Item ID Number	01027
Author	
Corporate Author	USDA-States-EPA 2,4,5-T RPAR Assessment Team
Report/Article Title	The Biologic and Economic Assessment of 2,4,5-T
Journal/Book Title	
Year	1979
Month/Day	February 15
Color	☐
Number of Images	15
Description Notes	Alvin L. Young filed this item under the category "Human Exposure to Phenoxy Herbicides and TCDD".

Human File

FINAL DRAFT REPORT

ALVIN L. YOUNG, Major, USAF
Consultant, Environmental Sciences

THE BIOLOGIC AND ECONOMIC ASSESSMENT OF 2,4,5-T

Authors: 2,4,5-T RPAR ASSESSMENT TEAM

File under "R"

[redacted]

A REPORT OF THE USDA-STATES-EPA 2,4,5-T RPAR ASSESSMENT TEAM

February 15, 1979

ESTIMATION OF EXPOSURE BY THE ABSOLUTE METHOD

The absolute method of estimating exposure uses a combination of assumptions and direct measurements. The assumptions are geared to particular applicator exposure situations as described in the section on "Exposure of Applicators According to Use Pattern" in Part 5 of Chapter 5.

These assumptions and direct measurements have been applied to exposure situations as they exist in the field. Clothing described are the kinds actually used. Estimates of skin area exposed are believed to be accurate for the types of clothing described.

The direct measurements involve data from two experiments: (1) a 2,4,5-T dermal absorption experiment involving four human volunteers in a laboratory experiment (Newton 1978) and (2) a field experiment in which 2,4,5-T deposition (and absorption) was measured during operational application by helicopter (5 individuals), tractor sprayer (5 individuals), and backpack sprayer (12 individuals) (Lavy 1978a&b).

In the first part of this section the various assumptions are used with the data from the laboratory experiment to calculate maximum absorption (exposure) levels for particular exposure situations. The absorption (exposure) levels from the field experiment are used to calculate exposure as it occurs during actual use. In the second part of this section, exposure levels from both sources are presented in narrative form for each method of 2,4,5-T application in each of the four commodity groups.

EXPOSURE CALCULATED FROM A LABORATORY EXPERIMENT

Assumption Sets

The likelihood of an applicator or observer in spray operations being exposed to a given level of 2,4,5-T depends on the physical

circumstances during exposure. A series of sets of assumptions have been developed which describe the nature and extent of the exposure of applicators involved with particular types of application. Each set of assumptions closely approximates the actual conditions in which the chemical is used, based on experience of Assessment Team members and users in Oregon, Texas, Arkansas, California, Indiana, and Pennsylvania (Norris et al. 1979). Table 30 identifies the type of application (or situation) associated with each assumption set, and some of its conditions.

There are five sets of assumptions for ground spray workers and five for aerial spray workers. The various situations are those typical for backpack sprayer operators, tractor sprayer operators, tree injection personnel, aircraft mixer-loaders, and flaggers. Conditions for pilots were not described because they are protected more than the other workers. Each set embodies different assumptions relating to the concentration of spray mixture, protective clothing, skin exposed, and skin absorption. In addition there are 2 sets of assumptions from PD-1. In general, the assumptions in sets 1 through 10 are different from those used in PD-1 (EPA 1978). An explanation for the choices used follows.

Concentration of Spray Material

Concentrations of 2,4,5-T greater than 16 lb acid equivalent per hundred gallons (aehg) are seldom used in ground equipment. The higher cost for higher concentrations which do not substantially increase effectiveness precludes widespread use. None of the widely used products recommends higher than 6 aehg in water for general use; 2 to 4 aehg is more widely used. The rates of 8 to 16 aehg used here are in the upper range for oil sprays, but they are used with sufficient frequency to warrant calculations as upper limits of ordinary exposure. Higher concentrations are limited to mist blowers and aircraft.

Table 30—Typical job descriptions of workers exposed under assumption sets listed in Tables 31 and 32

Assumption set	Job description
1	Tractor mounted boom sprayer on rice levees or range and pasture lands
2	Backpack or handgun operator in right-of-way or rangeland basal spray operation, with gloves and long-sleeve shirt
3	Backpack, handgun or mistblower operator in forest or power line basal spray operation, short-sleeve shirt, no gloves
4	Same as 3, with long-sleeve shirt and gloves
5	Hypo-hatchet tree injector operator, 2,4,5-T amine, long-sleeved shirt, gloves
PD-1 a	Backpack spray operator without protection as described in PD-1
6	Helicopter mechanic-mixer, light (common) dose, gloves and long-sleeved shirt
7	Helicopter mechanic-mixer maximum concentration, wearing gloves and long-sleeved shirt
8	Flag person, 1 lb/A 2,4,5-T in 3 gpa, wearing broad-brim hat, long-sleeved shirt
	Exposure is derived as follows: flagger fails to move out of spray swath once for each 10 passes of the spray plane, or 4 times per hour. This gives an exposure of 1.042 mg 2,4,5-T.
9	Flag person, 2 lb/A 2,4,5-T in 5 gpa, wearing broad-brim hat, long-sleeved shirt.
	Exposure is as the same basis as in assumption 8, but adjusted by a factor of 2 for the higher rate of application. This gives an exposure of 2.084 mg 2,4,5-T.
10	Flag person, 2 lb/A 2,4,5-T in 5 gpa without protective clothing
	Exposure is as the same basis as in assumption 8, but adjusted by a factor of 2 for the higher rate of application and a factor of 8 for the greater degree of absorbtion due to less clothing.
PD-1 b	Flag person described in PD-1, with both dermal and inhalation exposure

Protective Clothing

Protective clothing of some kind is normally worn by all pesticide applicators. Long-sleeved shirts alone reduce exposure substantially below that of a tee shirt. Use of gloves and a long-sleeved shirt reduces skin exposure to 12.3 percent of that received when the applicator wears a short-sleeved shirt and no gloves (Wolfe et al. 1974). Addition of a wide-brim hat to long-sleeved shirt and gloves reduces exposure to 8.8 percent. Assumption sets 2, 4, and 5 for ground application and 6 and 7 for aerial application provide for long-sleeved shirts and gloves as protective clothing. This reduces exposure to 12.3 percent of the two square feet of skin surface estimated to be exposed to spray mixtures when a short-sleeved shirt and no gloves are used (assumption sets 1, 3 and PD-1a). Assumption sets 8 and 9 for flaggers involved with aerial applications include broad-brim hard hats, long-sleeved shirts, and gloves.

Dermal Absorption

In a previous section (The Factorial Method) the inappropriate use of the 10 percent 2,4,5-T absorption figure in PD-1 was discussed and a factorial correction factor developed. Unfortunately there are very limited data on which human exposure (via dermal absorption) to 2,4,5-T can be estimated. In this section we use data from a preliminary experiment involving humans as a basis for calculating 2,4,5-T absorption from dermal exposure (Newton 1978). In this experiment, four human volunteers were exposed to one of four spray solutions containing 2,4,5-T at concentrations of 2, 4, 16, or 32 aehg. The exposure involved placing a 144 square inch denim cloth soked with 40 ml of the appropriate spray mixture on the sking of one upper thigh. The cloth was covered and bound tightly in place with plastic wrap to insure good contact with the skin and to prevent drying. The skin was wet to saturation throughout the 2-hour exposure period. The assumption is this type of exposure results in maximum dermal uptake because the skin is as wet as it can be without the spray running off and the soaked

cloth provides a reservoir of chemical to replace any that is removed by dermal absorption. At the end of the 2 hour exposure period, the cloth was removed and the treated area washed with alcohol and wiped dry. Urine was then collected for 5-24 hour periods. 2,4,5-T excretion beyond 5 days was estimated by extension of the excretion curves to zero (to 15 days for the 16 and 32 aehg material and to 8 days for the 2 and 4 aehg material) and integration. The assumption is that all the 2,4,5-T absorbed was excreted in this time period. A reasonable correlation was observed between the concentration of 2,4,5-T in spray mixtures kept moist on skin and the amount of 2,4,5-T appearing in the urine during five days post-treatment period, although it was not strictly proportional (table 31).

Net absorption of 2,4,5-T per hour per square foot of skin exposed was estimated from data in table 31.

Concentration of spray material aehg	2,4,5-T absorbed (dermal) (mg/sq ft/hr)
2	0.220
4	0.419
16	0.570
32	1.125

It is emphasized these are maximum possible values because the skin was saturated throughout the exposure period. In actual practice these levels will not normally be attained. The assumptions outlined above and the dermal absorption data in table 31 (Newton 1978) were used to calculate maximum applicator exposure for each of the 5 assumption sets involving ground application (table 32) and the 5 sets involving aerial application (table 33). These calculations indicate lightly clad backpack sprayer, handgun sprayer, and backpack mistblower operators will receive the greatest exposure. Addition of a hat, gloves, and long-sleeved shirt will markedly reduce exposure.

Table 31--Absorption and excretion of 2,4,5-T by humans after dermal exposure [a/]

Concentration of spray mixture [b/]	2,4,5-T recovered in urine					Estimated 2,4,5-T excretion in urine beyond the 5th day	Estimated 2,4,5-T absorbed [c/]
	Day						
	1	2	3	4	5		
lb/100 gal	mg					mg	mg
2	0.073	0.142	0.107	0.025	0.034	0.062	0.441
4	0.218	0.250	0.134	0.079	0.037	0.125	0.843
16	0.116	0.222	0.124	0.107	0.095	0.500	1.164
32	0.276	0.358	0.250	0.210	0.196	1.000	2.380

a/ Exposure involved 144 square inch denim patches soaked with 40 ml of 2,4,5-T spray solution of the appropriate concentration and applied to the upper thigh. The patches were covered with plastic wrap to prevent drying and were bound snugly to insure good contact with the skin. The skin was wet with the spray mixture throughout the exposure period. Patches were removed after 2 hours, the skin washed with alcohol and dried, and urine collected for 5-24 hour periods. 2,4,5-T excretion in urine beyond the 5th day was estimated by extention of the excretion curves (to 15 days for the two highest concentrations and to 8 days for the two lowest concentration) and integration. (Newton 1978).

b/ Acid equivalent per 100 gallon (aehg).

c/ Estimated 2,4,5-T absorbed is the sum of 2,4,5-T excreted in five days and estimated excretion beyond 5 days.

Table 32—Sets of assumptions for exposure of applicators using 2,4,5-T with ground equipment. Maximum levels of exposure are listed for each assumption set because they assume constant wetness of exposed skin. Dosage based on 60 kg worker except for the applicator monitored data (80 and 110 kg).

Variable	Assumption set 1	2	3	4	5	PD-1a
Spray concentration, aehg	4	8	16	16	400	40
Fully clothed[a/]	No	Yes	No	Yes	Yes	No
Square feet of skin exposed	2	1/4	2	1/4	1/4	2+
Dermal absorption of 2,4,5-T mg/hr	0.838[b/]	0.11[b/]	1.14[b/]	0.142[b/]	0.15[c/]	51[d/]
2,4,5-T dosage, mg/kg/hr	0.014	0.0018	0.019	0.0024	0.0025	0.85
TCDD dosage[e/] µg/kg/hr	8.4×10^{-7}	1.1×10^{-7}	1.14×10^{-6}	1.4×10^{-7}	1.5×10^{-7}	2.1×10^{-5}
Applicator monitoring mg/kg/day 2,4,5-T			0.026 (for 8 aehg)		0.0025 (for 6 aehg)	

a/ Long-sleeved shirt and gloves reduces exposure 91 percent compared to short-sleeve shirt and no gloves (Wolfe et al. 1974).

b/ Newton (1978).

c/ Norris (1974) Based on absorption salts of organic arsenicals by injector operators using 6 lb/gal concentrate, maximum concentration of 1 ppm in urine with daily 6-hour exposure. The organic arsenicals as salts are better models for 2,4,5-T amine than is the 2,4,5-T ester used by Newton (1978).

d/ Value from PD-1 (EPA 1978).

e/ Based on 3×10^{-8} ppm TCDD in 2,4,5-T (Alford 1978) and an absorption rate for TCDD which is twice as great as for 2,4,5-T. Thus µg TCDD absorbed = mg 2,4,5-T absorbed x (6×10^{-5}).

Table 33—Sets of assumptions for exposure of applicators using 2,4,5-T with aerial equipment. Maximum levels of exposure are listed for each assumption set because they assume constant wetness of all exposed skin. Dosage based on 60 kg workers.

Variable	Assumption set					
	6	7	8	9	10	PD-1b
Spray concentration aehg	10	40	10	40	40	40
Fully clothed[a/]	Yes	Yes	Yes	Yes	No	No
Square feet of skin exposed	1/4	1/4	1/4	1/4	2	2+
Inhaled 2,4,5-T, mg/hr	0	0	2.5×10^{-5}[b/]	1×10^{-4}[b/]	1×10^{-4}[b/]	0.17[c/]
Skin deposit of 2,4,5-T, mg[d/]	-	-	1.042	2.084	16.86	-
Dermal absorption of 2,4,5-T mg/hr	0.125	0.371	0.052	0.104	0.834	0.75
Total exposure to 2,4,5-T, mg/hr	0.125	0.371	0.052	0.1041	0.8341	0.92
2,4,5-T dosage mg/kg/hr	0.002	0.006	8×10^{-4}	0.002	0.014	0.0103
TCDD dosage µg/kg/hr[e/]	1.2×10^{-7}	3.7×10^{-6}	5.2×10^{-8}	1×10^{-7}	8.3×10^{-7}	6.7×10^{-6}[c/]

a/ Long-sleeved shirt and gloves for assumption sets 6 & 7 reduces skin exposure 91 percent compared to short-sleeved shirt and no gloves. A broad brim hat is added for assumption sets 8 and 9 (Wolfe et al. 1974).

b/ Assumes inhalation rate of 0.1 µg/min per acre pound applied in adjacent swath when air movement carries fine droplets into flagmen's position (based on 20 min/day exposure between 0 and 165 feet downwind from spray swath, Akesson 1978).

c/ Value from PD-1 (EPA 1978)

d/ Value from table 30.

e/ Based on 3×10^{-8} ppm TCDD in 2,4,5-T (Alford 1978) and an absorption rate for TCDD which is twice as great as for 2,4,5-T. Thus µg TCDD absorbed = mg 2,4,5-T absorbed x (6×10^{-5}).

EXPOSURE MEASURED DURING OPERATIONAL APPLICATION

Lavy (1978b) monitored the deposition of 2,4,5-T on 22 applicators engaged in the operational application of herbicide by helicopter (5 applicators), tractor-mounted boom sprayer (1 applicator), tractor-mounted mistblower (4 applicators), and backpack sprayer (12 applicators). Workers were actively involved with the application for 1.93 hours (helicopter), 1.08 hours (tractor boom sprayer), 4.08 hours (tractor mistblower), or 3.0 hours (backpack sprayer). Patches (6 - 100 cm^2 patches for each worker) were attached to the clothing on the chest, back, both biceps, and both thighs. At the end of the spray period the patches were removed and analyzed for 2,4,5-T. The assumption is that the spray deposited on the six patches was representative of the spray deposited on exposed areas of skin.

Lavy (1978a) reported urine samples were collected from these same workers but a complete report of the data is not yet available (January 15, 1979). Lavy (1978b) indicates, however, that it appears approximately 4 percent of the 2,4,5-T estimated to be on the skin was recovered in urine. Lavy's (1978b) data, recalculated to show mg/kg/hour 2,4,5-T deposited on the skin and the amount of herbicide and TCDD absorbed (exposure), are in table 34.

The levels of exposure from an actual operational application (table 34) are substantially lower than those calculated from the laboratory experiment (tables 32 and 33). When calculated to be on a directly comparable basis in terms of concentration of spray and skin area exposed, the following values were obtained from the two experiments:

Table 34--Deposition and dermal absorption (exposure) of 2,4,5-T by humans during operational application.

Application method	Worker number	Skin exposed	Deposition of 2,4,5-T[a]		Absorption of 2,4,5-T[b]	Absorption of TCDD[c]
		m^2	mg/kg/hr		mg/kg/hr	µg/kg/hr
Helicopter[d]	1	0.294	0.0046		0.0002	1.2×10^{-8}
"	2	0.294	0.0072		0.0003	1.8×10^{-8}
"	3	0.173	0.0019		0.0001	6.0×10^{-9}
"	4	0.294	0.0070		0.0003	1.8×10^{-8}
"	5	0.294	0.0095		0.0004	2.4×10^{-8}
				Average	0.0003	1.6×10^{-8}
Tractor, boom[d]	6	0.294	0.042		0.0017	1.0×10^{-7}
Tractor, mistblower[d]	7	0.294	0.050		0.0020	1.2×10^{-7}
" "	8	0.173	0.035		0.0014	8.4×10^{-8}
" "	9	0.294	0.012		0.0005	3.0×10^{-8}
" "	10	0.173	0.026		0.0011	6.6×10^{-8}
				Average	0.0012	7.5×10^{-8}
Backpack[e]	11	0.294	0.054		0.0021	1.3×10^{-7}
"	12	0.294	0.373		0.0149	8.9×10^{-7}
"	13	0.294	0.281		0.0112	6.7×10^{-7}
"	14	0.294	0.299		0.0120	7.2×10^{-7}
"	15	0.294	0.615		0.0246	1.4×10^{-6}
"	16	0.294	0.676		0.0271	1.6×10^{-6}
"	17	0.294	0.123		0.0049	2.9×10^{-7}
"	18	0.294	0.027		0.0011	6.6×10^{-8}
"	19	0.294	0.107		0.0043	2.6×10^{-7}
"	20	0.294	0.202		0.0081	4.9×10^{-7}
"	21	0.294	0.197		0.0079	4.7×10^{-7}
"	22	0.294	0.749		0.0300	1.8×10^{-6}
				Average	0.0123	7.4×10^{-7}

a/ Data from table 5 (Lavy 1978b) adjusted to per hour basis.

b/ 4 percent of deposit

c/ mg/kg/hr 2,4,5-T absorbed x (6×10^{-5}), see footnote e, table 32 in chapter 5 of this report.

d/ Concentration of 2,4,5-T in spray solution: 40 aehg

e/ Concentration of 2,4,5-T in spray solution: 20 aehg

Method of application	Concentration of spray	Exposure to 2,4,5-T[a/] Laboratory Experiment[b/]	Field Experiment[c/]
	------aehg------	---------mg/kg/hr---------	
Helicopter	40	0.076	0.0003
Tractor mistblower	40	0.076	0.0012
Backpack sprayer	20	0.038	0.0123

[a/] 0.294 m^2 exposed skin (3.28 ft^2)

[b/] From tables 32 and 33

[c/] From table 34

This illustrates the maximum nature of the exposure calculated using the data from the laboratory experiment where skin was soaked throughout the exposure period. In practice this level of exposure does not occur except in rare instances where abnormally high, accidental exposure occurs. There are two cases of this type of exposure noted in tables 32 and 33.

The two spray workers who received substantial exposure to 2,4,5-T were (1) one worker sprayed Texas mesquite with 8 aehg 2,4,5-T in diesel fuel 3 out of 5 days for 8 hours each day. Clothing was coveralls without gloves. (2) One worker in Oregon sprayed blackberry bushes with 6 aehg 2,4,5-T in water. The sprayer hose broke and soaked the trousers and leather boots. The trousers and boots were worn for 4 hours before washing up (Newton 1978).

The Texas worker did not use gloves and his hands came in contact with the solution and the concentrate. The 80 kg Texas applicator equilibrated at the level of 2.12 mg total absorption per 6 hour day, for a dosage of 0.026 mg/kg/day. This is half the predicted dosage encountered with one-hour exposure under assumption set 3, table 32, which most closely resembles his situation in the field but is based on 16 aehg spray mixture. This emphasizes the "maximum nature" of the estimates in tables 32 and 33 which were derived from data in table 31.

The Oregon applicator data in table 32 indicated an uptake of between 3 and 4 mg 2,4,5-T from an exposure surface of 2 sq ft over a 4-hour period (0.037-0.50 mg/sq ft/hr). Assuming partial drying and soaked skin for 2 hours, this exposure is estimated to be the equivalent of 2 square feet for 2 hours (0.075 mg/sq ft/hr). This is slightly higher than the rates shown for either the 4 or 16 aehg data in table 32. In addition to the spill, however, the Oregon applicator reported a 3-hour exposure the same day in which a leaky valve kept his spray-wand hand wet constantly. Under the circumstances, this observation was clearly an extreme example under assumption set 3, table 32, corrected to 6 aehg. Both the above observations suggest that the data in tables 32 and 33 give maximum estimates of exposure under the described conditions.

It is unfortunate there is not a more adequate data base currently available on dermal absorption of 2,4,5-T by applicators. Lavy (1978a) indicates data on 2,4,5-T and its relation to deposition on applicators will be available for inspection by March 1, 1979. There is another study of applicator exposure to 2,4,5-T that is being planned by the Cook College Agricultural Experiment Statment, Rutgers University, New Jersey. The study will be completely by June 1, 1980 (Norris et al. 1979).

EXPOSURE LEVELS IN THE FIELD

Personnel applying 2,4,5-T in the field are usually operating under conditions reasonably close to one of the assumption sets - job descriptions in table 30. The exposures for each type of application listed below were estimated for the first hour of operation from tables 32, 33, and 34.

The following discussion of exposure opportunities in the various commodity uses has been presented to show the level of exposure and area treated for each worker hour. These may be expanded according to the number of hours per day actual operator time. Generally 2 values are given; one is the normal operational level as predicted by the data in

up to 0.076 mg/kg/hr for each 60 acres treated (assumption set 7, table 33).[1/] Adding gloves and a long-sleeved shirt, the exposure would be reduced to 0.007 mg/kg/hr even for a worst case of exposure based on data of Wolfe et al. (1974) (table 35).

Ground Application with Tractor Mistblowers - Broadcast Treatment

Lavy (1978b) (table 34) reports tractor mistblower operators may be exposed to 0.0012 mg/kg/hr 2,4,5-T under operational conditions. A comparable assumption set for the worst case of exposure was not developed, but is likely to be similar to that for the backpack sprayer (table 35).

Ground Application with Backpack Mistblowers - Broadcast Treatment; and Backpack Sprayers and Tree Injectors - Individual Stem Treatment

No operational exposure data are available for workers using backpack mistblowers. The similarity to backpack sprayers suggests the use of those data. Lavy (1978b) (table 34) reports exposure for this group is 0.0123 mg/kg/hr 2,4,5-T under operational conditions. Worst case exposure is illustrated from assumption set 3, table 32. Performance rate of one acre per hour per applicator would lead to an exposure of 0.030 mg/kg/hr. If long-sleeved shirts and gloves are used (assumption set 4) exposure is reduced to 0.003 mg/kg/hr in covering one acre. Workers using injectors are described in assumption set 5, table 32. Based on one-half acre treated per hour, a worker receives a maximum dose of 0.032 mg/kg/hr (table 35).

1/ Sample calculation: 0.006 mg/kg/hg (assumption set 7, table 33) x 12.67 (to adjust exposed area from 0.25 square feet to 0.294 m^2) = 0.76 mg/kg/hr. The exposed area correction factor is 1.58 to adjust from 2 square feet to 0.294 m^2. Adding long-sleeved shirt and gloves reduces exposure 91 percent or 0.076 mg/kg/hr x 0.09 = 0.007 mg/kg/hr.

Table 35—Summary of hourly exposure to 2,4,5-T estimated by absolute method

Exposure situation	Area treated per hour	Time exposed per day	Operational exposure[a/]	Reduced operational exposure[b/]	Maximum exposure[c/]	Reduced maximum exposure[d/]
	acres	hours	mg/kg/hr			
Timber						
Aerial	60	4	0.0003	0.00003	0.076	0.007
Backpack	1	4	0.0123	0.0011	0.030	0.003
Injection	0.5	4	—	—	0.032	0.003
Tractor mist blower	6.5	4	0.0012	0.0001	0.030	0.003
Backpack mist blower	1	4	0.0123	0.0011	0.030	0.003
Range and pasture						
Aerial						
mechanic	100-300	4	0.0004	0.00004	0.095	0.009
flagger (2)	100-300	4	—	—	0.034[a/]	0.003[c/]
Backpack	1	6	0.0049	0.0004	0.016	0.001
Tractor Boom spray	20	4	0.0028	0.0003	0.007	0.0006
Rights of way						
Aerial-mixer	20	6	0.0003	0.00003	0.076	0.007
Backpack and handgun	0.25-1.25	6	0.0123	0.0011	0.030	0.003
Truck-mount	1-10	6	0.00003	0.000003	0.011	0.001
Backpack mistblower	0.25-1.25	6	0.0123	0.0011	0.037	0.003
Rice						
Aerial						
mixer-loader	80	1	0.0002	0.00002	0.063	0.006
flag person (2)	80	1	—	—	0.034[a/]	0.003[b/]
Tractor boom sprayer	5	1.3	0.0026	0.0002	0.007	0.006

a/ Calculated from Lavy (1978b) with 0.294 m^2 exposed skin area (short-sleeved shirt).

b/ Calculated from Newton (1978) adjusted to 0.294 m^2 exposed skin area.

c/ Calculated from Lavy (1978b). Long-sleeved shirt and gloves reduces exposure 91 percent (Wolfe et al. 1974).

d/ Calculated from Newton (1978). Long-sleeved shirt and gloves reduces exposure 91 percent (Wolfe et al. 1974).