Ib) of a wettable powder formulation per tank and handled a total of 13.6 kg malathion and 2400 gm fluorescent tracer. Time worked ranged from 50 to 61 minutes. **Applicators**: Each sprayed 4 tanks, applying a total of 6.8 kg malathion and 1200 gm tracer. Time worked ranged from 72 to 122 minutes
Pesticide(s):	Malathion [O,O-dimethyl-S-(1,2-dicarbeth-1oxy-ethyl)phosphorodithioate]
Location(s):	California, central valley
Terrain/Field:	Citrus groves
Vegetative Cover/Crop:	Citrus trees (NOS)
Protective Clothing:	All workers wore baseball caps, half-mask respirators with pesticide cartridges, neoprene gloves, work boots, 100% cotton T-shirts, 65/35 cotton/polyester work pants, and either 65/35 cotton/ polyester coveralls or 50/50 cotton/polyester work shirts.
Application Rates:	18 690 L/ hectare (2000 gal./acre).
Kinetic Considerations:	Dermal exposure to applicators was correlated highly with total metabolite excretion (r=O.91). Mixer exposure was not correlated significantly (r=O.73) because of wide scatter in the data and the small number of workers monitored. Applicator exposures were more than 3 times higher than mixer exposures, reflecting the high exposure potential inherent in airblast spraying. Exposure to regions protected by gloves or clothing was more than 75% of total exposure for both mixers and applicators.
Biomonitoring:	Complete 72-hr urine samples were collected and analyzed for dimethylthiophosphate and dimethyldithiophosphate metabolites. Dermal exposure was measured through the addition or a fluorescent tracer to the tank mix, subsequent examination of the skin surface under long-wave ultraviolet light, and fluorescence quantification with a video imaging system.
Other monitoring:	Gauze patches were employed for determining relative deposition of malathion and tracer. Monitors (12) were attached to the outside of each worker's clothing at the traditional locations: head (2), shoulders (2), back (I), chest (I), forearms (2), thighs (2) and lower legs (2).(23)
Notes:	**The primary purpose of the study was to determine whether the fluorescent tracer technique could provide a valid relative measure of dermal exposure. Total urinary metabolite excretion was employed as a relative indicator of exposure upon which to judge the performance of the fluorescent tracer technique. This study was not used in 1998 analysis and is not used in the current reanalysis.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Frank et al. 1985**
Application Method:	Ariel (fixed-wing aircraft)
Worker Groups:	Mixing (2 females/1 male)/Loading (3 males)
Pesticide(s):	2,4-D iso-octyl esters (Esteron LV-600 and Pfizer 2,4-D Ester LV600) w/ concentration of 600 g/L a.e.
Location(s):	Kapuskasing and Iroquois Falls, Ontario, Canada
Terrain/Field:	Forest
Vegetative Cover/Crop:	Conifers
Protective Clothing:	**Mixers**: Tyvek disposable suit, neoprene gloves, rubber boots, hard hats, face shields, and half-face respirators. Protective clothing was worn at all times and showers were taken within 1 hour of each work period. **Loaders**: hard hat with flip-up visor, respirator with filter, non-breathing coveralls, neoprene gloves, and rubber boots (the two balloon men did not wear neoprene gloves), and all three workers changed coveralls after every 4 to 5 spray operations (i.e., every 2 to 3 days) and all showered within 1 hour after each spray session.
Application Rates:	1.1 to 2.2 kg a.e./ha (see Table 5 for details of applications rates/worker)
Kinetic Considerations:	**Mixers**: highest daily excretion of 2,4-D in urine was 0.30, 0.94, and 9.59 µg/kg bw for three workers. **Loaders** *(includes 1 worker involved in diluting and loading and 2 workers marking swaths for aerial application)*: highest daily excretion of 2,4-D in urine was 7.73, 8.37, and 22.2 µg/kg bw. **Bystander** *(directly sprayed)*: 0.44% was absorbed on based on urine analysis, and the highest daily excretion of 2,4-D in his urine was 4.75 µg/kg bw. For all 7 exposed individuals, the calculated exposure was less than the NOEL of 10 mg/kg bw/day by a large margin of safety.
Biomonitoring:	24-hour urine samples
Other monitoring:	Surface Swabs: to assess the source of indirect exposure, internal surfaces of the living quarters and vehicles were swabbed for contamination. Deposits of 2,4-D in the living quarters ranged from 0.7 to 288 µg/0.1 m^2 and 0.7 to 184 µg/0.1m^2.
Notes:	Cannot determine the amount handled by workers. Also, there appears to have been significant pre-spray exposures. As in the 1998 report, this study is not used to derive rates.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Franklin et al. 1981**
Application Method:	Ultra low volume spraying with orchard air blast equipment
Worker Groups:	Mixers/Loaders/Applicators, total of 17 in study, 16 with biomonitoring
Pesticide(s):	Guthion 50 wettable powder (azinophos-methyl)
Location(s):	South Okanagan Valley, British Columbia.
Terrain/Field:	Orchards
Vegetative Cover/Crop:	Trees
Protective Clothing:	Cotton pants, think short-sleeved cotton shirts, thick, long-sleeved coveralls, and a new respirator (individuals had option of using their own) w/new organic vapor/dust cartridges. Workers encouraged to wear whatever protective gear they felt necessary: all wore gloves (cotton, leather or rubber) and boots (leather or rubber). Four workers wore a rubber suit (coat and pants) and four others wore rubber coats. All workers used respirators. Authors assume that respiratory absorption was negligible. Operators were about 2 meters in front of the spray rig nozzles. No description is given of cabs on the rigs.
Application Rates:	1.25 lbs Guthion 50 W.P./acre (1.4 kg/ha).
Kinetic Considerations:	All workers had quantifiable levels of alkyl phosphates following exposure, and the 24-h urine samples provided a more reliable estimate than first morning voids. A high correlation was observed between 48-h alkyl phosphate excretion and amount of active ingredient sprayed.
Biomonitoring:	48-hour urine monitoring in Table 4 of study. Average amounts handled in Table 5. Blood collection and analysis: alkyl phosphate excretion and cholinesterase inhibition were also measured. No effect in any worker and AChE activity.
Other monitoring:	Air monitoring (personal air-sampling pump) and patches (gauze pads backed with impermeable plastic pinned to the underside of issued clothing).
Notes:	Rates are derived in Attachment 1. There are no significant differences in PPE groups so separate analyses are done. This is discussed in report.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Garry et al. 2001**
Application Method:	Backpack (n=7), Boom sprayer (n=4), Ariel (n=8), Skidder (n=5)
Worker Groups:	Applicators
Pesticide(s):	2,4-D (NOS)
Location(s):	Minnesota (NOS)
Terrain/Field:	Not specified
Vegetative Cover/Crop:	Not specified
Protective Clothing:	Not specified, except as a point of discussion on page 499 of the study: six of seven backpack sprayers stated they used rubber gloves and wore rubber boots as protective gear. Five of seven backpack sprayers wore a protective suit.
Application Rates:	Not specified
Kinetic Considerations:	Urine specimens obtained within 24 hr of the peak application show an exposure gradient according to application method. The relative rankings for urine 2,4-D levels by application method are back pack sprayer >boom sprayer > aerial application> skidder>control subjects. These data are consistent with the expected differences in acute exposure for manual ground application (backpack) versus mechanical (boom sprayer), closed cabin, or aerial application (helicopter or fixed wing). There is a 10-fold difference in the mean urinary concentration levels (380.1 ppb) for all backpack and boom spray applications versus the pooled values of all aerial and skidder closed-cab applications (33.2 ppb)
Biomonitoring:	First-voided morning urine and morning blood specimens obtained after an 8-hour fast at the end of the peak of the 2,4-D application season.
Other monitoring:	Not specified.
Notes:	**Table 1 compares application method, urinary 2,4-D levels, and total volume of herbicides used for exposed and control subjects. Total 2,4-D excretion not measured. Cannot be used to derive rates.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Geer et al. 2004**
Application Method:	Handheld spray gun, Aerial, Planter, Ground boom
Worker Groups:	Mixer/Loaders, Applicators, Re-entry Scouts, and Mixer/Loader/Applicators
Pesticide(s):	Various formulations of chlorpyrifos, which are study specific (see Table 1 for details) Authors also summarize data for exposure to 3,5,6-TCP (principal metabolite)
Location(s):	Not specified
Terrain/Field:	Not specified
Vegetative Cover/Crop:	Not specified
Protective Clothing:	Study specific (see Table 1 for details)
Application Rates:	Study specific (see Table 1 for details)
Kinetic Considerations:	Among the four job classes investigated, applicators were consistently ranked as the most highly exposed based on median values of both median total (inhalation and dermal combined) exposure-derived absorbed dermal doses ($EDAD_{tot}$) and biomarker-derived absorbed doses (BDAD). Results showed that doses were highly variable and differed by job class ($P < 0.05$) with median total (inhalation and dermal combined) exposure-derived absorbed doses ($EDAD_{tot}$) of 129, 88, 85 and 45 µg/application for applicators, mixers/loaders/applicators, mixers/loaders and re-entry scouts, respectively. Doses derived from the measurement of 3,5,6-trichloro- 2-pyridinol (3,5,6-TCP) in urine were similar in magnitude but differed in rank with median values of 275, 189, 122 and 97 µg/application for applicators, mixers/loaders, re-entry scouts, and mixers/loaders/applicators, respectively
Biomonitoring:	Urine samples collected 1 day prior to exposure (background), the day of exposure, and 4 days following exposure.
Other monitoring:	Passive dosimetry
Notes:	**This is a review and summary of studies data from five registrants that included exposure measurements based on both external measurements and biological monitoring were used to examine methods of assessment, routes and determinants of exposure and dose to the pesticide chlorpyrifos. Good publication but cannot get the amounts handled by each worker and thus cannot get rates.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Gosselin et al. 2005**
Application Method:	Backpack spray/tractor mounted boom spray
Worker Groups:	Applicators
Pesticide(s):	Triclopyr (Garlon 4)
Location(s):	Province of Quebec, Canada
Terrain/Field:	Workers sprayed Garlon 4® under voltage transmission lines
Vegetative Cover/Crop:	Stumps of recently cut trees /leaves under transmission lines
Protective Clothing:	Long pants, rubber boot, and a helmet (backpack sprayers)/rubber boots, glove, overalls, and a helmet (tractor-mounted boom sprayers)
Application Rates:	Not specified
Kinetic Considerations:	Measured urinary amounts of triclopyr varied between 1 and 13 mg. The absorbed daily doses were estimated from the amounts of triclopyr in urine through the use of a kinetic model that links the rates of triclopyr elimination to absorbed doses. These estimated doses were compared with the no-observed-effect level (NOEL) observed in rats: 5 mg per kg of body weight. The upper-bound estimations of the worker's daily absorbed doses were found to be 13.3% or less of the rat NOEL.
Biomonitoring:	Urine samples collected from 8 am on final workday until 6 am following day (i.e., 22 hours). (See Table 2 for amounts of triclopyr measured in 22-hour cumulative urinary samples of workers and their body weights).
Other monitoring:	
Notes:	**Last page of the study includes the differential equations from Figure 1 of the study, which illustrates a modified kinetic model developed by Carmichael et al. 1989. Study does not specify the average amount of triclopyr handled by workers or the application rate of triclopyr used in either the backpack or boom spray applications**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Grover et al. 1986**
Application Method:	Spray operations with tractor-drawn ground-rigs, involving handling, transferring, mixing, and applying the herbicide
Worker Groups:	Farmers
Pesticide(s):	2,4-D dimethylamine salt (water soluble formulation)
Location(s):	Regina, Saskatchewan, Canada
Terrain/Field:	Prairie farms
Vegetative Cover/Crop:	Wheat
Protective Clothing:	**Laundered set of standardized work clothing**: cotton work pants, a short-sleeved, cotton T-shirt, a long-sleeved, cotton overall of heavy material, and an open-mesh baseball cap One farmer wore protective (NOS) gloves None of the farmers used respirators
Application Rates:	315 to 630 g/ha a.e.
Kinetic Considerations:	Urinary 2,4-D excretion accounted for I to 2% of the potential cumulative exposure. The total calculated amount of 2,4-D deposited on the body (minus the hands) and the total amount excreted in the urine were highly correlated with the number of tank fills, area sprayed, amount sprayed, and duration of the spray operation.
Biomonitoring:	Composite 24-hr urine samples were collected beginning I day before the first spray operation and then continuously throughout succeeding operations and up to 7 days after the last spray operation. Each farmer was involved in 1 to 7 applications over a period of several days.
Other monitoring:	Air was sampled at 2.0 L/min using a portable pump for the entire spray operation (see Table 2 for details). During each spray operation, 2.4-D deposition was determined by a patch method (Franklin *et al.* 1981, 1982). (See Table 1 for details) After each spray operation, the applicator's hands were rinsed in 750 mL of 1% NaHC03 solution, which was then transferred to a polyethylene bottle and stored until analysis.
Notes:	**The hands received most of the 2,4-D (a.e.) deposited on the body (80 to 90% of the total cumulative potential exposure). The calculated dermal deposition on the rest of the body was 10 to 20% of the total cumulative potential exposure, whereas the calculated amount available for inhalation was less than 1% in most cases. Less than 2% of the calculated cumulative potential exposure was excreted in the urine**. **The total 2,4-D excretion is given in Table 4 of study. The total amount applied is given in Table 5 of study. These are used in EXCEL workbook to estimate rates. Note that the data are for the cumulative exposure/use for differing numbers of days for different workers.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Harris et al. 1992**
Application Method:	Spreading (granular formulation) or spraying (liquid formulation)
Worker Groups:	Home gardeners (applicators)
Pesticide(s):	2,4-D (granular formulation of fertilizer with1% a.i. for spring application/liquid formulation with 250 g/L 2,4-D amine for fall application)
Location(s):	Not specified, but likely to be Guelph, Ontario, Canada
Terrain/Field:	Homeowners' property
Vegetative Cover/Crop:	Turf (NOS)
Protective Clothing:	Clean overalls, gloves (NOS), and rubber boots). Tables II & III summarize applicator and bystander exposure w/respect to grams (a.i.) 2,4-D applied in protective clothing.
Application Rates:	Can be derived (see above).
Kinetic Considerations:	No significant correlation between amount of liquid or granular 2,4-D applied and applicator exposure was found (r^2 = 0.05 and 0.14 respectively). All six cases of quantifiable exposure in the non-protective group (#'s la, 2b, 4d, 5e, 6f and 7g) were directly related to spills of liquid concentrate on the bare hands or forearms. It appears that the use of protective apparel for application of a granular formulation of 2,4-D does not reduce exposure in the applicator. However, an obvious difference occurs when applying 2,4-D liquid. The use of rubber gloves and possibly overalls and rubber boots, when pouring and applying the pesticide and cleaning the equipment reduced exposure.
Biomonitoring:	96-hour urine sample immediately following application
Other monitoring:	Air sampling (inside home and downwind of the application site)
Notes:	**The original hypothesis that the use of a weed and feed formulation of 2,4-0 results in lower exposure to the applicator than a liquid formulation cannot be substantiated when protective apparel is worn.** **Most exposures are non-detects. The exposure conditions are not comparable to Forest Service applications. This study is not used.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Harris et al. 2005**
Application Method:	Spray (NOS)
Worker Groups:	Professional Turf Applicators (tasks include spray only, spray and mix, and mix only)
Pesticide(s):	2,4-D products (NOS)
Location(s):	Ontario, Canada
Terrain/Field:	Not specified
Vegetative Cover/Crop:	Not specified
Protective Clothing:	As all employers, except one, who answered the follow-up survey reported that their employees usually wore gloves while spraying, agreement with employee-reported glove use was low. If employer-reported glove wear for the entire branch is used to classify individual employees, almost half would be misclassified with the majority of those not wearing gloves (95%) classified as wearing gloves.
Application Rates:	Workers applied an average of 15.6 L of concentrated product over a 6-day period. Although the number of hours worked was not strongly related to pesticide use, the self-reported number of hours spent spraying (weed hours) showed a moderate relationship, as did the reported number of properties sprayed (see Table II for details).
Kinetic Considerations:	Those who performed spraying tasks only, had significantly higher doses of 2,4-0 when compared with those who performed both spraying and mixing, and both these groups had significantly higher doses when compared with mixers only ($P < 0.05$).
Biomonitoring:	Two 24-hour urine samples were collected from workers at the end of a work week (i.e., 6-day period).
Other monitoring:	
Notes:	**Study objective is to evaluate job titles and task classifications in relation to absorbed doses of herbicides in 98 professional turf applicators using self-reported use data and employer records. Although the seasonal pesticide use questionnaire is not included in the study, Table 1 of the study summarizes the arithmetic and geometric mean daily and total weekly doses categorized by job titles and tasks performed.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Harris et al. 2010**
Application Method:	Spray (NOS)
Worker Groups:	Employees of TruGreen
Pesticide(s):	2,4-D, MCPA, mecoprop, dicamba, and imidacloprid
Location(s):	National study: Sterling VA; Plano TX; Puyallup WA; Plainfield IL, and Salt Lake City, UT. Sites chosen to reflect geographic differences in TruGreen pesticide programs (i.e., different pesticides, concentrations, or formulations used) and the timing of applications (due to climatic conditions).
Terrain/Field:	Lawns
Vegetative Cover/Crop:	Turf (NOS)
Protective Clothing:	Questionnaires were provided to the workers to collect information relevant to pesticide use, including demographic data, smoking status, number of years employed, protective equipment worn, frequency of uniform laundering, and personal hygiene. No details provided in the study.
Application Rates:	Not specified
Kinetic Considerations:	An important strength of this study is the availability of repeated urine metabolite measures for each applicator. This allows us to examine the extent to which geographic region, spraying season, or day of work may contribute to the variability in urinary pesticide levels. The repeated measures design of this study also provided us the opportunity to characterize exposures with respect to between- and within worker variability.
Biomonitoring:	Total urine output was collected for two consecutive 24-h periods during the herbicide sprays and for four consecutive 12-h periods (insecticide), following a minimum of 3 consecutive workdays.
Other monitoring:	Not specified
Notes:	**This paper describes a repeated measures study of 135 TruGreen applicators over three spraying seasons via the collection of 1028 urine samples. These applicators were employed in six cities across the United States. Twenty-four-hour estimates (μg) were calculated for the parent compounds 2,4-D, MCPA, mecoprop, dicamba, and imidacloprid and for the insecticide metabolites MPA and 6-CNA. Descriptive statistics were used to characterize the urinary levels of these pesticides, whereas mixed models were applied to describe the variance apportionment with respect to city, season, individual, and day of sampling.** **In comparison to previously published studies in professional turf applicators in Canada (3-5), this study finds, on average, lower amounts of herbicides, specifically 2,4-D, MCPP, MCPA, and dicamba, in the urine samples. This is likely not reflective of differences in geography, spraying practices, or hygiene, but rather reflects the current study design… Because investigators measured urinary metabolites over an entire work season, and during times when only insecticides were being sprayed, they expect greater variation in the levels.** **This is an excellent study but the amount of pesticides handled by each worker is not given.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Hines et al. 2008**
Application Method:	Airblast or hand spray
Worker Groups:	Private Orchard Applicators
Pesticide(s):	Captan
Location(s):	Iowa or North Carolina
Terrain/Field:	Apple or peach orchards
Vegetative Cover/Crop:	Apple or peach trees
Protective Clothing:	PPE is included in the *Exposure intensity score* (see Appendix I on pg 164), and there are several references to PPE in the study. The various types of PPE are listed in Appendix 1; however, I am not sure how to capture that information..
Kinetic Considerations:	Applicators who hand sprayed captan in orchards had a distinctly different exposure distribution than applicators using air blast sprayers. For most external and for all biological exposure measures, captan and its metabolite THPI were detected more frequently among air blast applicators than among hand spray applicators.
Application Rates:	Not specified.
Biomonitoring:	Pre-application first morning urine and subsequent 24-h urine sample/applicator/on each sampled day. Sampling was conducted on 2 days at least 7 days apart. Parent compound and two of its human metabolites, THPI and TTCA
Other monitoring:	Personal air; hand rinse performed at the end of the handling activities on the dominant hand (except for hand spray where the hand holding the wand was sampled), and 10 dermal patches attached to clothing or skin at 10 locations. See Table 1 for results.
Notes:	**This study is primarily an evaluation of a pesticide exposure algorithm. Cannot get rates.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Jauhiainen et al. 1991**
Application Method:	Spraying with a brush saw.
Worker Groups:	Forest workers/applicators
Pesticide(s):	Roundup (i.e., 360 g/L glyphosate as isopropylamine salt) Formulation: Kantotehoste®, Kemira Inc., Finland. Final spraying solution contained 8% Roundup, 87% water, and 5% commercial carrier liquid that contained 40% isopropylamine alcohol.
Location(s):	Northeastern Finland
Terrain/Field:	Forest
Vegetative Cover/Crop:	Brush. Not otherwise detailed.
Protective Clothing:	Cotton overalls, cotton or rubber gloves, a hat or safety helmet, and rubber boots. On two rainy days, workers worn rain clothes (NOS).
Application Rates:	Average 9.8 L of solution/day/man for about 6 hours/day.
Kinetic Considerations:	During the fillings and while repairing the brush saws, skin contamination by the glyphosate mixture occurred. There was no possibility for the men to wash their hands in the field. The work is characterized as *physically heavy*. During the spraying week and also after a 3-week work period, the glyphosate concentration in the urine samples remained below the gas chromatographic detection level of <0.1 ng/µL (<1.0 µmol/L). One urine sample was further quantified with selective ion monitoring mass spectrometry and was found to contain a glyphosate concentration of 0.085 ng/µL (0.85 µmol/L). The metabolite AMPA was not detectable in the urine samples.
Biomonitoring:	Urine samples were taken at the end of each workday during the study week. A follow-up sample was taken from each of the 5 sprayers after the 3-week work period.
Other monitoring:	Air samples (collected with a portable pump) in breathing zone of workers. Sampling time varied from 1to 6 hours.
Notes:	**The herbicide mixture for each day was mixed at the field store by the sprayers themselves; they also filled the saw tanks (3.5 L) when necessary. During the fillings and while repairing the brush saws, skin contamination by the glyphosate mixture occurred. There was no possibility for the men to wash their hands in the field.** **Can derive only an average rate. This study is used semi-quantitatively in text but is not included in EXCEL workbook.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Lavy et al. 1980**
Application Method:	Backpack, tractor mist blower, and helicopter (both raindrop nozzle and microfoil boom).
Worker Groups:	**Backpack team**: mixer-supervisor and six applicators; **mist blower team**: supervisor, two tractor drivers, and a mixer; **helicopter crews**: a pilot, a mixer, a supervisor, and two flagmen.
Pesticide(s):	ESTERON 245 (4 lbs 2,4,5-T a.e./gallon formulated as propylene glycol butyl ether ester). A single batch was used for all studies.
Location(s):	South Central Arkansas Section of Southern Pine Belt
Terrain/Field:	Forest
Vegetative Cover/Crop:	Trees
Protective Clothing:	None: typical attire included long trousers, shirt (long or short sleeves) and cloth sneakers, leather shoes, or field boots. All crew members wore heats, except four members of the backpack team.
Application Rates:	**Backpack**: 1.6 lb/A (a.e. equivalent basis) in 10 gal water; **mist blower and helicopter**: 2 lb/A in 10 and 5 gal water/A, respectively.
Kinetic Considerations:	Exposure to 2,4,5-T averaged 0.0005, 0.586, and 0.033 mg/ kg body weight for inhalation, patch, and internal measurements, respectively. These measurements indicate that the worker excreting the highest amount of 2,4,5-T received exposure levels below those toxic to laboratory animals. In these studies, conducted without alterations in the habits and spray routines of field workers, none of the data revealed levels of 2,4,5-T that would appear to constitute a hazard to health. The amounts excreted were well below the toxicity levels observed in laboratory tests with mice and rats (Roll, 1971; Sparschu et al., 1971). The greatest individual exposure was considerably less than the 7.0 mg/kg for backpack sprayers which the EPA working group *(Federal Register*, 1978) had predicted for this type of spray operation.
Biomonitoring:	Total urine excreted was collected from each 12-h period 1 day prior to spraying, on the spray day, and for at least 4 days following each spray operation.
Other monitoring:	Portable air pump; six cellulose backed 10x10 cm gauze patches attached with safety pins to clothing (chest, back, upper arms, and upper thighs).
Notes:	**Although ESTERON 245 is not labeled for mist blower application, permission was granted by the EPA to allow consistency in the studies.** **Workers were selected who indicated on a questionnaire that they had not worked with 2,4,5-T for 2 weeks prior to the study.** **Worker spray habits and routines for the most part, did not include wearing gloves or special protective clothing.** **Only four patches were analyzed from each backpack crewman, since the thigh patches were not durable enough to remain intact for the duration of the spray period.** **As with 1998 report, a re-review of this study indicates that it cannot be used to derive rates because the amounts handled cannot be estimated.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Lavy et al. 1982**
Application Method:	Aerial (helicopter)
Worker Groups:	Three helicopter crews, each consisting of a pilot, mechanic, batchman-loader, supervisor, and two observers (located 25-175 yards from helicopter loading zone at time of spraying operation).
Pesticide(s):	Esteron 99 Concentrate (4 lb a.e. of 2,4-D/gal (butyl ether ester)
Location(s):	Raymond, W A, Cottage Grove, OR, and Gardiner, OR, for crews 1, 2, and 3, respectively
Terrain/Field:	100-acre tract within a larger forested area
Vegetative Cover/Crop:	Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco] in need of release from competing vegetation.
Protective Clothing:	T-1 Treatment: no special protective clothing; crews followed label directions/legal regulations and used ordinary measure of precaution. T-2 Treatment: protective clothing consisted of disposable Tyvek coveralls; pilots wore normal flying gloves and headgear; mechanics, batchman-loaders, and supervisors wore chemically impervious gloves and boots, clean hats, and goggles.
Application Rates:	Approximately 2 lb a.e./acre. Each treatment involved 100 acres treated at 2 lb/acre.
Kinetic Considerations:	External exposure was low with the highest level at 0.0911 mg/kg of body weight for a batchman in T-1. The total internal dose determined by urine analyses ranged from nondetectable to 0.0557 (in T-1) or 0.0237 (in T-2) mg/kg of body weight. Those crewmen working most closely with the spray concentrate or handling spray equipment (pilots, mechanics, and batchman-loaders) showed the highest doses. Protective clothing and good hygienic practices limited exposure. On the basis of analyses of toxic levels of 2,4-D in laboratory animals, human exposure levels in these tests were well below that which might endanger health.
Biomonitoring:	The total collection period in this study covered 2 days before the spraying occurred (to determine background levels), the spray day, and at least 5 days after each spray application.
Other monitoring:	Battery-powered air monitors; denim patches attached to crew members' clothing near bare skin areas.
Notes:	**Each crew performed two applications, which were approximately 1 week apart.** **In the first treatment (T-1), crew members made use of conventional spray techniques and performed their normal duties using ordinary precautions (Lavy, 1980). They followed label instructions and other legal regulations but received no additional guidance from research personnel.** **A second treatment (T-2), in which additional precautions were used, was conducted following the conclusion of the T-1 phase of the study.** Furthermore, **crew members were instructed to wash their hands before rest stops and meals and also to take showers and change into clean clothing soon after the spray operation.** **Using rates for Pilots (T1 and T2 together in EXCEL Workbook). Very small numbers. Poor statistics.** **Also using mixer/loaders for comparison to other studies. No remarkable difference between T1 and T2 so the results are pooled.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Lavy et al. 1987**
Application Method:	Group A: backpack sprayer Group B: Jim Gem injection bar Group C: Hypohatchet Group D: Hack-and-squirt
Worker Groups:	Ground workers (see Table 1) Four groups of 20 workers each were selected. Workers were to have had no known herbicide exposure for at least 7 d before beginning the test. Each worker applied herbicide in a 12-d, two-part test. The test included a pre-application day (day 1), an application day (day 2) on which usual application procedures (T-1) were used, 4 d of no new exposure (days 3-6), another pre-application day (day 7), a second application day (day 8) on which special precautions to minimize exposure (T-2) were taken, and 4 d of no new exposure (days 9-12).
Pesticide(s):	Group A: Weedone 170® (50% 2.4-D BEE, 50% dichlorprop BEE) as a diluted (24: 1) aqueous foliar spray. Groups B,C, and D: Tordon 101-R® (80% 2,4-D TIPA, 20% picloram TIPA) undiluted
Location(s):	Herbicides were applied at nine different forest locations in Arkansas, Oklahoma and Mississippi between May and August 1982 (Table I).
Terrain/Field:	Forests
Vegetative Cover/Crop:	Underbrush
Protective Clothing:	**T-1 Applicators**: nothing more than usual/conventional work clothes **T-2 Applicators**: New leather gloves and boots were issued to each participant on day 7, 1 day prior to the T-2 application. T-2 applicators were also given the following guidelines: (a) wear new neoprene gloves when mixing or filling containers; (b) wear new leather gloves covering the hands and wrists when applying herbicide; (c) wash hands before rest stops (before eating, using tobacco or using urine containers); (d) bathe and change into clean clothing as soon as possible after work; (e) prevent the chemical from contacting the skin and remove concentrate from skin or clothing as soon as possible; and (f) avoid walking through sprayed areas when possible (for backpack applicators in group (A). all three crews using Tordon 101-R were issued 100gal polyethylene storage containers with no-drip spigots for dispensing the concentrate into their specific application tool.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

<table>
<tr><td>Study:</td><td>Lavy et al. 1987</td></tr>
<tr><td>Application Rates:</td><td>See Table 1 for details about location/area treated (ha)/duration of application (h/man)/volume applied per worker (L)/total herbicide applied, a.e. (mg applied/kg bw/hour).
Backpack: Each worker applied 117 L (30.9 gallons) of 24:1 diluted Weedone (29.9% 2,4-D BEE and 29.3% Dichlorprop BEE). This corresponds to 1.24 gallons [30.9 gallons ÷ 25] of undiluted Weedone. A 1984 product label for Weedone (from the EPA label site) indicates that this formulation contains 1.85 lb a.e. 2,4-D/gallon and 1.85 lb a.e. dichlorprop per gallon. Thus, each worker handled about 2.294 lb a.e. [1.85 lb a.e./gal x 1.24 gallons] of each herbicide.
Hack and Squirt: These workers handled a Tordon formulation containing 2,4-D at 0.12 kg a.e./L and picloram at 0.0324 kg/L. The volumes per worker (from Table 1 in this paper) are given below along with calculations of the amounts (lb a.e.) handled by the different subgroups of workers:
<table>
<tr><th>Group</th><th>Volume Applied (L)</th><th>2,4-D (kg a.e.)</th><th>Picloram (kg a.e.)</th><th>2,4-D (kg a.e.)</th><th>Picloram (kg a.e.)</th></tr>
<tr><td>Ackerman, T1 and T2</td><td>1.9</td><td>0.228</td><td>0.06156</td><td>0.503</td><td>0.136</td></tr>
<tr><td>Pansy, T1</td><td>3.0</td><td>0.36</td><td>0.0972</td><td>0.794</td><td>0.214</td></tr>
<tr><td>Pansy, T2</td><td>3.8</td><td>0.456</td><td>0.12312</td><td>1.01</td><td>0.271</td></tr>
</table>
Kilograms converted to pounds as 2.2046 lb/kg, rounded to 3 significant figures. The pounds handled are used in the EXCEL worksheet to calculate exposure rates based on the tables in Lavy et al. 1987. No picloram values given for hack and squirt.</td></tr>
<tr><td>Kinetic Considerations:</td><td>For all application methods except that with backpacks, the T -2 treatment decreased the absorbed dose. During both T-t and T-2 the clothing of backpack sprayers often became saturated with spray, dew or perspiration, and these workers received a higher absorbed dose of 2,4-D (0.04-0.24 mg/kg body weight) than did workers in other crews. The absorbed dose of dichlorprop ranged from undetectable to 0.18 mg/kg. Hypohalchet workers received a greater dose than did injection bar or hack-and-squirt workers. The absorbed dose of picloram ranged from below the limit of dectation to 0.02mg/kg. If equal dermal penetration of 2,4-D and picloram is assumed, this represents much less dermal absorption than would have been predicted from the relative amounts of 2,4-D and picloram in Tordon 101-R®</td></tr>
</table>

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Lavy et al. 1987**
Biomonitoring:	The total urine output of each worker for each day during the l2-d test was collected (6 d each for both T-I and T-2). The total urine excreted in 24 h was collected since the volume of urine excreted varies widely and herbicide excretion patterns can differ from person to person. The first urine void of the morning was included with the urine collected the previous day to complete a 1-d sample. The second urine void of the day began the new sample collection period. Each urine sample was analyzed for herbicide and creatinine. The absorbed dose in both T-l and T-2 was the amount of herbicide measured in the total urine output for each worker for *5* d (on the day of application and during the 4 d following the day of application). This dose represents approximately 95% of the total absorbed dose (8). To guard against potential measurement errors resulting from inadvertent pre-exposure, background levels of herbicide were obtained by analyzing urine collected from each participant on days 1 and 7, i.e., the days prior to the application days for T-l and T-2.
Other monitoring:	
Notes:	The objective of this study was to determine the dose received by ground workers applying 2,4-D, dichlorprop and picloram by four methods. The amount they received during conventional application (hereafter referred to as T-I) was compared with that received when special safety procedures were followed, including wearing new leather gloves and new boots (hereafter referred to as T-2. Soap and water were always available for washing during T-2 applications. These items were sometimes present during T-l if the practice was customary for a particular crew. **Working Note: Per discussions with Paul Mistretta, only the backpack and hack-and-squirt applications are relevant. Because of the nature of the "protective equipment" (e.g., leather gloves rather than chemically resistant gloves), the absolute rates from this study are not relevant to current practice. The analysis of backpack vs hack-and-squirt, however, may be useful in deriving relative exposure rates for hack-and-squirt.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Lavy et al. 1992**
Application Method:	Backpack (or other directed foliar) and ground broadcast. Nursery applied approximately 2 gal of a 1:40 dilution of Roundup as many as 8½ days during the season In addition, glyphosate was occasionally applied to nearby weedy vegetated areas by tractor drivers using conventional tractor drawn spray equipment.
Worker Groups:	Ashe Nursery: applicators and weeders Phipps Nursery: applicators
Pesticide(s):	Roundup® Although Roundup® cannot be applied to conifer seedlings without phytotoxic effects, this compound was used at the Ashe Nursery to control adjacent weeds within the bed. This was accomplished by placing a 290 ml, 2.5 X 3.5 cm cylindrical metal shield (which served as a spray chamber) over the small weeds to be sprayed. The shield protected adjacent conifer seedlings in the bed while an individual weed was sprayed by manually depressing a trigger which released approximately 0.5 ml of the spray mix.
Location(s):	Ashe Nursery near Brooklyn, MS, and at the Phipps Nursery near Roseburg, OR.
Terrain/Field:	Conifer seedling beds
Vegetative Cover/Crop:	Conifer seedlings
Protective Clothing:	Tractor drivers wore protective coveralls and rubber gloves; essentially all of the applicators and weeders wore rubber gloves. Worker No. 6 (see Table 3) wore rubberized cotton gloves. Boots are mentioned only in the study abstract, which indicates: *The applicators, weeders, and scouts monitored all wore normal work clothing, which for applicators was a protective suit, rubber gloves and boots*.
Application Rates:	See Table 1 for details of kg applied/ha, ha treated
Kinetic Considerations:	Even though tractor drivers wore special clothing, analyses of patches and hand washes revealed that they received more exposure than did the scouts and weeders (Table 3). Since all workers, except the scouts, had positive hand washes and yet all wore gloves, it is apparent that total protection was not achieved or that hands became contaminated while removing the gloves at the end of the day. To decrease this exposure it is suggested that the outside of the rubber gloves be washed off before removing them. Urine analysis, did not reveal any positive samples. The lower limit of method validation for glyphosate in the urine samples was 0.01 µg/ml.
Biomonitoring:	Total urine samples were collected daily from each worker. Collections were initiated prior to the occurrence of potential exposure and continued well into the season, with final tests performed at least 8 weeks after glyphosate was last applied. Only the applicators driving tractor drawn equipment had a definitive "exposure day." Since weeders and scouts potentially had numerous days during which exposure could have occurred as they re-entered treated areas a continuous total urine collection scheme was prescribed for all weeders and scouts for 12 consecutive weeks. After this intensive 12-week collection period, a 24-h sample was collected each Wednesday from each worker for the next *5* months. By summing the total glyphosate present in urine over this period, a total absorbed dose for each worker for the entire season could be calculated. *Continued on next page.*

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Lavy et al. 1992**
Other monitoring:	Cotton gauze patches were attached 1 day/week to workers' clothing during their regular field operations. The location of the nine gauze patches per worker were as follows: two patches near the ankles, two on the front of the thighs, two on the lower forearms [two on the lower forearms inside the shirt for some workers}, one on the upper chest, one on the upper back near the neck, and one on the hat. Hand washes: A hand wash from the workers was taken at the end of each day patches were worn by using 250 ml of 10% methanol/ 90% water solution. As a measure of the total passive exposure occurring to each worker the amount of glyphosate present in the wash from both hands was added to that found from the patch analyses. Dislodgeable residues: Three randomly selected samples of approximately 100 g of fresh conifer seedlings were taken twice weekly at Ashe Nursery from May through August. The amount of glyphosate removed by shaking 100 g of fresh conifer seedlings with 250 ml of water for 45 sec was deemed to provide a realistic measure of "dislodgeable residues
Notes:	No detectable glyphosate in urine. Can estimate a plausible upper bound rate as in SERA (2010a). Handle semi-quantitatively in text.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Lavy et al. 1993**
Application Method:	Tractor-drawn sprayers
Worker Groups:	Applicators, weeders, scouts, and packers
Pesticide(s):	Benomyl (Benlate); Bifenox (Modown); Captan; Carbaryl (Sevin); Chlorpyrifos (Dursban), Fenvalerate (Pydrin); and Glyphosate (Roundup)
Location(s):	Ashe, MS, Phipps, Or, and Stone, OR
Terrain/Field:	USDA Forest Service Nurseries
Vegetative Cover/Crop:	Conifer seedlings
Protective Clothing:	During the monitoring period all were instructed to perform their duties in a normal manner, dress in normal work clothing, and follow the regular prescribed safety practices. Weeders pulling small weeds by hand commonly did not wear gloves. At Ashe Nursery**,** weeders used small hand-held sprayers with shielded nozzles to selectively apply glyphosate to weeds without contacting seedlings in the beds; these weeders were also classified as applicators. Many packers also wore leather or rubber gloves. Tractor-driver applicator-mixers. following label guidelines and USDA Forest Service instructions, wore disposable protective clothing, rubber gloves, and boots.
Application Rates:	Benomyl (0.56 kg a.i./ha); Bifenox (3.4 kg a.i./ha); Captan (2.2 kg a.i./ha); Carbaryl (0.56 kg a.i./ha); Chlorpyrifos (1.1 kg a.i./ha); Fenvalerate (0.11 kg a.i./ha), and Glyphosate (0.11 kg a.i/ha)
Kinetic Considerations:	Based on the low frequency of positive urine samples in the study, the low levels of metabolites when they were found, their apparent rapid excretion rate and the No Observed Effect Level (NOEL) data, furnished from other sources, nursery worker exposure to pesticides in these conifer nurseries is below health threatening levels. The three pesticides producing positive urine samples included one fungicide (benomyl), one herbicide (bifenox), and one insecticide (carbaryl). No herbicides were used at the Stone Nursery. Carbaryl was only used in the Ashe Nursery. Data in Tables 11, 12, and 13 provide an individual exposure log for each worker with respect to the urine samples as well as positive patch and hand rinse samples. For the other four biologically monitored pesticides in this study where no positive samples were produced the following number of applications had been made: 14 (glyphosate). 11 (captan). 13 (fenvalerate), and2 (chlorpyrifos). Overall, a pesticide metabolite was found in 42 of the 3134 samples analyzed.
Biomonitoring:	For weeders and scouts, a total daily urine collection was made for 12 consecutive weeks. Prior to initiating a daily urine collection for a continuous 12-wk period, one total24-h urine sample was collected from the weeders and scouts every Wednesday beginning in April or May. A similar weekly sampling pattern fallowed the 12-wk intensive sampling period
Other monitoring:	Dislodgeable pesticide residues were measured for each of the pesticides used at each of the nurseries. In addition, gauze patches attached to worker clothing were used as passive dosimeters to assist in providing an estimate of the amount of dermal exposure occurring. Hand rinses were taken from each worker during the day(s) that patches were worn.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Lavy et al. 1993**
Notes:	This study includes multiple pesticides; however, the authors indicate that due to the magnitude of the study, biomonitoring was performed at only three of the five nursery locations and on only seven of the pesticides. The total absorbed doses for individual workers for benomyl, bifenox, and carbaryl are given in Table 15 of study. The worker statistics (bw, job etc) are given in Table 3 of study. While job categories are given, the amounts handled for each worker are not provided. This study cannot be used to derive rates.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Libich et al. 1984**
Application Method:	Spray guns mounted on pickup trucks or ATVs or backpack sprayers.
Worker Groups:	Applicators
Pesticide(s):	Tordon 101 (2,4-D/picloram as mixture of TIPA salt) as a 463 g/L emulsifiable concentrate in the ratio 4:1 respectively of the active ingredients. 2,4-D, dichlorprop mixture was a 480 g/L emulsifiable concentrate of the active ingredients in the ratio of 1:1. Spray solutions used in the field consisted of one part formulation to 100 parts water for vehicle mounted equipment and 1 part herbicide formulation to 16 parts water for backpack sprayers.
Location(s):	1979: Kapuskasing and North Bay, ON 1980: Kapuskasing, North Bay, Tweed, and Walkerton, ON
Terrain/Field:	Power line corridors (Rights of Way)
Vegetative Cover/Crop:	Woody growth
Protective Clothing:	Clean coveralls daily and the general use of gloves. The type of gloves are not specified. Wash-up facilities were provided in the field for spills at the end of each day.
Application Rates:	Not specified
Kinetic Considerations:	Dermal absorption was found to be the major absorption route being up to 50 times greater than exposure by the inhalation route when using a hand gun sprayer, even with the mist blower herbicide application method, dermal absorption was 4 and 11 times greater than exposure by the inhalation route.
Biomonitoring:	Urine sampling included a pre-operation sample for baseline, several weekly samples taken on Thursdays before or after the air sampling week, and daily samples during the week of air monitoring. Each urine sample consisted of an AM and PM samples which were later combined to from a daily sample.
Other monitoring:	Air from the breathing zone was drawn through these sorption tubes at the rate of 200 mL/min by battery operated personal sampling pumps. Each member of the spray crew was sampled for 5 consecutive days during the spray operations which averaged 5 hours per day.
Notes:	**The major limitation in this study is that the amounts handled by the worker groups are not specified. In SERA (1998), rates were estimated based on assumptions of amounts handled. This approach does not appear to be justified and this study is not used quantitatively in the current analysis.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Lunchick et al. 2005**
Application Method:	Applicators employing an injection method for the test material used a sweep injection boom attached to and followed by disc equipment, which was in turn followed and attached to a set of wheel packers in the back of the rig. Applicators employing a topical application method for the test material used a Terra-Gator-type (Ag-Chem, Duluth, GA, USA) ground boom rig. NOTE: This application method may be only marginally useful to Forest Service.
Worker Groups:	Mixers-loaders and applicators. 20 males. Three workers monitored more than once with a 4 day interval between observations.
Pesticide(s):	Mocap® EC, a nematicide insecticide (active ingredient is Ethoprop; O-ethyl-S,S-dipropyl phosphorodithioate; CAS no 13194-48-4; Bayer CropScience, RTP, NC, USA)
Location(s):	13 separate sites in a potato-growing region in the south-central part of Washington State in the northwestern United States.
Terrain/Field:	Vacant fields in which potatoes would soon be planted.
Vegetative Cover/Crop:	
Protective Clothing:	Workers wore a variety of clothing of their choosing to meet or exceed the worker protection standard (3) requirements for handling Mocap EC. The requirements for a closed mixing-loading system are long sleeved shirt and long pants, shoes, socks, chemical-resistant apron, and protective gloves. The workers typically wore additional clothing, such as rubber boots, coveralls over shirt and pants, jackets, goggles (when mixing), and occasionally respirators. The requirements for the applicator are long pants and a long-sleeved shirt inside the cab with chemical-resistant coveralls. gloves, and a respirator available for when work is done outside the tractor.
Application Rates:	1.1 to 2.2 kg a.i./ha
Kinetic Considerations:	The monitored absorbed doses found in this study should be considered representative of the range of potential absorbed doses resulting from ethoprop use with engineering controls under the conditions of this study. Ethoprop assayed as MIM (O-ethyl S-propyl phosphorothioate), an ethoprop metabolite, with conversion back to ethoprop equivalents.
Biomonitoring:	Urine collection was conducted for the 24-hour period prior to the initiation of the study and then for 12-hour intervals for 4 days after participation in the study was begun [day 0 (day of mixing-loading-application), then for 3 additional days].
Other monitoring:	Inhalation exposure monitoring was performed with personal samplers
Notes:	As a further check on the validity of the urine collection, creatinine was also analyzed in all the samples. This sampling procedure provides an overestimate for the calculation of a single daily exposure for all the workers that continued to work with ethoprop during the 3 days following their first day's exposure. This overestimate was unavoidable since several of the workers were required to continue making applications to other farms in the area as part of their regular job. **The amount of active ingredient handled per day and the absorbed doses for different groups of workers are given in Table 1. These values are used directly in EXCEL workbook.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Middendorf 1992a**
Application Method:	**Streamline Basal Bark**: herbicide mixture sprayed from a pressurized backpack through a hand held pray gun system (Diaphragm Gunjet 30 or Piston Gunjet 30.)
Worker Groups:	Applicators/Mixers (trained volunteers)
Pesticide(s):	Garlon ™4: (butoxyethyl ester of triclopyr) in 2.5 gallon containers (a.i. = 4 lbs. a.e./gallon) Mixture: 20% Garlon™4/10% Cide-Kick (adjuvant)/Diesel fuel (solvent) The Garlon™ 4 used at Sites 1and 2 was from the same batch; the herbicide used at Site 3 was from a different batch
Location(s):	The three locations for the study were in the Daniel Boone National Forest of south-central Kentucky. The application sites were near London, Somerset, and Stearns, Kentucky.
Terrain/Field:	Forest
Vegetative Cover/Crop:	Brush: Stems 8-10 feet tall (see Table 1) **According to Material and Methods, at Site 1, The brush averaged about 2 to 3 feet tall and the density was low; at Site 2, The brush averaged about 6 feet high and was denser than at Site 1, and at Site 3, The brush typically ranged from 8 to 10 feet high and the density of underbrush was also similar to site 2.**
Protective Clothing:	The Forest Service supplied and required all volunteers to wear tightly woven, pre-washed, long-sleeved shirts and long pants. All volunteers also wore leather boots and a hard hat. Gloves were available for use at each site during applications; their use was required when handling the concentrate. The clothing met the Forest Service Guidelines. **Site 1:** All volunteers wore new cotton with leather palm gloves while applying. While mixing the concentrate, Norton Latex gloves (model # not available) were worn by the mixer. **Site 2:** None of the volunteers wore gloves while applying. The mixer wore Edmont Model 4-414 gloves while mixing. **Site 3**, All volunteers wore Best Sanitized gloves (model # not available) while applying. (See Table 2 of study details about gloves worn).
Application Rates:	**Site 1**: 1.92 lbs a.i/acre (each worker assumed to have applied 4.8 lbs a.i. as a.e and spent 5 hours in the field either mixing or applying the herbicide mixture). **Site 2**: 1.6 lbs a.i/acre (each worker assumed to have applied 4 lbs a.i. and a.e. and spent approximately 4 hours applying the herbicide mixture) **Site 3**: 1.11 lbs a.i./acre (each worker is assumed to have applied 4.5 lbs a.i. as a.e. and spent approximately 4 hours mixing or applying the herbicide mixture)
Kinetic Considerations:	Triclopyr is rapidly excreted in urine. The 5-day urine samples would be adequate to assess absorbed dose. See SERA (2011c) for more detailed discussion of pharmacokinetics.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Middendorf 1992a**
Biomonitoring:	Volunteers were instructed to collect all urine voids for 5 days: the day before application, the day of application, and for 3full days after application. The first sample each day was generally collected from the first void in the morning through the time the volunteer left work that day, approximately a 10-hour period. The second sample was generally collected from the time the volunteer left work through the first void the next morning.
Other monitoring:	Patch samples (see Figure 1) to estimate skin deposition, air samples to estimate inhalation exposure (see Figure 1), and hand-wash samples to estimate skin exposure on the hands.
Notes:	**This study is covered at some length in the Forest Service risk assessment on triclopyr (SERA 2011c). There are three entries in the EXCEL workbook: all workers, workers with gloves, and workers without gloves.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Middendorf 1992b**
Application Method:	Directed foliar spray from a pressurized backpack through a hand held spray gun system. In general, a group of applicators walks through an area spraying the foliage of undesired plant species.
Worker Groups:	Mixers/Applicators
Pesticide(s):	Garlon 4: (butoxyethyl ester of triclopyr) in 2.5 gallon containers (a.i. = 4 lbs. a.e./gallon) diluted to a 3% solution **Site 1 (Clarksville)**: Mixed concentrate in 50 gallon drum/applied with wand applicator (no adjuvant) to 24 acres **Site 2 (Blue Ridge)**: Mixed concentrate into backpack/applied with Model 30 Gunjet (no adjuvant) to 21 acres **Site 3 (Chatsworth)**: Mixed concentrate in 5 gallon jugs/applied with Model 30 Gunjet (adjuvant: 2.5 oz Cide Kick/3 gallons mix) to 7.5 acres **Site 4 (SRP)**: Mixed concentrate into 50 gallon drum/applied with Model 30 Gunjet or Wand applicator (adjuvant: 16 oz Cide Kick/50 gallons) to 18 acres
Location(s):	The first three locations for the study were in the Chattahoochee National Forest of northern Georgia. The application sites were near Clarkesville, Blue Ridge, and Chatsworth, Georgia. A fourth site (on the Savannah River Plant property near Aiken, S.C.) was later added to the study in which the study team dictated the conditions for application
Terrain/Field:	Forest
Vegetative Cover/Crop:	**Site 1**: low height (2 to 3 ft) low density brush **Site 2**: medium height (4 to 8 ft) medium density brush **Site 3**: medium to very tall (4 to 12 ft) high density brush **Site 4**: medium to tall (4 to 6 ft) medium density brush
Protective Clothing:	The Forest Service supplied and required all volunteers to wear tightly woven, pre-washed, long-sleeved shirts and long pants. All volunteers also wore leather boots and a hard hat. Gloves were available for use at each site during applications; their use was required when handling the concentrate. The clothing met the Forest Service guidelines. At **site 1**, All volunteers wore *new leather gloves* while applying. While mixing the concentrate, Edmont Everflex model 13-102 gloves were worn by the mixer and his assistant. [Note: Rates at this site are somewhat lower than at Sites 2 and 4 – i.e., latex or nitrile gloves.] At **site 2**, All volunteers wore latex gloves while applying and mixing. At **site 3**, Two of the five volunteers wore nitrile gloves while applying. The other three crew members did not wear gloves. The mixer was observed during one mixing period not wearing gloves while handling the concentrate and was immediately instructed to put on a pair of nitrile gloves. At **site 4**, All volunteers wore nitrile gloves while mixing and applying herbicide.
Application Rates:	**Site1**: 0.43 lbs a.i./acre **Site 2**: 0.63 lbs a.i./acre **Site 3**: 0.96 lbs a.i./acre **Site 4**: 0.46 lbs a.i./acre
Kinetic Considerations:	The geometric mean of doses was 1106 µg, a factor of 158 times less than the No Observed Effect Level (NOEL) observed in animal studies, Six of the twenty-one volunteers had doses greater than 1% of the NOEL. Of the six, only one did not have an attributable, controllable reason for the dose.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Middendorf 1992b**
Biomonitoring:	Volunteers were instructed to collect all urine voids for 5 days: the day before application, the day of application, and for 3 full days after application. The voided urine for each volunteer was pooled into two samples for each 24-hour period. *Continued on next page.*
Other monitoring:	Exposure monitoring of air concentrations in the breathing zones and body surface deposition were used to estimate inhalation and dermal exposures of volunteers. Inhalation exposures were estimated by using standard air sampling techniques to collect air from the breathing zones of volunteers; dermal exposures were measured using patches attached to clothing and hand rinses
Notes:	**After review of the product label, one of the sites (Site 3) was considered to be occupied by vegetation taller than recommended for directed foliar applications. Also, personal protective equipment was not used in accordance with Forest Service Guidelines. A fourth site was later added to the study in which the study team dictated the conditions for application.** **Note: This study is also presented in Middendorf et al. 1992 but Middendorf 1992b (this entry) is the full study.** **The only serious limitation is that individual BWs are not given. As in SERA (2011c), an average body weight of 83.1 lbs is used from Middendorf (1992a).** **The following entries are included in the EXCEL workbook:** **All workers all sites** **Sites 1, 2, and 4 (medium to low brush height)** **Sites 3 (high brush)** **Site 1 (leather gloves)** **Sites 2 and 4 (nitrile or latex gloves)** **Working Note: The results of this study suggest that leather gloves may be as effective as nitrile and latex gloves.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Middendorf 1993**
Application Method:	Directed foliar. Pressurized backpack with spray gun.
Worker Groups:	3 crews. Workers both mixed and applied.
Pesticide(s):	Glyphosate (Roundup, 2.3%)
Location(s):	Forest sites in Clayton, GA, Aiken, SC, and Edgefield, SC.
Terrain/Field:	Site 1: 18 acres. Brush height, 2 to 3 feet. Brush density low. Site 2: 18 acres. Brush height, 4 to 6 feet. Brush density not specified. Site 3: 13 acres. Brush height, 4 to 6 feet. Brush density not specified.
Vegetative Cover/Crop:	**Not well described. See above.**
Protective Clothing:	Tightly woven, pre-washed, long-sleeved shirts and long pants. All volunteers also wore leather boots and a hard hat. Gloves were available for use at each site during applications; their use was required when handling the concentrate. The clothing met the Forest Service Guidelines. Latex gloves worn during mixing. Site 1: Two of five workers wore gloves while spraying. Site 2: Two of five workers wore gloves while spraying. Site 3: All workers wore cotton gloves. See Worksheet Middendorf 1993 for individual data.
Application Rates:	0.18 to 0.35 lb a.i./acre
Kinetic Considerations:	Recovered glyphosate in urine multiplied by 1.19 based on kinetic study in monkeys to account for fractional excretion of glyphosate in the urine. For non-detects, the amount in urine taken as one-half the minimum detection limit for the sample.
Biomonitoring:	Complete 5-day urine collections following application.
Other monitoring:	Also did standard deposition study.
Notes:	One worker (worker C at site one is censored from analysis because the urine sample was missing. Equipment failure generally led to larger exposures. The volunteers who had leaks on average had a slightly higher geometric mean dose than the volunteers who did not have leaks.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Nash et al. 1982**
Application Method:	Aerial (WA) and Ground Broadcast (ND)
Worker Groups:	Pilots (WA) and Mixers/Loaders (ND)
Pesticide(s):	2,4-D (NOS)
Location(s):	Ariel (Eastern Washington) Ground (Eastern North Dakota)
Terrain/Field:	Wheat fields
Vegetative Cover/Crop:	Wheat
Protective Clothing:	No suggestion or attempt was made to alter work habits or clothing worn by the workers.
Application Rates:	Ariel – not specified Ground – 0.25 to 0.50 lbs /acre
Kinetic Considerations:	The urinary excretion level of 2,4-D by aerial and ground workers was not associated with age, weight, or type of clothing. However, 2,4-D excretion was associated with job for both aerial and ground workers and with amount of 2,4-D applied and with hours of exposure for ground workers. Presumably this reflects the amount of 2,4-0 taken into the body by absorption through the skin, inhalation, and possibly some ingestion.
Biomonitoring:	Each participant in both worker groups were asked to provide a one-time single voided urine sample prior to experimental initiation. Individual workers from aerial applications provided 24-hour urine samples on approximate alternate days for the continuous 2,4-D application. This represented what may be considered a typical situation during the height of 2,4-D applications to wheat in Eastern Washington Individual workers from ground applications provided six consecutive day 24-hour urine samples for a 1-week period following a single 2,4-D application
Other monitoring:	Not specified
Notes:	**The total excretion of 2,4-D and the amount handled by each worker is given in Table IV for aerial workers (M/L and pilots) and Table V for ground broadcast applications. These are used directly in the EXCEL workbook. For aerial applications, the M/L and pilots are handled separately. Workers are omitted from the analysis if the amount handled is not given.** **For pilots, the analysis included one pilot who also mixed and loaded. The rates for this pilot is only modestly higher than the rates for other pilots.** **For ground applications, separate analyses are conducted for applicators, mixer-loader/applicators, applicators & mixer/loader/applicators, and mixer/loaders. At total of 26 rigs were involved in study, 10 with cabs and 16 without cabs. Results are not reported separately for these subgroups.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Nigg and Stamper 1983a**
Application Method:	2,4-D was applied with a Bean adjustable handgun with trigger grip.
Worker Groups:	Airboat Aquatic Weed Applicators While one crewman drove the airboat, the other applied 3-4 tanks over a 1 hr period. The men then changed places, so that each subject applied 2,4-D and operated the airboat for approximately 1 hr while exposure was monitored
Pesticide(s):	2,4-D dimethylamine salt (99.9% pure) Eight ounces of Nalco-Tro1tVdrift additive (Nalco Chemical Co., Chicago, IL 60638) was added to each 50 gallons to control drift.
Location(s):	Polk County Florida
Terrain/Field:	Water (NOS)
Vegetative Cover/Crop:	Water hyacinth
Protective Clothing:	Not specified
Application Rates:	0.038 lbs a.i./gallon
Kinetic Considerations:	Estimated total body exposure averaged 15± 2 mg/hr, of which 74% was to the legs and feet with an additional 18% to the hands and arms. Estimated respiratory exposure was about 0.03% of the total body exposure. 24-hr urinary 2,4-D ranged from 0.190 to 0.645 mg.
Biomonitoring:	24-hour urine samples were taken from noon of each monitoring day until noon of the following day. One week after spraying stopped three consecutive 24-hour urine samples were collected.
Other monitoring:	During the exposure period each man wore α-cellulose pads and a personal air sampler
Notes:	From the pattern of exposure observed here, a practical reduction would be afforded by the use of disposable coveralls and hand protection. Exposures reported here are low and would not appear to represent either acute or chronic hazard to Florida handgun 2,4-D applicators **Nigg and Stamper (1983) monitored the exposure of four workers in the application of a liquid formulation of 2,4-D amine for the control of water hyacinths using airboat handguns. Each worker applied 3 to 4 tanks, 50 gallons/tank, of a 2,4-D solution containing 0.0046 kg a.i./L or 0.0038 kg a.e./L (0.0046×0.861). Taking 3.5 tanks as the average, each worker thus handled 2.52 kg a.e. 2,4-D [3.5 tanks × 50 gallons/tank × 3.785 L/gallon × 0.0038 kg a.e./L] or 5.6 lbs a.e. 2,4-D [2.52 kg × 2.2046 lbs/kg]. Absorbed dose was monitored as total urinary elimination of 2,4-D over a 24 hour period. This might have underestimated total excretion.** **The body weights of the workers are given in Table 1, p. 209. The 24-hour urine collections are given in Table 4, p. 213.** **Taking 3.5 tanks as the average, each worker thus handled 2.52 kg a.e. 2,4-D [3.5 tanks × 50 gallons/tank × 3.785 L/gallon × 0.0038 kg a.e./L] or 5.6 lbs a.e. 2,4-D [2.52 kg × 2.2046 lbs/kg].** **The above data are used to calculate worker exposure rates in the EXCEL workbook.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Spencer et al. 1997**
Application Method:	Swath: belly grinder (a spreader strapped to the torso)
Worker Groups:	Applicators and flagger/loaders
Pesticide(s):	Pronone® 10G (granular hexazinone)
Location(s):	National Forest (four sites) Eldorado, Amador; Eldorado, Pacific; Lassen, Hat Creek; Lassen, Almanor
Terrain/Field:	Varied from flat to 20% slope
Vegetative Cover/Crop:	Target species included ceanothus, gooseberry, lupine, grasses, manzanita, and chinquapin.
Protective Clothing:	Standard work clothing and personal protective equipment (PPE) at all sites included a long-sleeved or short-sleeved shirt (knit or woven fabric), denim pants, socks and leather high-top work boots, hard hat and knit gloves, generally worn over vinyl exam gloves. Some workers wore only one pair of gloves, either knit or vinyl; latex or leather gloves were observed occasionally. Use of eye protection and paper dust masks was intermittent. Workers wore jackets if the morning was cold and often removed them as the temperature warmed.
Application Rates:	Pronone®10: 19 to 30 lbs/acre Hexazinone: 1.9 to 3.0 lbs/acre
Kinetic Considerations:	Study data indicated that the EIS surrogate model under-estimated exposure for workers using belly grinders to apply granular hexazinone. The EIS estimated margins of exposure (MOE), for systemic effects (normalized for observed application rates) for workers handling and applying hexazinone were 144, 74 and 58, respectively, for realistic, conservative and worst case exposure scenarios. Study estimates indicated that, on average, crews received nearly three times (2.8) greater exposure than the EIS worst case estimate. Applicators were more highly exposed than flagger/loaders. Applicator exposures averaged 3.5 times the worst case estimate; flagger/loader exposures were approximately equal to the realistic exposure estimate and averaged only 0.28 times the worst case estimate. Dermal exposure accounted for 74% of applicator EAD and inhalation contributed 26% to EAD. For flagger/loaders, the dermal and inhalation routes contributed 88% and 12%, respectively, to EAD. The upper body received the greatest exposure.
Biomonitoring:	None.
Other monitoring:	Dermal exposure monitoring was conducted using long-sleeved cotton T-shirts and knee-length socks, which were worn next to the skin for the duration of the workday. dermal exposures to the hand and face/neck regions were evaluated by using commercial baby wipes to wipe these regions at intervals throughout the workday. Personal air pumps drew air through a 37-mm diameter glass fiber filter to measure breathing zone concentrations of hexazinone
Notes:	**This study does not provide biomonitoring data, but may be useful for determining relative exposure rates. The study does provide estimated absorbed doses.** **The study objective was to estimate dermal and inhalation exposure of workers who apply granular hexazinone (Pronone® 10G) to National Forest Service (USFS) lands and to compare these estimates to those contained in the USFS Environmental Impact Statement (EIS).** **This is the final report. The Forest Service hexazinone risk assessment had only the draft report.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Spencer et al. 2000**
Application Method:	Directed foliar backpack. tractor moved throughout the treatment plot so the applicators could refill their sprayers on-site.
Worker Groups:	Contract applicators. Ten male applicators and several baggers. All spoke Spanish as their primary language.
Pesticide(s):	Triclopyr BEE (Garlon 4 was present in each batch mix at 1% by volume with 1% surfactant by volume and 0.5% drift retardant by volume.)
Location(s):	Eldorado National Forest, California
Terrain/Field:	Moderately to steeply sloping terrain.
Vegetative Cover/Crop:	Ponderosa, Jeffrey, and Sugar pine, and White and Douglas fir on the Eldorado National Forest that had been planted about 3 months prior to study. Target foliage was approximately 2 - 3.5 feet; density was low to moderate.
Protective Clothing:	Typical work clothing consisted of hard hats, leather boots with laces, one shirt layer, socks, jeans and clean coveralls, either commercially laundered cotton/polyester or disposable TYVEK suits. They wore no outer clothing over their coveralls. The workers unzipped their coveralls partially or totally to keep cooler as they carried the heavy (approximately 40 lb when full) backpack sprayers while moving up and down hillsides during the warm summer days. Workers wore latex or knit gloves on either the right hand, which held the spray wand, or on both hands.
Application Rates:	1 lb a.e./acre
Kinetic Considerations:	To adjust for incomplete urine collection, Spencer et al. (2000) adjusted all urine volumes to 1400 mL.
Biomonitoring:	Attempted to obtain complete urine collections over each 24-hour period, the actual urine collections were highly variable (Spencer et al. 2000, Appendix 1, Table 4), ranging from 30 to 1400 mL.
Other monitoring:	Clothing exposure dosimeters, consisting of long-sleeved T-shirts (100% cotton, pre-washed), and knee-length athletic socks (80% cotton/20% polyester), measured triclopyr BEE residues. Exposure to both the face/neck regions and to the hands beneath the gloves was measured by skin wipes. Inhalation exposure to triclopyr BEE aerosol was measured by glass fiber filters attached via vinyl tubing to a personal air pump.
Notes:	This study is covered in some detail in the 2011 Forest Service risk assessment on triclopyr. See Table 14 of RA for details. These data are included in EXCEL workbook. See the plot of Day 1 vs Day 2. Correlation suggesting work habits in different workers.

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Wojeck et al. 1981**
Application Method:	Tractor-drawn airblast sprayer
Worker Groups:	Mixers and Applicators
Pesticide(s):	Ethion
Location(s):	Florida
Terrain/Field:	Citrus groves
Vegetative Cover/Crop:	Citrus trees
Protective Clothing:	All workers at Location I wore single unit denim coveralls which were laundered daily. The men showered and changed clothes at the end of the day. Workers at Location 2 wore long- or short-sleeved shirts and long trousers, which were often worn several days before being laundered. Showers were available at Location 2, but were not used. All men wore heavy shoes or boots and most wore hats. None of the participants normally wore gloves.
Application Rates:	Spray mixture at Location 1 contained a 0.06% ethion solution [6.0 L ethion (46.5% EC), 47.2 L FC 435-66 oil, and 1.2 kg of benomyl (50% WP applied in 4732 L water/ha. Spray mixture at Location 2 contained a 0.09% ethion spray solution [8.9 ethion (46.5% EC), 47.4 L FC 435-66 oil, 516 kg copper hydroxide, and 4732 L water/ha.
Kinetic Considerations:	Respiratory exposure was less than 1% of the total exposure. Hands represented 42% of the total body exposure for applicators and 76% for suppliers. At one location, suppliers exhibited a larger decrease in ChE activity than applicators. This difference appeared related to the higher mean dermal ethion exposure to suppliers. Acute symptoms of organophosphorus poisoning were not observed. The total percent/he of the probable human dermal LD_{50} was very low in *all* cases.
Biomonitoring:	***Urinalysis***: A urine void was collected from each worker 1 week prior to exposure to ethion. Additional urine samples were obtained 1 to 6 days during exposure to ethion. ***ChE Analysis***: Serum ChE was monitored in workers at Location I. Blood samples were collected before the spray season began and once during the last week of the season.
Other monitoring:	Dermal α-cellulose pads (10 cm x l0 cm) were attached to eight locations on the body: the dorsal area of each forearm, the top of each shoulder, the center of the back near the neck, the chest near the "V" of the neck, and the front of each thigh. Dermal exposure to the hands was estimated from ethion residues on 10 cm x 10 cm areas from the palms and backs of a pair of cotton gloves worn by each worker. All dermal exposure pads were located on the outside of the Workers' clothing.
Notes:	**Note: Paper does not give time course for urinary excretion, just means and SD. Cannot get amounts handled for each work. This paper cannot be used quantitatively**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Wojeck et al. 1982**
Application Method:	Tractor-drawn air blast sprayers.
Worker Groups:	Mixers, Loaders and Applicators
Pesticide(s):	spray mixture of lead arsenate
Location(s):	Central Florida
Terrain/Field:	Citrus groves
Vegetative Cover/Crop:	Grapefruit trees
Protective Clothing:	Workers wore long- or short-sleeved shirts, long trousers, heavy shoes or boots, and hats. loves and respirators were worn only during the monitoring period, since these items were not normally used by the workers.
Application Rates:	6.2 kg a.i./ha (2 gallons of 32.8% lead arsenate/acre)
Kinetic Considerations:	Although suppliers excreted an average daily total arsenic concentration of 228 ppb, slightly greater than the 200 ppb threshold value suggestive of arsenic poisoning, the average daily excretion of total arsenic by the applicators was 83 ppb, less than the threshold value. Exposure to arsenic of all workers was lower than the short-term no-effect level set by the U.S. Environmental Protection Agency.
Biomonitoring:	Total urine was collected between *12:00* noon and 5:30 pm during a 4- hr period the week before workers began applying lead arsenate
Other monitoring:	Dermal exposure pads attached to forearms, shoulders, fronts of the thighs, center of the chest near the jugular notch. Dermal exposure to the hands was estimated from arsenic residues on areas cuts from the palms and backs of clean cotton gloves worn by the workers. Respiratory exposure was monitored by respirators. It was assumed that the respirator filters were totally efficient in trapping respirable lead arsenate. The gauze pads, gloves, and respirators were worn for a carefully timed period while workers mixed and loaded or applied one or two tanks of spray mixture
Notes:	**Cannot get useful generic rates. For metals/inorganics, exposure rates would probably need to be handled on a case-by-case basis. Developing such rates is the beyond the scope of the current effort.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Wolfe et al. 1970**
Application Method:	Air blast spray machines
Worker Groups:	Applicators
Pesticide(s):	Parathion and DDT
Location(s):	Not specified
Terrain/Field:	Orchards
Vegetative Cover/Crop:	Trees
Protective Clothing:	Not specified
Application Rates:	12-20 lbs /acre for parathion 48-80 lbs /acre for DDT
Kinetic Considerations:	In each instance, excretory level of metabolite correlated well with exposure to the pesticide. Para-nitrophenol excretion levels showed changes of greater magnitude in response to a specific exposure than did DDA excretion. DDT is not eliminated predominantly in the urine.
Biomonitoring:	24-hour urine specimens were collected for several days during and following spray exposure periods. Assayed for p-nitrophenol and DDA (dichlorodiphenylacetic acid)
Other monitoring:	None
Notes:	**See p. 712 for estimating the amount handled.** **DDA and *p*-nitrophenol excretion studies were carried out during a 3-year period and included 18 different exposure situations involving 12 spraymen.** **This study investigated the usefulness of DDA excretion as a method of measuring acute exposure of orchard spraymen to DDT. It also compared excretory patterns of the metabolites, DDA and p-nitrophenol, in spraymen exposed to formulations containing DDT and parathion.** **This is a good study but there is no indication of how much the workers handled. Cannot be used to get rates.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Yeary 1986**
Application Method:	Sprayed with large droplet nozzle at a rate of 15.14 L (4 gallons)/02.9 sq meters (1000 sq ft)
Worker Groups:	Commercial lawn care specialists (
Pesticide(s):	Mixture of 2,4-D (650 ppm), MCPP (325 ppm), and Dicamba (55 ppm) Diluted solutions also contained fertilizer, and, in some instances, insecticide
Location(s):	Hartford, CT; Flint, Ml; Ann Arbor, Ml; and Columbus, OH
Terrain/Field:	Lawns
Vegetative Cover/Crop:	Turf
Protective Clothing:	Workers wore latex rubber gloves, a protective apron or coveralls, goggles or a face shield, and rubber boots while handling containers of concentrated pesticides during the process of filling spray tanks. However, while spraying the diluted spray mixtures, wearing of gloves was optional, eye protection was not required, and clothing consisted of rubber boots and clean uniform of long pants and a short-sleeve shirt.
Application Rates:	Total volume sprayed each day was in the range of 3028-4542 L
Kinetic Considerations:	The lawn specialists had been spraying lawns with 2,4-D for at least 3 weeks, and it was assumed that they were in steady-state for 2,4-D body burdens.
Biomonitoring:	Workers were instructed to empty their bladders before leaving the facility at the end of 1 work day. They were further instructed to void all urine during the subsequent 24-hour period. To optimize conditions for steady-state pharmacokinetics, the urine collections were made on Thursday in all locations except Ann Arbor, Ml, where other schedules dictated that the urine collection be done on Tuesday
Other monitoring:	Not specified
Notes:	**Neither MCPP nor Dicamba were detectable at sensitivities of 0.01 and 0.05 ppm respectively. The sensitivity of the method for 2,4-D was 0.01 ppm, and the data are summarized in Table 1.** **This study had been used in 1998 report but the amount handled by each worker group is not given. The 1998 analysis assumed that the amount of 2,4-D used in the injection gun applications was identical to that used in the dilute spray applications. This assumption does not seem justified. The study is not used in the current analysis.**

Appendix 2: Summary of Studies Assessed for Worker Exposure Rates (*continued*)

Study:	**Zhang et al. 2011**
Application Method:	Backpack sprayer
Worker Groups:	Applicators, a mixer/loader, and a field supervisor.
Pesticide(s):	Garlon 4 and 2,4-D LV 6 tank mix (Tank mix analysis provided in Table 3)
Location(s):	Klamath National Forest near Weed, CA.
Terrain/Field:	Young, regenerating conifer forests (elevation about 1830 m), rugged and uneven, slopes ranged from 10 to 50%
Vegetative Cover/Crop:	Brush species (0.3 to 2 m), including greenleaf manzanita *Arctostaphylus patula*, snowbrush *Ceanothus velutinus*, and red flowering current *Ribes sanguineum*
Protective Clothing:	Each worker wore either Worker Protection Standard (WPS) clothing consisting of their personal long sleeved shirt and long pants or a cotton union suit (Sears®) beneath long-sleeved cotton coveralls. Additionally, a plastic safety helmet, impervious nitrile work gloves (14 mil gauntlet type), and knee-high, corked rubber boots were worn. Five spraymen (Group A) were randomly selected by draw to wear whole body, cotton suits. All workers were supplied daily with cotton socks and light cotton gloves that were worn beneath their work gloves. The mixer/loader and field supervisor wore their usual WPS clothing beneath their cotton coveralls. Spraymen in Group A wore whole body suits under long sleeved cotton coveralls. The body suits served as passive whole body dosimeters. In addition, the spraymen provided 24-h urine specimens. Those in Group B wore their normal work clothes and provided only 24-h urine collections each day. Clean cotton coveralls were supplied to both groups each day.
Application Rates:	Table 2 provides daily acres treated and tank mix applied during conifer release study.
Kinetic Considerations:	Six consecutive days of concurrent urine collections showed that backpack applicators excreted an average of 11.0 μg (a.e.) 2,4-D/kg-d and 18.9 μg (a.e.) triclopyr/kg-d. Estimates based upon curve fitting were 17.1 and 29.3 μg (a.e.)/kg-d, respectively.
Biomonitoring:	Backpack sprayer applicators, the mixer/loader, and the field supervisor provided pre-work and complete 24-h urine specimens during a 6-day spray program.
Other monitoring:	Serving as passive dosimeters, the union suits (whole body suit) were changed daily and analyzed for herbicide residues that were considered potential dermal exposure (DE).
Notes:	**Results suggest that passive dosimetry for 2,4-D consistently overestimated the dosage measured using biomonitoring by a factor of 2-3 fold. For triclopyr, passive dosimetry underestimated the absorbed dose based on biomonitoring by a factor of 2-4 fold.** **See the derivation of exposure rates on p. 289-290 as well as the comparison with PHED on p. 290 to 291 of the paper** **The paper gives exposure rates are 0.0147 mg a.e./kg bw/lb applied for triclopyr BEE and 0.0062 mg a.e./kg bw/lb applied for 2,4-D isooctyl ester based on curve fitting of mean daily dose values.** **For the peer review draft (May 2014), Robert Krieger and Xaiofei Zhang provided individual data for the applicators. The data are discussed further in Section 3.2.2.2.1 of the report and the data are given in worksheet Zhang et al. 2011 of the attachment to the report.**

Appendix 3: Reanalysis of Nolan et al. (1983, 1984)

NOTE: As discussed in Section 3.1, Appendix 3 is taken from the Forest Service risk assessment on picloram (SERA 2011d). The following appendix has been modified only in term of formatting for 508 compliance. The references cited in this appendix are given in the Forest Service risk assessment.

As discussed in Section 3.1.3.2.1(First-Order Dermal Absorption), Nolan et al. (1984) conducted a pharmacokinetic study in human volunteers following oral doses of 0.5 and 5.0 mg/kg and a dermal dose of 2 mg/kg bw. In the dermal study, a dose of 2 mg/kg was applied to the back of each volunteer (over about a 1000 cm^2 area), and the volunteers were instructed to shower 12-14 hours after application. The mean body weight of the subjects during the dermal phase of the study was 79.2 kg. Thus, the average dermal loading was about 0.16 mg/cm^2 [2 mg/kg x 79.2 kg ÷ 1000 cm^2 = 0.1584 mg/ cm^2]. As discussed further in Section 3.2.2.2, this dermal loading is very similar to the upper bound dermal loadings in the accidental exposure assessments for workers developed in the current risk assessment.

Based on a standard two-compartment model (e.g., O'Flaherty 1981), the analysis of the data from the oral phase of the study, including both concentrations of picloram in blood as well as the amounts of picloram excreted in the urine yielded an estimated urinary excretion rate for picloram by humans of 0.775 day^{-1}. As illustrated in Figures 1 and 2 from Nolan et al. (1984), the model offered a satisfactory fit to both the concentrations of picloram in blood and the amounts of picloram excreted in the urine.

For the dermal phase of the study, no picloram was detected in blood. Consequently, Nolan et al. (1984, footnote to Table 1) used the kinetic parameters from the oral study with the urinary excretion data from the dermal phase of the study to estimate the first-order dermal absorption rate constant for picloram. All model parameters were estimated with DACSL (Dow Advanced Continuous Simulation Language), which appears to have been a precursor to the current commercial programs, Advanced Continuous Simulation Language (http://www.acslx.com/).

An average proportion (*P*) of 0.0018 of the applied dose was excreted by six volunteers over a 72-hour period after dosing (Nolan et al. 1984, Table 1, column 3). Among the six volunteers, the proportion of the dose excreted in the urine ranged from 0.0005 to 0.0048 with a mean of 0.0015 (Nolan et al. 1984, Table 1, last column). Based on the model optimization, the average first-order dermal absorption rate constant is given as 0.056 $hour^{-1}$ with a range of 0.031 to 0.075 $hour^{-1}$ (Nolan et al. 1984, Table 1, column 6).

The dermal absorption rates reported by Nolan et al. (1984) do not appear to be consistent with the urinary excretion data following dermal exposure. Under the assumption of first-order absorption, the proportion absorbed (*P*) at time *t* is:

Equation A9-1

$$P = 1 - e^{-kt}$$

Assuming rapid urinary excretion – i.e., a urinary excretion rate of 0.775 day^{-1} as noted in the oral phase of the Nolan et al. (1984) study – a dermal absorption rate of 0.056 $hour^{-1}$ over a 13-hour exposure period (i.e., the central point in the showering interval) the proportion absorbed would be 0.49 or about 50% [$1-e^{-0.056 \times 12} = 0.489$]. As noted above, however, the average proportion recovered in the urine was only 0.0015 of the applied dose or 0.15%.

The reason for the discrepancy between the dermal absorption rates reported by Nolan et al. (1984) and the urinary recovery reported by Nolan et al. (1984) is not clear. One possible explanation may involve the use of a classical kinetic model for route extrapolation. In general, classical kinetic models are viewed as descriptive but are less well-suited to extrapolations, including route-to-route extrapolations, than physiologically-based pharmacokinetic models (e.g., Thompson et al. 2008). No physiologically-based pharmacokinetic model for picloram, however, has been developed and the development of such a model is beyond the scope of the current effort.

In an attempt to further explore the discrepancy between the dermal absorption rate and urinary excretion data reported by Nolan et al. (1984), additional details of the Nolan et al. (1984) data were requested from Dow AgroSciences. Dow AgroSciences provided a copy of the internal Dow report by Nolan et al. (1983) but this reported does not contain the raw data – i.e., the urinary excretion for each individual for each time period.

As illustrated in Figure A9-1, however, this report does contain a copy of the average urinary excretion rates with standard errors bars, similar to Figure 2 in Nolan et al. (1984). Figure A9-1 was imported into a graphics program and the data points – i.e., the average cumulative urinary excretion – were estimated. These data are summarized in Table A9-1. A plot of the data from Table A9-1 is given in Figure A9-1.

As illustrated in Figure A9-2, a biphasic excretion pattern, similar to that noted by Nolan et al. (1984) in the oral study, is apparent. The slower phase of excretion, however, appears to be associated with the showering interval of 12 to 14 hours. After the individuals showered and removed at least a significant portion of picloram from the surface of the skin, it is reasonable to expect that the rate of excretion of picloram will diminish. This pattern, however, is not associated with a physiologically meaningful deep compartment.

Based on the data in Table A9-1, an alternative estimate of the dermal absorption rate for picloram may be based on the flip-flop principal – i.e., under the assumption that the dermal absorption rate is much less than the excretion rate, the first-order dermal absorption rate constant may be estimated from the excretion rate (e.g., O'Flaherty 1981).

Appendix 3: Reanalysis of Nolan et al. (1983, 1984) (*continued*)

Linear regression was used to estimate the slope of natural logarithm of the proportion of picloram that was not excreted in the urine with time in hours as the independent variable. In order to avoid an underestimate of the absorption rate associated with collection intervals after showering, the analysis was restricted to the 3-hour to 24-hour collection intervals. The regression analysis yield estimates of the slope, equivalent to the first-order dermal absorption rate constant, of 5.0 (3.0 to 7.1) x 10^{-5} $hour^{-1}$, with a correlation coefficient of 0.954 and a *p*-value for the model of 0.00043.

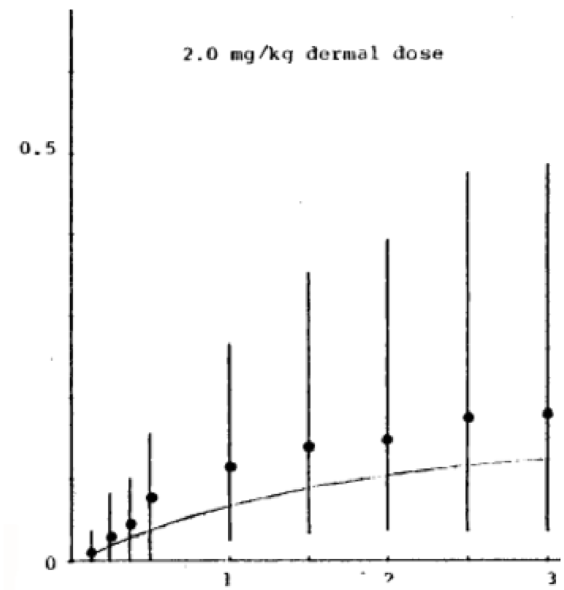

Figure A9-1: Cumulative Urinary Excretion of Picloram Following Dermal Administration from Nolan et al. (1983)

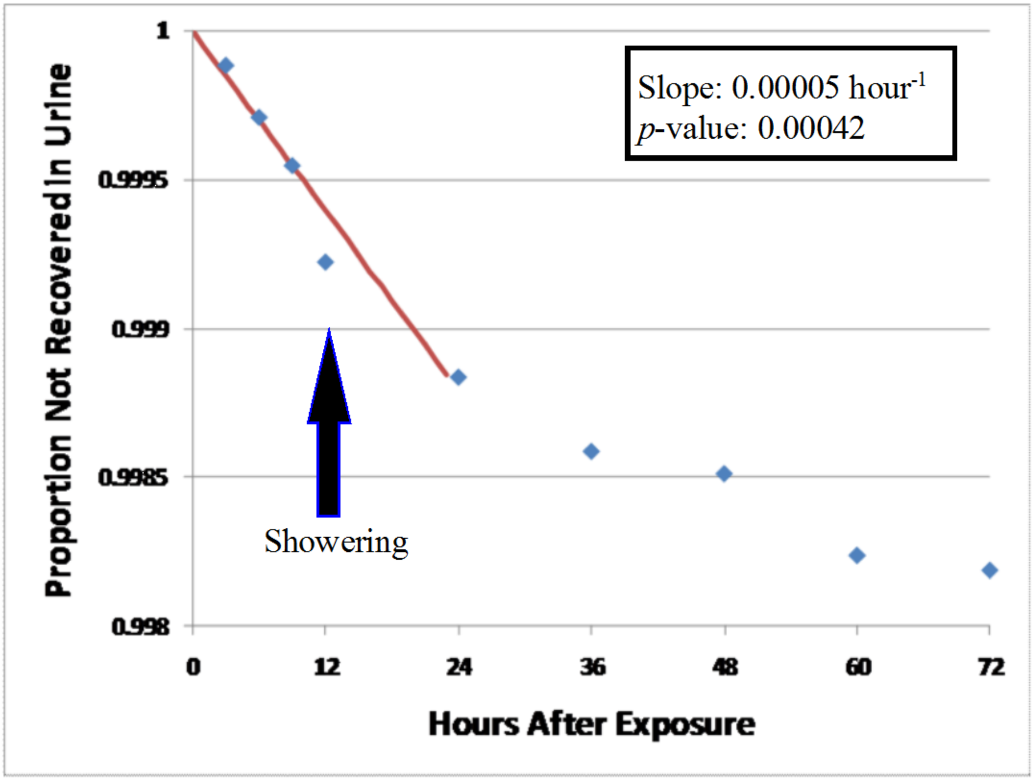

Figure A9-2: Proportion of Picloram Not Recovered in the Urine.

See Table A9-1 for data.

Appendix 3: Reanalysis of Nolan et al. (1983, 1984) (*continued*)

Table A9-1: Average Cumulative Proportion of Urinary Excretion Following Dermal Administration from Nolan et al. (1983).

Hours	Prop Excreted %	Ln Prop Remaining
3	0.0113	-0.000113
6	0.0288	-0.000288
9	0.0450	-0.000450
12	0.0775	-0.000775
24	0.1163	-0.001163
36	0.1413	-0.001413
48	0.1488	-0.001489
60	0.1763	-0.001764
72	0.1813	-0.001814