PRELIMINARY HUMAN PESTICIDE EXPOSURE ASSESSMENT

DIAZINON
(For Use on Residential Turf and Soil)

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Worker Health and Safety Branch
Department of Pesticide Regulation
California Environmental Protection Agency

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EXECUTIVE SUMMARY

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PURPOSE

Preliminary examination of residential use scenarios for diazinon suggests that turf and soil treatments have the highest likely exposure, in part because of the comparatively high application rate and very short reentry intervals involved. This type of treatment has been used for Mediterranean fruit fly (Medfly) eradication in California since 1980. Their effect is to destroy the pupae that still have not emerged from the ground. This report characterizes the exposure potential for young children playing on lawns and soil treated with diazinon for Medfly eradication. The exposure assessment has its focus on young children because potentially they would have the most dermal contact with treated lawns or soil around their home. For completeness, also characterized is the occupational exposure potential for applicators who spray diazinon for Medfly eradication. The daily exposures calculated for these young children and eradication applicators are expected to be incorporated into the Department's risk assessment for diazinon used in the eradication program.

BACKGROUND

Diazinon is a synthetic organophosphorous compound which has been used for the control of a wide variety of sucking and chewing insects and mites. There are over 200 diazinon products registered in California. Of these, only one diazinon formulation has been used for Medfly eradication. This diazinon formulation is labeled as a Toxicity Category II, federally restricted use pesticide. In 1989 the U. S. Environmental Protection Agency called for more effective precautionary use directions on the label for those diazinon products that would be used on food crops and around the home. Between 1982 and 1990, there were 81 illnesses and 2 deaths (suicides) occurring in California that were reported to have been associated with diazinon used in nonoccupational situations. Of the 20 cases that were reported to have been given a test for cholinesterase depression, 4 cases (20%) were confirmed as positive (i.e., having a subnormal cholinesterase level). When administered orally to animals, diazinon is rapidly absorbed and extensively metabolized. The metabolites are mostly excreted in the urine within 24 hours; and their elimination is complete in about one week. There were no illnesses or injuries reported as related to diazinon used for Medfly eradication.

METHODS

Monte Carlo simulation and data from five field studies were used to determine the best conservative estimates of daily dosage for both the oral intake and the dermal uptake of diazinon in soil by children. Monte Carlo simulation techniques are those probabilistic methods wherein probability distributions for the various key exposure factors (e.g., body weight, soil concentration, soil ingestion rate, skin-soil loading, etc.) are used instead of their point estimates. The best conservative estimate for the dermal uptake of diazinon in turf was based on a transfer rate for 2,4-D herbicide available in the literature, and on the diazinon turf dislodgeables measured by the field teams of this Branch. The best estimates calculated here should also be considered as the maximal dermal uptake and oral intake for adults gardening in treated soil, since a young child has the greatest body surface area per unit of body weight and is likely to have the worst mouthing behavior. The best conservative estimate of daily dosage calculated for a professional worker applying diazinon for Medfly eradication was based on the surrogate data from a worker exposure study, in which three nonprofessional volunteers spraying diazinon in yards on residential properties were monitored for both potential dermal and inhalation exposures to the residues.

MAJOR FINDINGS

The best conservative estimates of daily dosage calculated for a child were 0.8 μg per kilogram of body weight for soil oral intake, 0.3 μg/kg for soil dermal uptake, and 0.4 μg/kg for turf dermal uptake. The best conservative estimate of daily dosage calculated for a worker applying diazinon for Medfly eradication was 2.6 μg/kg. There were no illnesses or injuries reported as related to diazinon used for Medfly eradication.

ABSTRACT

Preliminary examination of residential use scenarios for diazinon suggests that turf and soil treatments have the highest likely exposure, in part because of the comparatively high application rate and very short reentry intervals involved. This type of treatment has been used for Mediterranean fruit fly eradication in California since 1980. Their effect is to destroy the pupae that still have not emerged from the ground. Diazinon is a synthetic organophosphorous compound which at a high dose could cause acute cholinergic signs. Activities such as walking or playing on the treated soil or sod may bring children in contact with residues, as it must be regulated on the assumption that they will enter the treated areas once the sprays have dried (usually within a few hours of treatment). Treatment crews may also be exposed to diazinon when they mix/load and apply the insecticide to residential soil or sod. This assessment was performed to calculate the absorbed daily dosages for these mixer/loader/applicators, and for a two-year-old child from soil ingestion and from dermal uptake of diazinon on turf and in soil. The best conservative estimates of daily dosage calculated for a child of this age were 0.8 μg/kg for soil oral intake, 0.3 μg/kg for soil dermal uptake, and 0.4 μg/kg for turf dermal uptake. The best conservative estimates for both the oral intake and the dermal uptake of diazinon in soil by the two-year-old child were determined using Monte Carlo simulation techniques and soil levels from five field studies. The best conservative estimate for the turf dermal uptake by the two-year-old child was based on a transfer rate for 2,4-D herbicide available in the literature, and on the diazinon turf dislodgeables measured by the field teams of this Branch. These estimates should also be considered as the maximal dermal uptake and oral intake for adults gardening in treated soil, since a two-year-old child has the greatest body surface area per unit of body weight and is likely to have the worst mouthing behavior. The best conservative estimate of daily dosage calculated for a worker applying diazinon for Medfly eradication was 2.6 μg/kg. This estimate was based on exposure data from a study in which three volunteers spraying diazinon in yards on residential properties were monitored for both potential dermal and inhalation exposures to the residues. The results of a recent human study indicated that dermal absorption of diazinon over a 24-hour exposure period is likely to be well below 10%. A review of the animal metabolism studies revealed that once absorbed, diazinon and its three major pyrimidol moiety metabolites are excreted rapidly (50% of applied dose in 12 hours) via the (rat) urine and feces.

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I. INTRODUCTION

Preliminary examination of residential use scenarios for diazinon suggests that turf and soil treatments have the highest likely exposure, in part because of the comparatively high application rate and very short reentry intervals involved. This type of treatment has been used for Mediterranean Fruit Fly (Medfly) eradication in California since 1980. Their effect is to destroy the pupae that still have not emerged from the ground. Diazinon is a synthetic organophosphorous compound which at a high dose could cause acute cholinergic signs. Activities such as walking or playing on the treated soil or sod may bring children in contact with residues, as it must be regulated on the assumption that they will enter the treated areas once the sprays have dried (usually within a few hours of treatment). Treatment crews may also be exposed to diazinon when they mix/load the insecticide and apply it for Medfly eradication. In order to determine if residential use of diazinon warranted expedited risk assessment/management, Worker Health and Safety Branch (WH&S) undertook an exposure assessment especially for its turf and soil use. This exposure assessment is written to be an integral part of the Department's risk characterization document for diazinon used on residential turf and soil. The results and information contained in this document may also serve as the starting point for developing mitigation measures if the estimated exposure is found to cause excessive risk.

II. PHYSICAL AND CHEMICAL PROPERTIES

Diazinon [*O*, *O*-diethyl-*O*-(2-isopropyl-6-methyl-4-pyrimidinyl)-phosphorothioate; CAS Registry No. 333-41-5; molecular formula $C_{12}H_{21}N_2O_3PS$; molecular weight 304.4] is a synthetic organophosphorous compound which has been used for the control of a wide variety of insects and mites including cockroaches, lice, and flies. It is commercially available as a non-corrosive, light amber to dark brown liquid. The vapor pressure of diazinon ranges from 1.4×10^{-4} (at 20°C) to 1.1×10^{-3} mm Hg (at 40°C), with a specific gravity of 1.12 at 20°C and a boiling point of 83 - 84°C under 2×10^{-3} mm Hg. Diazinon has an octanol-water partition coefficient of 2×10^3 and a very low Henry's Law constant of 0.067 Pa m^3/mol. Although diazinon has moderately low solubility in water (40 mg/L at 20°C), it is completely miscible with alcohols, benzene, cyclohexane, dichloromethane, ethers, hexane, and other common organic solvents (Ciba-Geigy Corporation, 1979; Suntio *et al*., 1988; The Royal Society of Chemistry, 1990).

III. FORMULATION/INTENDED USE PATTERN

Diazinon was first synthesized in Switzerland in 1951 and was once a trade name registered to Ciba-Geigy. In recent years the compound has been approved by the U. S. Environmental Protection Agency (USEPA) for use on more than 200 food crops and ornamental plants. The chemical is also federally registered for the control of many household insects and home garden pests. Diazinon has now become a common name for all pesticides that contain this chemical as the active ingredient (AI).

There are over 200 diazinon products registered in California. Of these, only one diazinon product is currently being used for soil treatments by the California Department of Food and Agriculture (CDFA). This Department, the Department of Pesticide Regulation (DPR), has initiated this review partly in response to CDFA's use of diazinon for soil treatments in the Medfly Eradication Program. The formulation under review is an emulsifiable concentrate of diazinon (Diazinon AG500, EPA Registration No. 34704-41) that contains 4 lb AI per gallon of product. The label for this formulation specifies that a maximum of 5 lb AI be applied per acre of soil or sod area (i.e., approximately 0.12 lb AI per 1,000 sq ft of soil or sod area).

IV. U. S. EPA/CALIFORNIA STATUS

On January 6, 1986, USEPA initiated a Special Review for the use of diazinon on golf courses and sod farms (USEPA, 1986). That initiative was prompted by a number of bird kills reported earlier from ingestion of ganules. Included in the Special Review was an evaluation of the risks calculated for avian species. As a result of that special evaluation, USEPA issued a final order on March 29, 1988 to cancel the registration of diazinon for use on golf courses and sod farms (USEPA, 1988). At the same time, they issued a Registration Standard for the re-registration of all other diazinon products (USEPA, 1989), and classified all diazinon products of Toxicity Categories I (danger) and II (warning) as restricted use pesticides. That standard also called for more effective precautionary use directions on the label for those diazinon products that would be used on food crops and around the home. The deadline for complying with that label revision requirement was August 30, 1990 for product shipment, and August 30, 1991 for product distribution and sale.

A number of Special Local Need (SLN) uses of diazinon have been registered in California under FIFRA Section 24(c). Specific instructions are provided on the label for use of these SLNs. In particular, SLN No. CA-830017 (which was initially issued in 1983) allows the use of certain diazinon products in California as a soil (or sod) treatment for the control of fruit flies.

V. USAGE IN CALIFORNIA

Diazinon is not a restricted pesticide for many of the products (especially those for residential lawns and exterior home foundations) registered in California; as such, only licensed pest control operators were required to report its usage in California prior to 1990. (Now all pesticide use must be reported by *all* commercial users effective 1/1/90). The amount of diazinon applied by CDFA for Medfly eradication is expectedly small, compared to that for homeowner uses. During the 1990 and 1992 use seasons, a total of 49 lb of diazinon were applied on residential properties under the Medfly Eradication Program. No application of diazinon was made by CDFA for Medfly eradication in 1991 (per personal communication with Pat Minyard of CDFA Pest Detection/Emergency Projects Branch). The above usage suggests that approximately 1,000 residential properties were treated during 1990 - 1992 for Medfly eradication. This estimation is based on the assumption that each residential site was treated only once at the maximum label rate of 0.12 lb AI per 1,000 sq ft, and that these sites averaged about 400 - 500 sq ft (as only the soil and sod areas immediately around the infested host trees need to be sprayed).

VI. LABEL PRECAUTIONS

Of all the diazinon products registered in California, only a few products are labeled as having Category I toxicity and approximately 80 products, including Diazinon AG500, as Category II. The hazards from ingestion, inhalation, and dermal contact with this insecticide have been indicated on the labels; and a statement of practical treatment has been included. According to the labels, *unprotected* persons including children are not allowed to enter a treated (residential) area until the sprays have dried. For workers engaged in agricultural activities in California, the interval for reentry into treated citrus, grapes, peaches, and nectarines is 5 days after application. This longer reentry interval for agricultural workers is based on the observation that their activities are far more contact intensive, and that the application methods involved between residential and agricultural uses are quite different. The SLN Registration No. CA-830017 label specifies that all applicable directions and precautions given on the current USEPA-registered labels be followed. In addition, this SLN label requires that an inspector remain at the (residential) site until the spray drench is absorbed into the soil, that the individual whose properties are to be treated be advised of the appropriate label precautions, and that children and pets be kept off treated areas until the soil-drench treatment has dried.

VII. NONOCCUPATIONAL ILLNESSES

There were 81 illnesses and 2 deaths occurring in California between 1982 - 1990 that were reported to have been related to diazinon used in nonoccupational situations (PISP, 1993). The nonfatal cases included 72 systemic illnesses and 11 skin reactions or eye injuries. These illnesses represent a small number (< 10%) of such cases reported in California as related to all pesticides used in nonoccupational situations during 1982 - 1990. One of the two fatal cases (both suicides) and a majority (> 80%) of the nonfatal cases were reported to have been related to exposure to diazinon which was used as the only pesticide in nonoccupational situations. Twenty cases were known to have been given a test for cholinesterase depression; of these, 4 cases (20%) were confirmed as having a subnormal cholinesterase level. There were no illnesses or injuries reported as related to diazinon used for Medfly eradication.

VIII. DERMAL TOXICITY/SENSITIZATION

Acute dermal toxicity has been investigated in animals for technical diazinon and for several of its commercial formulations. For Diazinon AG500, the product under review, the acute dermal LD_{50} was reportedly 900 mg/kg in rabbits (Sax, 1984). Technical diazinon was shown to be capable of inducing the classical signs of acute cholinesterase inhibition in rabbits treated topically with 100 mg/kg (Ciba-Geigy Corporation, 1988). These signs included anorexia, ataxia, fasciculation, tremors, diarrhea, hypoactivity, hypotonia, and salivation. The diazinon products (including technical diazinon) were shown to have caused only a mild to moderate skin irritation (Category III or IV toxicity) in rabbits or rats (Ciba-Geigy Corporation, 1981a; 1981b; The Royal Society of Chemistry, 1990).

Technical diazinon was not demonstrated to be sensitizing when topically applied to guinea pigs (Y-TEX Corporation, 1989). However, according to a 1964 study reviewed by USEPA (1989), 10% of the 56 human volunteers showed positive dermal sensitization to diazinon as technical or 4E.

IX. DERMAL ABSORPTION

There is only one literature report on percutaneous absorption of diazinon in humans or animals, which was published recently by Wester *et al*. (1993). The results in this report were used rather extensively in this exposure assessment, since the study was found to have followed an acceptable protocol and the subjects used were human volunteers.

The study by Wester *et al*. involved a total of 18 human volunteers exposed for 24 hours to ^{14}C-ring labeled diazinon applied in acetone solution to the forearm or abdomen at 2.0 μg/cm^2, or in lanolin wool grease to the abdomen at 1.47 μg/cm^2. Complete void urine samples were then collected from these volunteers daily for 7 days. In addition, four female rhesus monkeys were each given an intravenous dose of 31.8 μg ^{14}C-diazinon (containing 2.1 μCi) in propylene glycol. The urinary ^{14}C excretion observed in these animals for 7 days was used to correct for the disposition of ^{14}C in human subjects that could not be accounted for by urinary excretion. The total accountability (dose recovery) in the rhesus monkey study was 78.4%. Reproduced in Table 1 are the (arithmetic) means and standard deviations of diazinon percutaneous absorption in human volunteers observed by Wester *et al*. These means were calculated by the investigators from human urinary values that had been corrected with the monkey urinary disposition after intravenous dosing for incomplete other route excretion. The highest mean of diazinon percutaneous absorption was 3.85% with a standard deviation of 2.16, and was observed in human volunteers whose forearms were applied with ^{14}C-diazinon in acetone.

Table 1. Percutaneous Absorption of Diazinon in Human Volunteers[a]

Skin Site	Vehicle	Mean ± S. D.[b]
Forearm	Acetone	3.85 ± 2.16
Abdomen	Acetone	3.24 ± 1.94
Abdomen	Lanolin	2.87 ± 1.16

[a] calculated from human urinary ^{14}C disposition corrected with the monkey urinary data for incomplete other route excretion; and based on six volunteers per group (Wester *et al*., 1993).

[b] both arithmetic mean and standard deviation (S.D.) were in % of dose.

X. ANIMAL METABOLISM

The animal metabolism of diazinon was investigated by many researchers between 1950 and 1970. This research interest was initiated mainly by the widespread application of the compound as a veterinary ectoparasiticide. According to a report by World Health Organization (1973), which was based on the observation by Schrader (1963) published in German, diazinon can be broken down to diazoxon and tetraethylmonothiopyrophosphate which are considered to be very potent cholinesterase inhibitors. Diazinon and its metabolites are also found to be very short-lived and to be rapidly excreted in animal urine and feces.

The excretion balance, distribution in organs, and the structures and properties of the main metabolites of diazinon in the rat have been extensively studied by Mucke *et al*. (1970). In their mass balance study the metabolism of diazinon ^{14}C-labeled (radiopurity not specified) in the pyrimidine ring and in the ethoxy groups was investigated in Wistar WU rats of approximately 200 grams. Feed and water were offered *ad libitum* while the animals were kept in all glass metabolism cages. The test materials were administered in the form of water-ethanol solution (8:2 v/v) orally by stomach tube or intravenously into the tail vein. The radioactivity in the urine was measured directly by liquid scintillation. The CO_2 in the expired air was absorbed into 3*M* sodium hydroxide solution, recaptured into ethanolamine-methanol solution (6:44 v/v) after acidification with sulfuric acid, and counted by liquid scintillation. The feces were homogenized and extracted 3 times with methanol-acetone (1:1 v/v). The fecal extract was then evaporated to dryness under vacuum, redissolved in methanol-toluene (1:1 v/v), and radioassayed, again by liquid scintillation.

The rapid excretion of diazinon and its metabolites in both male (n = 4) and female (n = 2) rats was demonstrated by the short time interval of approximately 12 hours that was required for the excretion of 50% of the radioactivity applied. Of the amount eliminated, 69 to 80% was excreted via the urine, 18 to 25% via the feces. The average total recovery of radioactivity ranged from 90.2 to 98.3% of the dose applied. These findings are found consistent with those observed in monkeys in the dermal absorption study by Wester *et al*. (1993) cited earlier. Three main metabolites representing approximately 70% of the total radioactivity applied were identified in rat urine and feces by Mucke *et al*. (see Figure 1). The position of these three major metabolites in the general pathway was demonstrated by following their metabolism after intravenous administration. Their main degradative mechanisms were found to involve hydrolysis of the ester bond yielding 2-isopropyl-4-methyl-6-hydroxypyrimidine and oxidation at the primary and tertiary C-atom of the isopropyl side chain. Upon loss of the phosphate moiety, these metabolites were reported to be no longer capable of inhibiting cholinesterase; and their acute oral toxicities were found to be less than one tenth of that of the parent compound.

Rats in the Mucke *et al*. study were also sacrificed at 6 hours, 1, 2, 5, or 8 days after dosing. All organ samples were immediately dissected and, except for fat, were refrigerated immediately and later homogenized with 4 volumes of water. The fat samples were treated in the manner described for feces. Muscles (drawn from back, foreleg, and hindleg) and fat (collected from the intestinal, subcutaneous, and testis fat deposits) were assumed to constitute 39% and 14% of the body weight, respectively. The results of these experiments showed that no accumulation of diazinon or its metabolites occurred in the essential organs of the rat; these organs included esophagus, stomach, small intestine, cecum/colon, liver, spleen, pancreas, kidneys, lungs, testis, muscles, and fat.

In addition to their own experiments, Mucke *et al*. provided a summary of the results from a series of residue studies that involved the metabolic and residual fate of diazinon in other animals. These residue studies included the residue analyses in fat and milk of cows (Bourne and Arthur, 1967; Claborn *et al*., 1963; Derbyshire and Murphy, 1962; Matthysse and Lisk, 1968) and sheep (Harrison and Hastil, 1965; Matthysse *et al*., 1968), in which diazinon had been applied regularly by spraying and dipping or by feeding the animals on treated pasture. In these studies only trace amounts of very short-lived diazinon residues were detected in fat and milk of cows and sheep, whereas other tissues in these animals were found to be free of residues (at the limit of detection). In two early studies in the cow (Robbins *et al*., 1957) and in the goat (Vigne *et al*., 1957), the rapid and complete excretion of the ^{32}P-labeled diazinon was reported to have occurred mainly via the urine.

XI. DISLODGEABLE FOLIAR RESIDUES

The data for diazinon dislodgeables on turf are now available to WH&S from its own field study conducted recently (Schneider *et al*., 1994). In this field study, diazinon was applied to a total of six residential lawns located in Sacramento County, utilizing procedures that were normally followed for Medfly eradication. With these data, it was possible for WH&S to more accurately estimate the dermal uptake of foliar diazinon for children playing on treated lawns. A further description of these dislodgeable foliar residue (DFR) data is given in the next section.

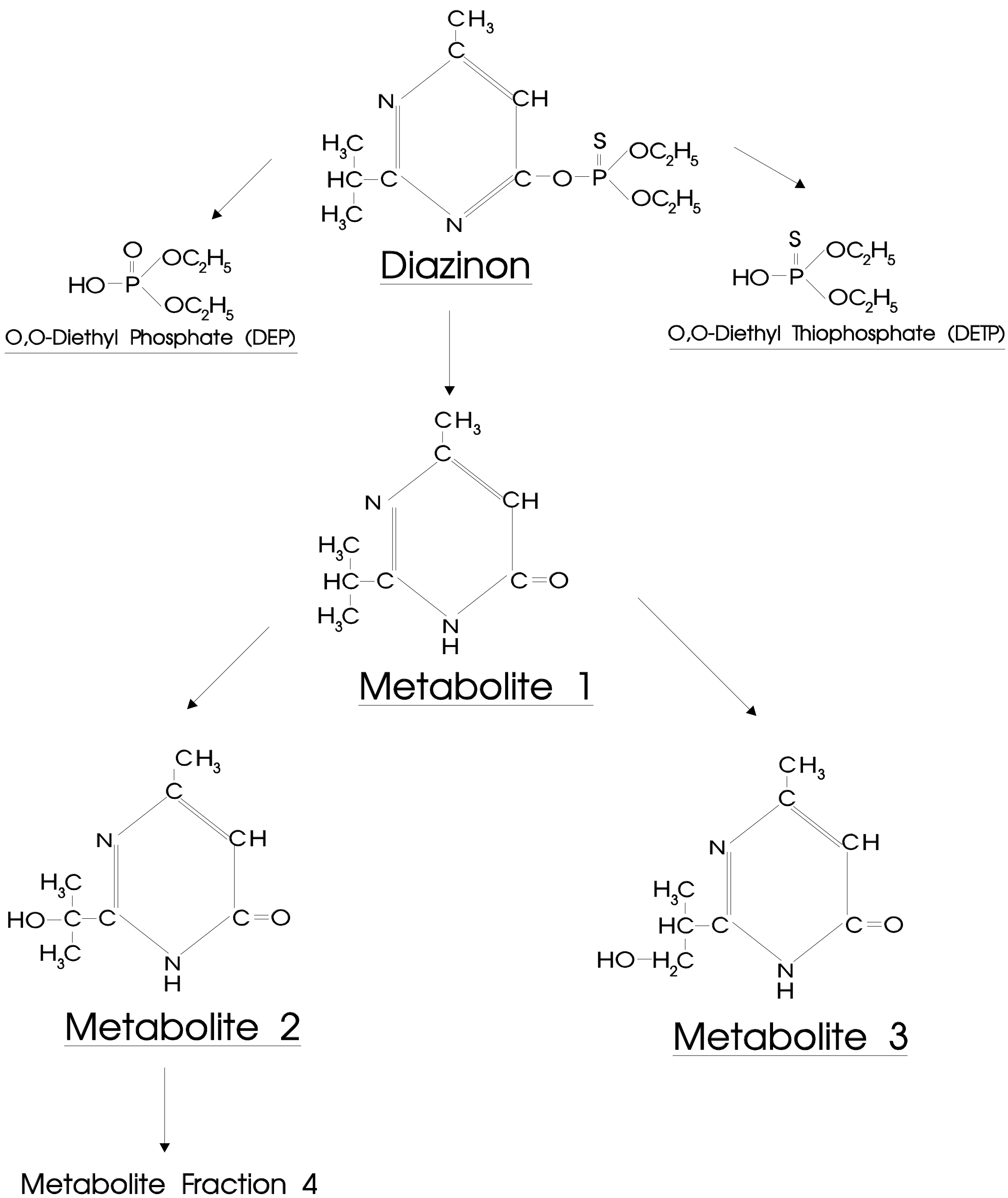

Figure 1. Metabolic Pathway of the Pyrimidine Moiety of Diazinon in the Rat, adapted from Mucke *et al*. (1970)

XII. EXPOSURE ASSESSMENT

Treatment Program for Medfly Project

The CDFA Pest Detection/Emergency Projects Branch has been using diazinon soil treatments as part of its Medfly Eradication Projects since 1980 (CDFA, 1989). The action plan of these eradication projects is to initiate diazinon treatments within the eradication zone as soon as Medfly larvae are detected or suspected to infest host fruit. These diazinon soil treatments are expected to destroy the Medfly pupae that still have not emerged from the ground.

An emulsifiable concentrate of diazinon formulated at 4 lb AI per gallon of product is being used in soil treatments under the authority and stipulations of California SLN No. CA-830017. This SLN permits soil treatment under various host plants (e.g., stone and pome fruits, nuts, berries, and vegetables) at the maximum allowable rate of 5 lb AI per acre. The emulsifiable material is to be diluted with water (at 120 gallons per acre or 3 gallons per 1,000 sq ft) and applied to the ground or sod with spray equipment operated at low pressure. The treated area is then drenched with sufficient water to move the material to a depth of 0.5 in. in the soil without runoff from the treated site. Soil or sod is treated under the host tree out to the drip line. Up to three applications can be repeated at the same site at 14 - 16 day intervals, where propagation conditions permit and if an infestation is confirmed.

Residents whose property will be treated are notified in writing prior to the treatment whenever possible. Treatment notices include the name of the pest, the material used, the boundaries of the treatment area, and information phone numbers for project questions and medical attention. Prior to treatment, any fruit present is stripped from all host trees on the infested property and properties adjacent to it. These treatments are performed by personnel (usually consisting of a team of five workers) from the Pest Detection/Emergency Projects Branch of CDFA or the County Agricultural Commissioners Office. An inspector then remains at the site until the spray drench is absorbed into the soil. Residents of treated properties are advised through verbal or written contact to stay away from the treated soil or sod *until the sprays have dried* (usually after 3 to 5 hours).

Modes of Exposure for Residents of Treated Properties

Residents may be exposed inadvertently to some diazinon residues, as it must be assumed that they will enter or pass through their treated residential areas within a few hours of treatment. Activities such as walking or playing on the lawn or soil under treated hosts may bring residents in contact with residues by dermal or inhalation exposure. Since the residents are not advised to wear any protective clothing when reentering their treated residential areas, it must also be assumed that nearly all parts of their body are available for dermal exposure. In addition, the remote possibility that diazinon soil residues can be absorbed into late-emerging host fruit must be considered.

In practice, the method of application and the physical characteristics of diazinon preclude much of the exposure to residents from some of the routes considered above. Inhalation of airborne diazinon residues could be a possible route of exposure for children playing in treated areas or for a person mowing a treated lawn. Diazinon does have a moderate vapor pressure (1.4×10^{-4} mm Hg) at 20ºC (Ciba-Geigy Corporation, 1979), suggesting that its residues on soil could act as a source of potential inhalation exposure. However, exposure to diazinon via this route is alleviated in part by the method of application involved in the diazinon treatment. Even though diazinon has limited water solubility, the water drench following the diazinon application washes most of the residues into the thatch and soil. The increased surface area of the soil particles will bind much of the diazinon residues and, hence, will substantially reduce their volatility.

Several home and garden products formulated with diazinon as the active ingredient are registered for the control of lawn pests. A worker exposure study by Weisskopf *et al*. (1988) showed that the inhaltion exposure ranged from 13 - 168 µg/hr for crew workers applying 14% diazinon *granules* with a variety of spreaders. Since the maximum inhalation exposure to a pesticide generally occurs during mixing/loading and application, the inhalation exposure experienced by these applicators should be considered the maximum a person could experience from airborne diazinon residues.

The actual inhalation exposure which children will receive from playing on a treated lawn (or which a person will receive from mowing a treated lawn) is expected to be several thousand times less, however, primarily because of the activities, the application procedures, and the formulation involved. For instance, a worker exposure study was conducted a decade ago by Davis *et al*. (1983), in which three volunteers were monitored for potential dermal and inhalation exposures to diazinon from applying the insecticide to residential lawns with either a compressed air or a hose-end sprayer. These sprays were prepared from home product emulsifiable materials that were diluted in sufficient water to give a concentration equivalent to that used for Medfly soil treatments. The highest average inhalation exposure observed for the volunteers (using hose-end sprayers) was less than 10 µg/hr. It is important to point out again that under the Medfly Eradication Program, children are restricted from playing in the treated area until the diazinon turf or soil residues have been watered in and until after the sprays have dried, by that time the airborne residues would dissipate almost completely.

Mowing the lawn could also be another source of dermal exposure. This potential exposure is mitigated by several circumstances, however. Because of the inherent risks from operating a lawn mower, the operator is expected to wear some clothing that would provide protection from dermal exposure. Shoes, in particular, will provide protection from the most likely site of exposure for soil residues or for those presented on turfgrass. An application exposure study of home gardeners indicated that clothing could provide 90% protection from dermal exposure to many pesticides in use (Bode and Kurtz, 1985). Most lawn mower operators are subject to minimal contact with the cut grass except when emptying the grass catcher. This minimal contact, together with the infrequency of lawn mowing (i.e., normally ≤ once a week) by homeowners, is expected to further reduce the likelihood of their exposure to diazinon residues present on treated lawns.

The possibility that soil residues from a diazinon treatment can be absorbed into host fruit has been investigated by the U. S. Department of Agriculture (USDA). A study was conducted in Santa Clara County, California in 1983 by the USDA in conjunction with a Medfly eradication project (Fairchild, 1983). In that study, one application of diazinon was made at 5 lb AI per acre to soil underneath apricot, lemon, and orange trees. A second application was made between 21 and 35 days after the first. Soil, leaves, and fruit were sampled before treating and at various time intervals after the first application, As a result, more than 100 fruit and leaf samples were measured. All the post-application samples taken from the apricot and orange trees were negative. Two leaf samples from the lemon trees taken 21 days after the first treatment had diazinon residues below 0.03 ppm (parts per million). Three fruit samples collected from the lemon trees at 35 days post-application contained diazinon residues ranging from 0.01 to 0.08 ppm.

Although it is apparent that little or no soil residues from a diazinon treatment will be absorbed into host fruit, there is still a slight possibility that fruit could be contaminated by some splashing of the material during application. This risk is mitigated, however, by the project protocol that calls for all fruits to be stripped from hosts prior to treatment. Most of the host plants treated under the Medfly Eradication Project have existing food tolerances for diazinon. The tolerance of 0.7 ppm for diazinon in lemons is approximately 9 times greater than the highest residues detected in the USDA study. In the remote possibility that soil diazinon residues can be absorbed into host fruit over an extended period of time, these residues in late-emerging fruit are expected to be less than the accepted tolerance levels set by USEPA. This speculation is not without justification, since soil diazinon residues will degrade over time.

Estimation of Diazinon Exposure from Treated Soil

The degradation of diazinon in California soil was also investigated in the above residue study by USDA. In that study, 40 soil samples were collected at each sampling 1, 7, 21, and 35 days post-application. The diazinon soil residues measured within 1 day post-application ranged from 1.19 to 49.6 ppm, with an arithmetic mean of 9.95. These levels dropped to a mean of 2.13 ppm at 7 days post-application. Recently, the field staff of DPR also conducted four studies in which the soil level was monitored for diazinon applied with procedures specific for a typical Medfly soil drench treatment in California. The results of these recent studies, together with those from the USDA study in 1983, are summarized in Table 2.

Soil Concentration. Table 2 shows that soil levels for samples taken from all studies at all sites ranged from 0.3 to 80.7 ppm, with a grand geometric mean of 13.4 (which was taken over all individual site-specific arithmetic means). The grand *geometric* mean, rather than the grand *arithmetic* mean, was considered in this exposure assessment because environmental chemical concentrations tend to be lognormally distributed. A normality test of the data on hand supported this assertion, in that the arithmetic means listed in Table 2 were shown to have more a lognormal than a normal distribution. The grand geometric mean weighted by the number of samples (replicates) in each study was not used here because the replicates in many studies since 1992 were measured primarily for reproducibility, whereas those in the 1983 study included measurements at different sites. Otherwise, the *weighted* grand geometric mean would give a slightly lower level of 13.3 ppm.

Table 2. Soil Levels of Diazinon Applied with Procedures for Medfly Treatment in California[a]

Field Study	Location	Samples from Day 1	Range (ppm)	Mean (ppm)[b]
Fairchild, 1983	Santa Clara	40	1.2 - 49.6	9.95
Leyva, 1993	Rosemead	8	17.6 - 80.7	42.85
	Granada Hills	8	9.5 - 50.5	30.58
		8	2.4 - 33.9	14.19
Ando *et al*., 1993[c]	Duarte	8	5.3 - 27.7	14.54
		8	0.3 - 33.5	14.73
Schneider *et al*., 1994	Sacramento	3	3.0 - 10.9	8.27
		3	11.2 - 16.1	13.03
		3	8.5 - 14.5	10.60
		3	9.0 - 15.7	12.94
EMPM, 1994[d]	Sacramento	4	15.9 - 23.3	20.19
		4	5.9 - 11.0	7.90
		4	2.2 - 6.7	4.95
			Grand Geometric Mean	13.43[e]

[a] samples taken within 1 day after watering-in and to a depth of 1 cm.

[b] arithmetic mean.

[c] from the first and the second successive application (14 days apart) at the same general sampling sites; 8 other samples from the third successive application (also 14 days later and at the same general sampling sites) are not included here because of their unexpectedly low values detected (ranging from 0.7 to 5.8 ppm with a mean of 1.8).

[d] data obtained through personal communication, as the report of this study has not yet been finalized by the Environmental Monitoring and Pest Management Branch (EMPM) of this Department.

[e] taken over all arithmetic means (see subsection on Soil Concentration above for further discussion), with a geometric standard deviation of 1.76 ppm.

As only summary statistics were given in the USDA study by Fairchild (1983), only the arithmetic means and ranges of soil level from all the studies are listed in Table 2. Figure 2 below nonetheless provides a frequency histogram of all the soil levels measured in all the studies since 1992. As expected, this histogram shows graphically that the composite soil levels tended to have a lognormal distribution.

The Worst-Case Approach. There are no available data that have measured the dermal exposure of individuals performing activities on diazinon-treated soil (or turf). However, from a literature review USEPA (1992a) has recently concluded that for adults as well as children, the *best average* soil-to-skin adherence per event is 0.2 mg of soil per cm^2 of skin surface, with an upper bound of 1.5. From the above estimates for skin-soil loading, it can be assumed that the dermal uptake from treated soil will be at most 80.7 ppm x 1.5 mg/cm^2 = 121.1 x 10^{-6} mg of diazinon residues per cm^2 of skin surface. This estimate also represents the maximum *daily* exposure for a two-year-old child, in that USEPA (1990) recently has estimated that 1.6 hours would be the average time *per week* spent outdoors by children of age 3 - 11.

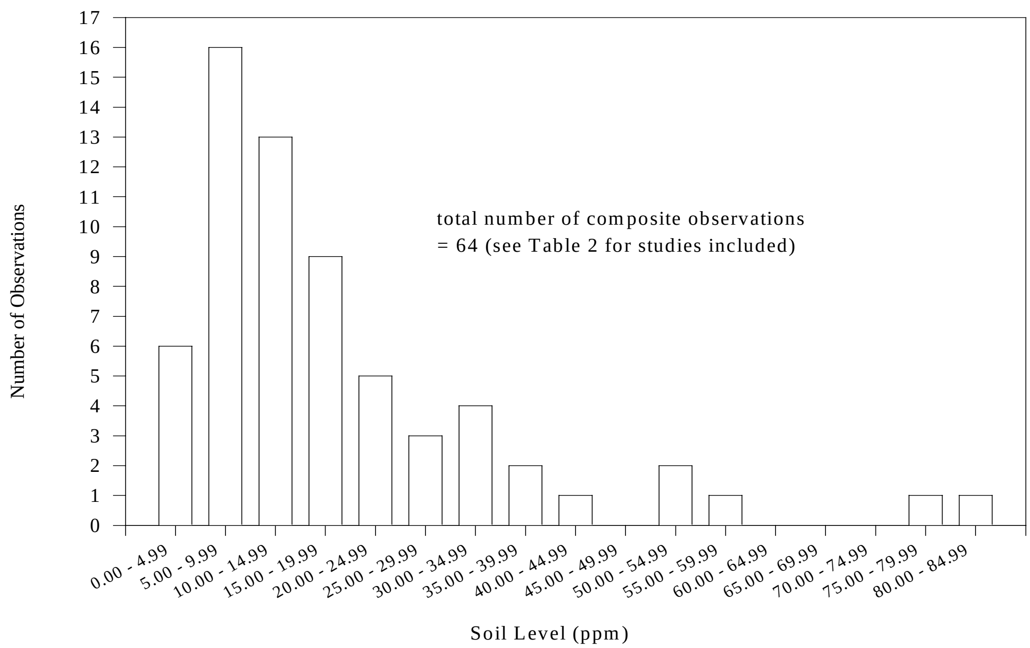

Figure 2. Histogram of Composite Diazinon Soil Levels from Studies Since 1992

Note that even though there might be more than one contact event occurring within an hour, the estimates used above for skin-soil loading should still be adequately treated as for the entire loading in an hour or in 1 day. It is also important to note that the dermal absorption of 3.85 ± 2.16% listed in Table 1 for diazinon was *over a 24-hour exposure time*. If this absorption could *indeed* occur and be completed within a few minutes or so after a single skin-soil loading event, then the basic assumption is that there would be *no further absorption* of the remaining ≥ 90% of diazinon that is left on the skin during the remaining 24 hours. In that case, another loading of soil from the *second* or *third* contact event during the 1 or 2 hours of playtime would be immaterial. However, the absorption of diazinon from soil is not expected to be completed until a couple of hours after the soil matrix has been loaded onto the skin. There is at least one literature report (Wester *et al*., 1990) on hand showing that the amount of benzo(α)pyrene or of DDT from soil that penetrated into human or monkey skin was manyfold less than the same amount of chemical prepared in acetone solution. Results from this literature report further support the notion that much less than 100% of the loaded soil diazinon residues would be absorbed into the skin.

In this exposure assessment, the one-hour exposure time assumed for a two-year-old child was also based on a radon study by Rogers *et al*. (1986), who found that children of age 6 - 15 would spend on the average 1 hour outdoors per day; a two-year-old child is expected to play outdoors less frequent or in shorter duration than this. The observation made by Rogers *et al*. is consistent with the survey conducted recently by the California Air Resources Board (Phillips *et al*., 1991) on the activity patterns of children. According to the California survey, children under age 12 would spend an average of about 1 hour per day playing in their yard (based on *all* children surveyed). WH&S further contends that it is highly unlikely for any children to play vigorously for more than 1 hour on treated lawns or soil *on the day the treatment is made*. Even if their area is to be treated with diazinon in the morning, the children would have at most a couple of hours to play outdoors that afternoon due to the three- or four-hour (i.e., until the sprays have dried) reentry restriction. It is also important to note that usually only the immediate areas around the infested host plants will be treated. These assumptions and conditions, together with the use of the following rather conservative model for exposure extrapolation, should provide an estimate of the worst-case dermal exposure that could occur for children playing on treated lawns or soil.

According to USEPA (1990), the 5*th* and 50*th* percentile for girls of age 2 are 10.4 and 12.6 kg, respectively. The total body surface area (SA) of a child at this age can then be approximated using the following empirical formula by Costeff (1966): SA = (4 x BW + 7)/(BW + 90). For a girl having a 1*st* percentile body weight, which can be reasonably assumed to be about 9 kg, her body surface approximated from the above formula would be 4,343 cm^2. Of this total body surface, up to 55% (at the 99*th* percentile) has been assumed to be the exposed area responsible for skin-soil loading (Thompson *et al*., 1992). The means and standard deviations listed in Table 1 also suggest that the dermal absorption of diazinon in humans can be as high as 10%.

Under these assumptions, the maximum absorbed daily dosage (ADD) would be 3.2 µg/kg/day for a two-year-old child from dermal uptake of diazinon in soil (i.e., [121.1 x 10^{-6} mg/cm^2 x 55% x 4,343 cm^2 x 10%] ÷ 9 kg = 3.2 µg/kg/day). This dosage could also be considered as the maximum dermal uptake for adults gardening in treated soil, since a two-year-old child (girl) has the greatest body surface area per unit of body weight (and is likely to have the worst mouthing behavior). Mathematically, this ADD calculated under this set of worst-case assumptions would be reduced six-fold if the geometric mean of 13.4 ppm for diazinon soil level were used instead. The same ADD would be reduced another seven- or eight-fold if the best average of 0.2 mg/cm^2 for skin-soil loading were also used, instead of the upper bound of 1.5.

Many children have periods of intensive mouthing behavior, during which soil or dust particles can thus be transferred from their hands or play objects into their mouths. The highest daily soil intake among children is reportedly around 800 - 1,000 mg for normal mouthing behavior, and 10,000 mg for pica or abnormal mouthing behavior (USEPA, 1992a). These soil ingestion rates can be translated into a maximum daily dosage of 9.0 µg of diazinon residues per kilogram of body weight for normal behavior and of 90.0 µg/kg for abnormal behavior, given that the highest reported soil level was 80.7 ppm and that an oral absorption of 100% is often taken as the default (e.g., 80.7 ppm x 10,000 mg/day x 100% ÷ 9 kg = 90 µg/kg for a two-year-old child having pica).

The studies or reports from which the likely-used extreme values were derived for the above worst-case models are listed in Table 3. Also included in Table 3 for further appreciation are the related means or approximations of central tendency and the ranges leading to these extreme values.

Table 3. Literature Data Used for Estimation of Dermal Uptake and Oral Intake of Diazinon in Soil

Exposure Parameter	Study/Report	Mean/Fair Estimate(s)	Range	Likely-Used Extreme Value
diazinon soil level, ppm	Table 2[a]	13.4	0.3 - 80.7	80.7
skin-soil loading, mg/cm^2	USEPA, 1992a[b]	0.2	0.2 - 1.5	1.5
	Thompson *et al*., 1992		0.5 - 1.5	
dermal absorption, %	Wester *et al*., 1993	3.85 ± 2.16		≥ 6.0[c]
fraction of skin exposed	USEPA, 1992a[d]		0.05 - 0.25	
	Thompson *et al*., 1992	0.12 ± 1.65[e]	0.03 - 0.55	0.55
soil ingestion, mg/day	Whitmyre *et al*., 1992	200	40 - 1,000	
	USEPA, 1990[f]	200	10 - 10,000	≥ 1,000
body weight (BW), kg	USEPA, 1990[g]	12.6	9.0 - 16.2	9.0
body surface, m^2	Costell, 1966	= (4 x BW + 7)/(BW + 90)		0.43

a samples (n = 104) taken after watering-in, to a depth of 1 cm, and within 1 day of treatment with 0.12 lb emulsifiable concentrate (in 3 gallons of water) per 1,000 sq ft of soil.

b per event (treated as per day, *see* text for further discussion); same range as that listed in Finely and Paustenbach (1994).

c this highest observed arithmetic mean plus 1 standard deviations is treated as the minimum extreme.

d the suggested fraction for winter, spring, summer, and fall were 5, 10, 25, and 10% of the skin, respectively.

e shown are the geometric mean (GM) and the geoemtric standard deviation (GSD); the likely-used extreme was a 99*th* percentile calculated from multiplying GM by GSD^3 for a central 98% distribution.

f including children with pica; otherwise, a normal upper bound was estimated to be 800 - 1,000 mg/day.

g the 5*th* and 50*th* percentiles for a girl of age 2 were reportedly 10.4 and 12.6 kg, respectively; the 1*st* and 99*th* percentiles are hence estimated to be 9.0 and 16.2 kg, respectively.

The Probabilistic Approach. The above conventional worst-case approach to estimating the ADD has an apparent major drawback, in that the degree of conservatism in the assessment cannot be appreciated. It is also highly possible that the use of the above default, conservative values might generate a scenario that rarely, if ever, happens. As a matter of fact, in reality it would be extremely rare to find a very skinny two-year-old child (girl) who would take in soil at the maximum reported ingestion rate while, and at the same time, the soil concentration of diazinon in her treated property is also at the highest observable. In light of these concerns, a Monte Carlo-based probabilistic model was constructed to simulate a reasonable, yet sufficiently conservative probability distribution of the ADD estimate in question.

The technique used for the simulation was based on the procedures developed recently by Finley and Paustenbach (1994), by Thompson *et al*. (1992), and by Whitmyre *et al*. (1992). It treated each of the key input exposure parameters (e.g., skin-soil loading, soil concentration of diazinon, soil ingestion rate, etc.) as a random variable. The simulation then relied on the computer to draw one random value from the pre-defined probability distribution for each random input variable under study, and finally to compute a single ADD estimate using the values randomly selected (and those that were fixed for other nonrandom input parameters, if any). This simulation process was repeated 10,000 times in order to produce a fairly representative set of the estimated values for the ADD in question. This large set of 10,000 estimated values was then used to provide a reasonable high-end (e.g., the 90*th* or the 99*th* percentile) of the ADD estimate. There were 10 simulation trials performed (each consisting of 10,000 runs) in an effort to ensure fairer randomness of the value selection and more precision of the high-end estimation, thus yielding a total of 10 large sets of estimated values for each of the uptake and intake ADD in question.

Table 4. Variables and Constants Used in the Simulation

Parameter	Units	Probability Distribution	Fixed Value/ Mean ± S.D.[a]	Range[b]	Source[c]
A. For Dermal Uptake of Diazinon in Soil					
Soil Concentration	mg/kg	Lognormal	13.4 ± 1.82	1 - 100	*C*
Skin-Soil Loading	mg/cm^2	Uniform		0.5 - 1.5	*B*, *D*, *F*
Body Weight	kg	Normal	12.6 ± 1.2	9.0 - 16.2	*E*
Body Surface	m^2	= (4 x BW + 7)/(BW + 90)		0.43 - 0.68[d]	*A*
Fraction of Skin Exposed		Lognormal	0.20 ± 1.4	0.05 - 0.65	*D*, *F*
Dermal Absorption		Uniform		3.85 - 10.3%	*G*
B. For Oral Intake of Diazinon in Soil					
Soil Concentration	mg/kg	Lognormal	13.4 ± 1.82	1 - 100	*C*
Soil Ingestion Rate	mg/day	Lognormal	200 ± 1.71	10 - 10,000	*E*, *H*
Body Weight	kg	Normal	12.6 ± 1.2	9.0 - 16.2	*E*
Oral Absorption			100%		default

[a] the 50*th* percentile for girls of age 2 was used as their *mean* body weight; for a lognormal, the above geometric mean and geometric standard deviation (S.D.) after logarithmic transformation were used to describe the underlying (normal) distribution; for a uniform, the lowest and the highest were used; and where necessary, the required S.D. was estimated from setting a reported extreme value (which was not necessarily the upper limit) at the 99*th* percentile. (*see* also Table 3).

[b] based on a conservative approach, especially for the upper limits (some of which were greater than their 99*th* percentile).

[c] from: (*A*) Costeff, 1966; (*B*) Finley and Paustenbach, 1994; (*C*) Table 2 of this assessment document; (*D*) Thompson *et al*., 1992; (*E*) USEPA, 1990; (*F*) USEPA, 1992a; (*G*) Wester *et al*., 1993 (also *see* Table 1 of this document); and (*H*) Whitmyre *et al*., 1992.

[d] based on the range for body weight (BW) and the empirical formula by Costeff (1966) as shown above.

The random variables were each pre-assigned a range of values whose selection during each simulation run was governed by some pre-defined probabilistic rules. Many of the probabilistic rules (i.e., the assumed probability distributions, means, and fixed values) used in this simulation study were based on those adopted by Costeff (1966), Thompson *et al*. (1992), USEPA (1990, 1992a), or Whitmyre *et al*. (1992). The actual simulation was implemented using *Crystal Ball* (1993), a computer software designed specifically for this type of iterative analysis. The input parameters used, along with their probability distribution or fixed value where applicable, are provided in Table 4. Examples of simulation output based on a case study using similar input distributions are available in an attachment to the report by Dong *et al*. (1994).

Table 5. Absorbed Daily Dosages Simulated for Dermal Uptake of Diazinon in Soil[a]

Percentile	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
0.0%	0.004	0.002	0.005	0.004	0.003
2.5%	0.015	0.015	0.016	0.015	0.015
5.0%	0.019	0.019	0.020	0.020	0.019
50.0%	0.076	0.078	0.078	0.077	0.077
95.0%[b]	0.288	0.298	0.295	0.292	0.291
97.5%	0.370	0.378	0.373	0.374	0.371
100.0%	1.243	1.324	1.653	1.784	1.348

Percentile	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10
0.0%	0.004	0.002	0.004	0.004	0.004
2.5%	0.015	0.015	0.014	0.015	0.015
5.0%	0.020	0.020	0.019	0.020	0.019
50.0%	0.078	0.078	0.077	0.079	0.076
95.0%[b]	0.284	0.295	0.293	0.288	0.295
97.5%	0.373	0.367	0.382	0.375	0.376
100.0%	1.381	1.738	1.713	1.638	1.039

[a] in µg/kg/day for a two-year-old child (girl) playing in residential soil within 1 day after treatment for Medfly eradication; *see* text (under subsection for the Worst-Case Approach) for basic algorithm used for dosage calculation; and each trial is comprised of 10,000 simulation runs.

[b] this 95*th* percentile averaged over the 10 trials should be used as the dosage for risk assessment.

The results of the 10 simulation trials for dermal uptake and for oral intake are presented in Tables 5 and 6, respectively. Table 5 shows that for a two-year-old child (girl) playing on treated soil within 1 day post-application, the 95*th* percentile simulated for the uptake ADD averaged 0.3 µg per kilogram of body weight. The highest value simulated for this uptake ADD based on all 10 trials was 1.8 µg/kg, which is 44% less than the worst-case uptake value calculated earlier. The average 95*th* percentile of the ADD simulated for oral intake was 0.8 µg/kg, as shown in Table 6 The highest value simulated for this intake ADD based on all 10 trials was 6.8 µg/kg, which is 24% less than the worst-case intake value calculated earlier for normal mouthing behavior and 92% less for pica behavior. These findings suggest that the worst-case scenarios considered earlier for dermal uptake and oral intake will rarely, if ever, happen. Literally, it means that many more simulation runs than 100,000 (i.e., 10 trials x 10,000 runs/trial) are needed before there will be one success attained of having *all* the extreme values (e.g., the highest reported values for soil concentration of diazinon, for skin-soil loading, for soil ingestion rate, etc.) selected *simultaneously* for calculation of the ADD in question.

Table 6. Absorbed Daily Dosages Simulated for Oral Intake of Diazinon in Soil[a]

Percentile	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
0.0%	0.010	0.011	0.013	0.006	0.006
2.5%	0.039	0.039	0.041	0.040	0.042
5.0%	0.052	0.052	0.054	0.055	0.055
50.0%	0.207	0.211	0.214	0.210	0.213
95.0%[b]	0.806	0.791	0.823	0.818	0.825
97.5%	1.077	1.034	1.038	1.090	1.070
100.0%	5.269	5.862	4.668	6.831	5.766

Percentile	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10
0.0%	0.012	0.006	0.007	0.011	0.005
2.5%	0.042	0.041	0.040	0.041	0.041
5.0%	0.055	0.054	0.054	0.054	0.053
50.0%	0.208	0.209	0.206	0.210	0.206
95.0%[b]	0.826	0.811	0.821	0.844	0.800
97.5%	1.060	1.058	1.065	1.122	1.050
100.0%	4.374	4.546	6.525	4.237	5.202

[a] in μg/kg/day for a two-year-old child (girl) playing in residential soil within 1 day after treatment for Medfly eradication; *see* text (under subsection for the Worst-Case Approach) for basic algorithm used for dosage calculation; and each trial was comprised of 10,000 simulation runs.

[b] this 95*th* percentile averaged over the 10 trials should be used as the dosage for risk assessment.

According to USEPA's Guidelines for Exposure Assessment (1992b), the high-end estimator from a Monte Carlo simulation should be somewhere between the 90*th* and 99.9*th* percentiles. In accord with this recommendation, WH&S proposes that a 95*th* percentile be used as a reasonable upper-bound estimate for this exposure assessment using the Monte Carlo technique, since a value beyond the 95*th* percentile would normally be subject to relatively greater uncertainty (Finley and Paustenbach, 1994). As pointed out earlier, the average 95*th* percentiles simulated for dermal uptake and oral intake of diazinon in soil were, respectively, 0.3 and 0.8 μg/kg/day, and are less than their worst-case estimate calculated above by ten-fold or more.

Conservative 95th Percentiles. It is important to note that the 95*th* (and other) percentiles simulated in this exposure assessment for the uptake and intake ADD were themselves conservative estimates. As shown in Table 4, the lowest value used for skin-soil loading in this simulation study was 0.5 mg/cm^2, which is more than twice the best average of 0.2 mg/cm^2 reported by USEPA (1992a). This range restriction was deemed appropriate to some assessors or was treated as conservatively necessarily here, in that the soil treated with diazinon for Medfly eradication could be of the type that would have a higher skin-soil adherence property. In accordance with the assumption made by Thompson *et al*. (1992), skin-soil loading in this simulation study was further assigned a uniform distribution wherein the upper limit (1.5 mg/cm^2) would have the same probability of being selected as would any other value within the range. In this simulation study, dermal absorption of diazinon was likewise assigned conservatively a uniform distribution ranging upward from the highest mean (3.85%) listed in Table 1 to three standard deviations from this mean (10.3%). Three other input probability distributions and value ranges are also noteworthy here. These are those used for diazinon soil concentration, fraction of skin exposed, and soil ingestion rate.

Although the highest soil concentration observed was 80.7 ppm, the upper limit permissible for selection in the simulation was set at 100 ppm. The assignment of lognormal distribution to this variable was discussed in the subsection on Soil Concentration. As footnoted in Table 2, the associated geometric standard deviation was calculated to be 1.76 ppm. This geometric standard deviation will yield a 99*th* percentile of 73.1 ppm (for derivation *see* footnote *e* in Table 3) for the underlying normal distribution. In this simulation, the geometric standard deviation was extended conservatively to 1.82 ppm (*see* Table 4), however, in order to set the highest observed level (80.7 ppm) at the 99*th* percentile. In addition, a higher geometric mean of 13.4 ppm was used in this simulation, as footnoted in Table 2, by excluding from the calculation a set of 8 soil levels in the study by Ando *et al*. (1993) that were found unexpectedly or atypically low.

The range of values used by Thompson *et al*. (1992) for fraction of skin exposed was from 2.5 (1*st* percentile) to 55% (99*th* percentile), with a geometric mean of 12%. Their range restriction for this input parameter was consistent with the literature findings summarized in a report by USEPA (1992a). In that same report, USEPA also suggested that a reasonable estimate of surface area exposed would be 5% of the skin during the winter, 10% during the spring and the fall, and 25% during the summer. The geometric mean and the upper limit used for fraction of skin exposed in this exposure assessment were, respectively, 20 and 65%. These fractions are considered to be conservative estimates, in that soil treatments for Medfly eradication in California usually occur between the spring and the fall, not just in the summer.

In their simulation for soil intake, Whitmyre *et al*. (1992) used the soil ingestion rates of 200 and 1,000 mg/day as the geometric mean and the 99*th* percentile, respectively. These rates are essentially those recommended by USEPA (1990) for normal mouthing behavior and, hence, were used accordingly in this exposure assessment. The upper limit for soil ingestion in this exposure assessment was extended to 10,000 mg/day, however, in order to include the remote possibility that a two-year-old child could have pica. Note that the soil ingestion rates suggested by Finley and Paustenbach (1994) for ages 1.5 - 5 years were much lower (ranging 9 to 50 mg/day).

Results of sensitivity analysis from *Crystal Ball* (1993) indicated that these five input variables had a greater influence over the intake and uptake simulation than body weight had. This is expected since the body weight for a two-year-old child (girl) is assumed to follow a normal distribution with a relatively very narrow range (9 - 16 kg), and is quantitatively related to the value used for body surface (which has an effect offsetting that exerted on the dosage by body weight).

Estimation of Diazinon Exposure from Treated Lawns

There are again no measurements of dermal exposure available to WH&S for children playing on lawns sprayed with diazinon. Accordingly, the exposures to diazinon calculated below for these children were based on the DFR data recently collected by WH&S's field teams (Schneider *et al*., 1994), and on a transfer rate derived from a study by Harris and Solomon (1992) on 2,4-D herbicide. The transfer rate derived from the 2,4-D study was used for this exposure extrapolation because of the high degree of *compatibility* in exposure activities found between that study and the scenario considered here.

The 2,4-D herbicide in the study by Harris and Solomon was applied to turfgrass at the rate of 0.02 lb AI per 1,000 sq ft. All 10 adult volunteers in the study were exposed to a 2 m by 15 m area of turf for 1 hour, during which they alternated between walking and sitting or lying on the turf surface for intervals of 5 minutes. Half of the volunteers wore long pants, a short-sleeved shirt, socks, and closed footwear, while the other five wore shorts and a short-sleeved shirt and were barefoot. These two groups were all asked to perform the required activities 1 hour after the first application and 1 day following the second which took place one month later. Urinary 2,4-D above the detection limit was found in only three volunteers who were all in the group wearing shorts, and were all exposed to 2,4-D 1 hour following the first application. The average total body dose of 2,4-D, as monitored in the urine from these *three* volunteers, was 227.6 µg.

2,4-D Transfer Rate. In addition to the total 2,4-D body doses, Harris and Solomon measured the dislodgeable residues on treated turf during the 1 hour exposure period. They collected the 2,4-D dislodgeables off five 1 m x 1 m plots through vigorous wiping, using the sampling procedures described by Thompson *et al*. (1984). The wiping involved scuffing backwards and forwards across the grass for 1 minute and was performed with a double layer of cheesecloth tied over the shoes. The 2,4-D dislodgeables measured for the five plots 1 hour after application were between 4.9 and 10.9 mg/m^2, with an average of 8.45. Although a statistical analysis showed that the 2,4-D turf dislodgeables tended to follow more a normal than a lognormal distribution, the geometric mean of 8.15 mg/m^2 was used in this exposure assessment in order to derive a slightly more conservative transfer rate. Based on the above observations and considerations, the transfer rate for dermal uptake from turf was calculated to be 227.6 µg/hr per 8.15 mg/m^2 of turf dislodgeables, or 27.9 µg/hr per mg/m^2 of turf dislodgeables. The dermal absorption of 2,4-D in humans was determined previously by Feldmann and Maibach (1974) to be 5.8%. With this dermal absorption for back-calculation, the transfer rate for *dermal exposure* would be 480 µg/hr per mg/m^2 of *turf dislodgeables that could be wiped off by scuffing in a one minute interval*.

Diazinon DFR and Dosages. Table 7 lists the time-dependent DFR predicted for diazinon levels that are likely to be found on residential lawns treated for Medfly eradication. These DFR were projected from the log-linear regression curve that was constructed to summarize the dissipation of diazinon dislodgeables present on treated lawns. The regression coefficient and the associated correlation coefficient are footnoted in the table. The data used for the regression were from field samples recently taken at six residential lawns located in Sacramento County (Schneider *et al*., 1994). These field data were collected by WH&S's field teams who followed closely the sampling procedures of Thompson *et al*. (1984) and, hence, also those by Harris and Solomon (1992). As pointed out earlier, the field teams also applied diazinon to the residential lawns following treatment procedures that were normally used for Medfly eradication. In performing the regression analysis, the average DFR from each time point (ranging from 2 hours to 14 days post-application in 7 time points) was used. Where the mean value was listed under a time interval (e.g., 10 - 14 days), the midpoint of the time interval (e.g., 12 days) was used.

Table 7. Dermal Uptake of Foliar Diazinon from Treated Lawns[a]

Hours Post-Application	Predicted DFR (μg/m²)[b]	Dermal Exposure (μg)[c]	Absorbed Daily Dosage (μg/kg BW)[d]
4	93.0	44.64	0.40 (0.28)
12	84.3	40.46	0.36 (0.26)
24	72.8	34.94	0.31 (0.22)
48	54.2	26.02	0.23 (0.17)
72	40.4	19.39	0.17 (0.12)
96	30.1	14.45	0.13 (0.09)
120	22.4	10.75	0.10 (0.07)
168	12.4	5.95	0.05 (0.04)
240	5.1	2.45	0.02 (0.02)
336	1.6	0.77	0.01 (0.01)

[a] with application procedures normally followed for Medfly eradication.

[b] from the following log-linear regression, which was derived from the dissipation data on diazinon dislodgeable foliar residues (DFR) summarized in a recent study (Table III) by Schneider *et al*. (1994): $\log_{10}$ [DFR] = 1.99 - 0.128 (days), $r^2 = 0.91$ (see text for further detail).

[c] based on the 2,4-D transfer rate of 480 μg/hr per mg/m² of foliar dislodgeables observed by Harris and Solomon (1992).

[d] based on a dermal absorption of 8%, which is the highest mean listed in Table 1 plus two standard deviations and on the body weight (BW) of a two-year-old child at the 1*st* percentile (9 kg); in parentheses are dosages calculated using the 50*th* percentile body weight (12.6 kg).

The DFR observed by Schneider *et al*. (1994) were found to be highly consistent with those reported in Sears *et al*. (1987), who also used the same sampling method of Thompson *et al*. to collect the foliar dislodgeables of diazinon that was applied to turf at 3.6 - 4.0 lb AI per acre. The DFR levels of diazinon on turfgrass measured by Sears *et al*. immediately following application averaged 4.4 mg/m² (from their Tables 3 and 4). Their data (in their Table 3) also showed a reduction of nine-fold in these diazinon DFR if they were measured at day 1 after *rainfall*, or a reduction of five-fold if they were measured *4 hours post- application*. The average diazinon DFR levels observed by Sears *et al*. would hence be reduced to ≤ 0.14 mg/m² (= [4.4 mg/m² x 5 lb/3.6 lb] ÷ [9 x 5]) at 4 hours post-application (at which time the level would be reduced five-fold), after adjustment for application rates and for the nine-fold reduction due to the watering-in effect (which is assumed to be not less than that of rainfall occurring at day 1). As shown in Table 7, the diazinon DFR level projected from the data provided by Schneider *et al*. was nearly 0.1 mg/m^2 for 4 hours post-application (after which time the sprays should have dried to give a relatively more stable dissipation rate).

It should be pointed out again that the 2,4-D dislodgeables on turf were measured per m^2 of lawn surface and were collected by wiping off onto a cheesecloth tied to the shoe. In their 2,4-D study, Harris and Solomon (1992) used the sampling method by Thompson *et al*. (1984) to measure turf residues probably because they thought that whatever the amount of 2,4-D that could be wiped off by scuffing would be the amount of dislodgeables that could be transferred onto the skin through contact with the treated turf surface. The one minute duration set by Thompson *et al*. for scuffing was intended to standardize the sampling procedures.

Table 7 shows that the diazinon residues measured by Schneider *et al*. (1994) were substantially lower than the 2,4-D turf dislodgeables observed by Harris and Solomon (1992). Such a difference in DFR is not unexpected, however, since the diazinon residues were measured after the treated area was *drenched* with a large amount of water. Included in Table 7 are the absorbed daily dosages estimated for two-year-old children playing on treated lawns. These daily dosages were first calculated from multiplying the predicted DFR by the above transfer rate for dermal exposure (i.e., 480 µg/hr per mg/m^2 of turf dislodgeables), then corrected for a dermal absorption of 8%, which is the highest mean listed in Table 1 plus two standard deviations, and finally normalized for body weight. Since the distributions and the value ranges for the predicted DFR and, especially, for their transfer rate could not be determined at this time, Monte Carlo simulation was not performed here to estimate the daily dosage.

It is not surprising that some people might still be discontent with using 1 hour as a reasonable exposure time, or with children playing on a lawn as totally compatible to adults lying and sitting on a lawn. However, there should be no disagreement that the uncovered lower body and forearms of an adult in total are far greater in surface area than even the totally exposed body of a two-year-old child. The data on vapor pressure (The Royal Society of Chemistry, 1990) also suggest that diazinon foliar residues would tend to get evaporated off the skin much more or faster than 2,4-D foliar residues. These data thus support the argument that compared to 2,4-D foliar residues, diazinon foliar residues will become less available for dermal penetration once they have been dislodged on to the skin. As pointed out earlier, the 2,4-D transfer rate was based on the body doses attained by three of the ten volunteers in the study by Harris and Solomon (1992). Had the body doses from the remaining seven volunteers been included in the calculation, the average body dose of 2,4-D would have been substantially lower since they were all below the detection limit (hence resulting in a lower transfer rate). The dermal absorption of 8% used here for turf dermal uptake was based on the highest mean listed in Table 1 plus two standard deviations. While this value is consistent with the mean (7.1%) simulated from the 100,000 runs performed for soil dermal uptake, it represents more than 90% of the dermal absorption values observed in the human study by Wester *et al*. (1993). There is also the general notion that during the 1 hour of playtime, a child would tend to spend more of this time on the untreated turf surface than in the treated soil or sod areas immediately around the host trees (partly because of the relative available surface areas of treated vs. nontreated soil/lawn).

As shown in Table 7, the dermal uptake of foliar diazinon could be as high as 0.4 μg/kg/day for a two-year-old child (girl) playing on a treated lawn. This maximum absorbed daily dosage was calculated from a rather conservative extrapolation model as described above, and was based on the DFR predicted for 4 hours post-application (i.e., until after the sprays have dried). The exposure calculated earlier by USEPA (1989), on the other hand, was only 0.031 μg/kg/hr for a 10 kg child playing on turf treated with diazinon after the sprays have dried. Their estimate was based on a much higher application rate of 10.9 lb AI per acre without watering-in.

Estimation of Worker Exposure

A treatment team for Medfly eradication at each residential site usually consists of one crew leader, two water drenchers, and two mixer/loader/applicators, who all are required to wear protective clothing while working with the diazinon insecticide (per personal communication with Rick Sauber of CDFA Pest Detection/ Emergency Projects Branch). Of this crew, the applicators would be subject to the highest occupational exposure since they would actually handle the diazinon insecticide at the site. Accordingly, worker exposure to diazinon was estimated in this assessment for this work group only. There are no measurements of dermal or inhalation exposure available to WH&S for workers handling diazinon under the Medfly Eradication Program. The absorbed daily dosage calculated below for the eradication applicators was hence based primarily on the data from the previously-cited worker exposure study by Davis *et al*. (1983), in which three volunteers spraying diazinon in yards on residential properties were monitored for both potential dermal and inhalation exposures to the residues.

Three types of application were used (one after another) by all three volunteers in the above surrogate study in spraying diazinon in their own or their neighbors' yards. These three different types included treating lawns with a compressed air sprayer at label-specified rate (0.12 lb AI per 1,000 sq ft); treating shrubs to runoff with a compressed air sprayer; and treating lawns with a hose-end sprayer at label-specified rate (0.16 lb AI per 1,000 sq ft). Of the three types of application, the *first* was considered to have provided an exposure scenario most compatible to that involving the eradication applicators. This consideration is based on the fact that eradication applicators have not used a hose-end sprayer for application, as this type of sprayers cannot deliver accurately or efficiently the amount of insecticide specified on the label; and that they do not spray diazinon to shrubs to runoff. As can be seen in Ando *et al*. (1993), soil treatments for Medfly eradication were made at the maximum label rate of 0.12 lb AI per 1,000 sq ft, typically using a hand held Chapman sprayer equipped with a fan tip nozzle.

The average total *potential* dermal exposure measured by Davis *et al*. was 5.7 ± 4.0 mg/hr for the volunteers wearing only a bathing suit (and shoes) and treating lawns with a compressed air sprayer. This average hourly exposure was the arithmetic mean taken over 17 replicates. The (arithmetic) mean potential inhalation exposure measured for these individuals was trivial, as it was 1.9 ± 2.2 μg/hr. From these hourly averages the absorbed hourly dosage was calculated to be 45.6 μg per person, or 0.66 μg/kg assuming the three volunteers (whose gender was not given) had an average male/female body weight of 68.7 kg. This dosage calculation was based on a default clothing protection of 90% for wearing the required protective garments, and on the dermal absorption of 8% that was conservatively set earlier for dermal uptake of diazinon from turf.

From the above estimate for average hourly dosage, it is reasonable to assume that the expected absorbed *daily* dosage would be 2.6 μg/kg or less for workers spraying diazinon from site to site for Medfly eradication. Here the daily dosage for the eradication applicators is expected not to exceed four times their hourly dosage primarily because they are expected to spend much of their eight hours on traveling to various treatment sites (which can be miles apart if the sites are not located within the same neighborhood), or on setting up or putting away their spray equipment. While the practice has been for two eradication applicators to complete the soil treatment at a given site, each of them is expected to spend more (non-exposure) time to cover the same footage than each volunteer did in the study by Davis *et al*. This expectation is based on the practice that as only the soil or sod areas immediately around the host trees need to be sprayed, an eradication applicator will spend a considerable portion of the same work hour just for walking around host trees (or for walking from one tree to another). Note that an upper-bound estimate of the *hourly* dermal exposure (e.g., mean plus two or three standard deviations) was not used here because the applicator is not expected to experience the same high(est) *hourly* exposure all day long.

The absorbed daily dosage calculated above is considered to be a fairly conservative estimate used for the eradication applicators for a couple of reasons. One reason is the fact that the dermal absorption used was nearly two standard deviations from the highest mean observed by Wester *et al*. (1993). Another reason is that while the eradication applicators can spray pesticides in a more professional (hence presumably safer) manner than the volunteers did, the residues which the applicators are exposed to during their last couple of work hours would not be as readily absorbed into the skin as would those which they are exposed to during the first couple of hours. This is because absorption of chemicals into the skin is a time-dependent physiological phenomenon and professional applicators routinely take a shower or bath shortly after they get off work. Monte Carlo simulation was not performed here because the absorbed daily dosage calculated for the eradication applicators was based only on the two input variables dermal absorption and daily exposure, the latter of which was treated as a constant.

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