

ESTIMATION OF EXPOSURE OF PERSONS IN  
CALIFORNIA TO PESTICIDE PRODUCTS  
CONTAINING EPTC

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HS-1531 November 17, 1989  
Revised August 8, 1995

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ABSTRACT

EPTC is a broad spectrum herbicide that must be incorporated into soil to be effective. In California EPTC is applied primarily to alfalfa, corn, sugar beets, and potatoes. Possible adverse effects associated with EPTC exposure in animals include neurotoxicity, nasal cavity degeneration/hyperplasia, blood coagulation abnormality, and neuromuscular degeneration in experimental animals. Dermal absorption studies conducted in rats indicate that EPTC is rapidly absorbed and eliminated. Percutaneous absorption of a dose comparable to field worker exposure was estimated to be 18.25% of the administered dose in 24 hours. After the exposure dose is removed, EPTC in the skin is readily metabolized and eliminated. Elimination is primarily by urinary excretion of a number of metabolites. S-(dipropylcarbamoyl)-cysteine and S-(dipropylcarbamoyl)-N-acetylcysteine constitute more than 50% of elimination and can be used for biological monitoring. Some estimated absorbed daily dosages (ADD,  $\mu\text{g}/\text{kg}/\text{day}$ ) for occupational exposure are: mixer/loaders (liquid - ground application) - 46.8, mixer/loader/ applicators (liquid - ground application) - 89.8, loaders (granule - aerial application) - 85.1, applicators (granule - flowers/ornamentals) - 14.3, mixer/loader/applicators (liquid - center-pivot) - 221, and applicators (water-run) - 5.34. Plant surface residues are not encountered by field workers since EPTC is immediately incorporated into the soil.

This report was prepared as an Appendix to the Department's risk assessment process for EPTC.

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## APPENDIX A

### California Department of Pesticide Regulation Worker Health and Safety Branch

#### Human Exposure Assessment

#### EPTC

August 8, 1995

This Appendix A is being prepared as part of the ongoing California Department of Pesticide Regulation evaluation of pesticides pursuant to SB 950.

#### **INTRODUCTION**

EPTC (S-ethyl-dipropylthiocarbamate) is an amber liquid with an amine odor. It is a storage stable compound with a half-life of 483 weeks at 80 °C. EPTC is non-corrosive and moderately water soluble (370 ppm). It has a high vapor pressure ( $3.4 \times 10^{-2}$  mm Hg at 25 °C) for an agricultural chemical. Its boiling point is 138 °C at 30 mm Hg and its molecular weight is 189.3 (C<sub>9</sub>H<sub>19</sub>NOS).

#### **U.S. EPA STATUS**

The U.S. Environmental Protection Agency (U.S. EPA) has published a reregistration guideline for EPTC (U.S. EPA, 1983). Additional information was requested in this guideline concerning the effect of EPTC on blood clotting in test animals. This request was based on impaired clotting in subchronic and chronic rat studies. Information on clotting was requested specifically for dog studies running a year or longer, rat oncogenicity studies, teratogenicity studies in two species, and from a two-generation reproduction study. U.S. EPA proposed a tolerance in all agricultural commodities of 0.1 ppm for EPTC.

#### **USAGE**

EPTC is used as a pre- and postplant herbicide to control annual grasses, broadleaf weeds and some perennials. To be effective, EPTC requires immediate soil incorporation by discing, chemigation, or injection by subsurface equipment. Its mode of action involves inhibition of germination and seedling development. In 1992, the total amount of EPTC sold in California was 936,766 pounds (DPR, 1992a), whereas total reported use was 667,112 pounds equivalent to 71.2% of the total amount sold (DPR, 1992b). For 1992, the major crop uses of

EPTC in California were alfalfa (34.5% of total use), corn (15.2%), sugar beets (13.7%), and potatoes (11.1%). EPTC was also used on forage crops, for landscape and open land maintenance, and on ornamentals and flowers. Table 1 shows the maximum application rates for major crops.

Table 1. Label maximal application rates of EPTC on major crops.

Crop	Application	Formulation	lbs a.i./acre
alfalfa	chemigation	EC	3.0
corn	preplant soil incorporation	EC	4.0
sugar beets	pre- or postplant	EC	4.5
potato - Irish	lay-by, chemigation	EC	4.0

EC = Emulsifiable concentrate

Brodberg, WH&S, 1995

Most of the use of EPTC, an unrestricted compound, is by farmers and direct consumers, not by certified applicators. This has been confirmed by discussions with county agricultural personnel (Acosta, 1989; Perry, 1989; Gruenberg, 1989) who reported that field applications of EPTC on alfalfa and potatoes are primarily by chemigation. Spraying and incorporation are done simultaneously using boom sprayers mounted across the center of a tractor and rear mounted discing equipment. County agriculture personnel estimate that about 50 acres of beans can be treated per day (Acosta, 1989; Perry, 1989; Gruenberg, 1989).

## FORMULATIONS

There are 10 products registered for use in California in 1995. These products are either emulsifiable concentrates (82.6-87.8% a.i.) or granular formulations (2.3-20% a.i.). The liquid formulations are used for broadcast, chemigation, and lay-by weed control in crops. The granular formulations are used primarily for weed control on nursery, home flower, and ornamental plantings.

## LABEL PRECAUTIONS

The U.S. EPA registers EPTC products as Toxicity Category III pesticides bearing a signal word "CAUTION." Persons exposed to the various formulations are cautioned not to ingest EPTC-containing products or inhale mists or dusts produced by these products. They are also cautioned to avoid contact with eyes, skin, and clothing. The Worker Protection Standard (WPS) requires handlers of EPTC products to wear clean clothing (long-sleeved shirt, long pants), shoes plus socks, chemical-resistant gloves, and protective eyewear. However, some of the current product labels in the Department's library have not shown requirements under

the WPS. Areas to which EPTC is applied by chemigation must be cleared of people during the application.

Clothing protection required for early entry to treated fields that involves contact with anything that has been treated is: coveralls, waterproof gloves, shoes plus socks, and protective eyewear.

## **WORKER ILLNESSES AND INJURIES**

The California Pesticide Illness Surveillance Program reported 12 cases of illness/injury (1985-1992) that were attributed to exposure to EPTC. Those that were attributed to exposure to EPTC in combination with other pesticides during the same time period numbered only 3 cases (Mehler, 1995). These illnesses/injuries associated with EPTC are in the form of eye irritation (5 cases), skin irritation (4 cases) or systemic illness (3 cases).

## **DERMAL TOXICITY**

EPTC is not highly toxic by any route. A dermal LD<sub>50</sub> of 2,750 mg/kg has been reported in New Zealand rabbits with a formulated product containing 87.8% a.i. (Sanders, 1979). Granular products are not skin or eye irritants in New Zealand rabbits. Liquid concentrates are moderate skin irritants and moderate to severe eye irritants (Sanders, 1979; Miller, 1981; Morgan, 1981-1982; Thompson, 1982; Billow, 1983; Jameison, 1982).

## **ANIMAL METABOLISM**

Metabolism studies have been conducted in both rats and mice. The rat studies are more relevant since they are comparable to dermal absorption studies that also used rats. The two available rat studies support similar conclusions with respect to absorption and elimination of EPTC and its metabolites.

Ong and Fang (1970) used ethyl-1-<sup>14</sup>C-EPTC to follow EPTC metabolism in adult female Wistar rats. Doses of 0.6, 1.0, 1.5, 3.0, 20.6, 50.6 and 100.6 mg/kg were administered in corn oil by stomach tube. Two to four animals were treated at each dose. Expired <sup>14</sup>CO<sub>2</sub> was measured directly in an ionization chamber calibrated against known standards. Urine and feces were collected daily for 3-4 days and stored frozen for analysis of <sup>14</sup>C-EPTC and metabolites. <sup>14</sup>CO<sub>2</sub> expiration was the primary route of elimination for all doses. The percent of dose recovered as CO<sub>2</sub> was inversely proportional to the dose administered (84.6% at the lowest dose vs. 38.2% at the highest dose). The production of <sup>14</sup>CO<sub>2</sub> was rapid and reached a peak 1-2 hours after administration. Elimination via this route was complete within 15 hours at low dosages (<20.6 mg/kg) and within 35 hours at high doses. Urinary excretion was also a major pathway of elimination and increased with dose. Elimination via urinary excretion increased from 8.4% at 0.6 mg/kg to 35.6% at 100.6 mg/kg. Fecal elimination ranges

between 4.0% and 12.6% of the dose but does not show a consistent dose response. Some of this recovery may be due to urine contamination of feces. Dose remaining in the carcass is not reported, but recoveries for CO<sub>2</sub>, urine and feces account for 77.6-97.4% of the administered dose.

Hubbell and Casida (1977) examined the metabolism of EPTC using <sup>14</sup>C-carbonyl-EPTC administered in methoxytriglycol via stomach tube to male Sprague-Dawley rats. Two animals were dosed with 13.5 mg/kg and one with 132.5 mg/kg and their metabolism of EPTC was followed for 48 hours. Expired <sup>14</sup>CO<sub>2</sub> was collected in a 2:1 mixture of monoethanolamine-methyl cellosolve. Recovery of expired <sup>14</sup>CO<sub>2</sub> was 46% and 52% of the low and high administered dose, respectively. Urine and feces were collected in glass metabolism cages. Urinary excretion accounted for 44.7% of the low dose and 33.9% of the high dose. Elimination via feces was minor, accounting for 1% or less of the administered high and low dose. After 48 hours, 3.3% of the low dose and 1.4% of the high dose remained in the carcass. About half of the recovered dose was expired or excreted in 6 hours, and 93-99% by 24 hours. Total recovery of the administered dose was 94.7% and 88.3% for the low and high doses, respectively.

These two rat studies are not directly comparable because the position of the radiolabel differs. However, both show a general trend toward rapid quantitative elimination of EPTC metabolites via CO<sub>2</sub> expiration and urinary excretion after oral administration. Fecal elimination of EPTC metabolites represents a minor route that is greatly exceeded by urinary excretion. Body retention is also low. These same trends are noted in the mouse study of Casida *et al.* (1975).

The above studies also identified certain EPTC metabolites in the urine. Sulfur oxidation is a primary *in vivo* metabolic pathway in rats and carbon oxidation appears to be a secondary pathway elucidated with *in vitro* mouse studies (Casida *et al.*, 1975). Ong and Fang (1970) separated 9 urinary metabolites by paper chromatography or thin-layer chromatography. Metabolites were detected by autoradiography or color reactions. The relative amount of most of these metabolites varied with dose. Only urea was accurately characterized as a labeled metabolite by cochromatography (Ong and Fang, 1970). It represented 17% of urinary excretion at all dose levels. Some parent compound was detected (2-4%) by a nonspecific method (isooctane soluble products of steam volatilization). Hubbell and Casida (1977) characterized glutathione derivatives by cochromatography against synthetic standards in two two-dimensional solvent systems. Parent compound was absent in the urine in this study. S-oxidation and glutathione (GSH) conjugation produced primarily S-dipropylcarbonyl (DPC) cysteine (with 1 or 2 impurities) and S-(DPC)-N-acetylcysteine. In a one solvent system, S-(DPT) cysteine represented 15% of urinary metabolites, and S-(DPC)-N-acetylcysteine represented 39%. In the second solvent system they accounted for 19% and 51%, respectively. The identity of both of these metabolites was confirmed by gas chromatography-mass spectrometry of methylated derivatives. These metabolites have been used for biological monitoring (Ross *et al.*, 1986). Ten unidentified minor metabolites were isolated and some S-(DPC) mercaptoacetic acid (3-6%) was characterized but not identified.

## DERMAL ABSORPTION AND INHALATION ABSORPTION

Two dermal absorption studies used male Sprague-Dawley rats dosed with propyl 1-<sup>14</sup>C-EPTC. Careful examination of the data from these investigations is important because 60-80% of the labeled dose may be lost to evaporation during dermal exposure. This volatility of EPTC makes high total recoveries difficult. Both studies maximized recovery by collecting volatiles in a filter or resin cartridge mounted over the site of application. Both studies also met many of the criteria set forth in the U.S. EPA Procedure for Studying Dermal Absorption (Zendzian, 1987) and are acceptable for estimating dermal absorption.

Knaak *et al.* (1986) did three experiments measuring percutaneous absorption of EPTC in male Sprague-Dawley rats. Each rat's back was shaved the day before dosing. Animals in all experiments were fitted with Queen Anne collars to restrict their access to the treatment site. Labeled formulated EPTC EC in an aqueous emulsion was used for each dose. Application was completed using a micropipette. The exposure time for each experiment was 24 hours. Urine, feces, <sup>14</sup>C-volatiles, and <sup>14</sup>CO<sub>2</sub> were collected through 24 hours. XAD-2 resin was used to collect <sup>14</sup>C-volatiles and <sup>14</sup>CO<sub>2</sub> was collected in 2N KOH. Animals were anesthetized at 24 hours by dosing with sodium pentothal and then sacrificed. The exposure site was not washed prior to sacrifice. Skin from the exposure site was excised prior to the collection of other samples. Skin was stretched and washed, and then frozen. A blood sample was collected by cardiac puncture using a heparinized needle and syringe. Tissue samples taken at sacrifice included heart, liver, kidney, gastrointestinal tract, fat, and remaining carcass. These samples were stored frozen at 0 °C.

In general, this study conformed closely to U.S. EPA guidelines for dermal absorption studies. Absorption was measured in male rats of a strain used in one of the metabolism studies. They were treated with an appropriate volume of an aqueous emulsion of the field product. A non-exchangeable carbon was radiolabeled at 1.67 μCi/μmole. The skin mounted resin cartridge used in experiments 2 and 3 of this study facilitated good recovery of the dose (85.9% and 95.3%, respectively) and protected the application site. Experiment 1 did not use this resin cartridge and showed a lower recovery (76.5%, Table 2). Because of this low recovery it has been excluded from further consideration in estimating percutaneous absorption. Although use of these cartridges increased recovery, the small size needed to reduce bulk and weight also had the effect of limiting exposure area in experiments 2 and 3 to 2.54 cm<sup>2</sup>. Other deviations from guidelines included the use of heavy animals (280-431 g), and only 3 subjects in experiments 1 and 3. Experiment 2 used four 280 g animals. Although a 24-hour exposure was used, no interim sample time points were taken. Sacrifices were handled well except that residual bladder urine was not collected and there was no pre-

sacrifice skin wash. Overall experiment 2 was the most acceptable and Experiment 3 showed the same trends discussed below.

For propyl-labeled EPTC, CO<sub>2</sub> expiration is a negligible route of elimination. Evaporation accounts for the largest percentage of the dose (69.8% and 77.8% in experiments 2 and 3, respectively). Urine is the primary elimination route (about 5.8% of the total) and about 8% of the dose remained in the carcass and organs at 24 hours. Less than 2.8% of the dose remained at the application site at 24 hours, and fecal elimination accounted for 0.4% or less of the exposure dose. Summing the percentage of dose in excreta, expired air, washed skin, body organs and carcass yields percutaneous absorption values of 13.7% and 14.7% for experiments 2 and 3, respectively (Table 2). These values are not corrected for recovery.

The study by Jeffcoat (1988) met more of the criteria of the U.S. EPA guidelines and produced similar results to Knaak *et al.* (1986). A higher specific activity (35 mCi/mole) and larger exposure area (29.4 cm<sup>2</sup>) were used. Once again animals were fitted with a special filter cartridge to collect volatiles directly above the exposure site. Medical adhesive was used to attach a foam ring to the skin at the application site. Then a charcoal filter covered with gauze was attached to the ring. This resulted in 88-95% recovery of the exposure dose. Male Sprague-Dawley rats 228-260 g were exposed to one of four dilutions for 1-24 hours. The doses used were neat formulated EPTC EC, 1:10 dilution, 1:50 and 1:100 dilutions in water. These correspond to 8740, 890, 196, and 94 µg/cm<sup>2</sup> after correction for inaccurate dilution. The doses were applied using a Teflon<sup>®</sup> tipped glass syringe. The animals were housed in glass metabolism chambers that separated urine and feces. At 24 hours the dose was washed off and the filter cartridge extracted. A new charcoal filter was installed on some animals and they were followed for up to 96 hours. Data were collected for 4 animals at each dose sacrificed at the following time points: 1, 4, 10, 24, 48, 72, and 96 hours. Urine and feces were collected at sacrifice or every 24 hours. The skin at the exposure site was washed just before sacrifice. Prior to sacrifice animals were sedated and a blood sample withdrawn by cardiac puncture. Sacrifice was by injection of euthanasia solution (American Hoechst) directly into the heart. Residues on the second filter cartridge were also extracted. Bladder urine was aspirated and combined with the total cage urine. The remaining carcass was solubilized in ethanolic sodium hydroxide. It was possible to follow the absorption and elimination of EPTC and its metabolites through a 96 hour time course in this study. Both absorption and elimination were rapid and followed similar kinetics regardless of dose. Total percutaneous absorption was derived from the sum of the percentage of dose in the skin, excreta, and carcass versus the total exposure dose. Elimination was derived from the percentage of fecal and urinary excretion versus the total exposure dose.

The rate of absorption was most rapid in the first hour of exposure at all doses. EPTC levels increased in the body carcass and the skin to a maximum of 3.6% of the applied dose during the first 4 hours following application. Body values then declined to about 1% of the total exposure by 48 hours and fell to 0.6% by 96 hours. Maximal total absorption at all doses occurred at or before the 24 hour sacrifice point.

Elimination was also very rapid. Elimination at all time points was primarily by urinary excretion. During the first 24 hours there was a linear increase in the percentage of the exposure dose eliminated in the urine. Total urinary excretion, as a percent of dose, plateaued at 24 hours. This is the point at which the dermal dose was washed off. Fecal excretion reached a maximum between 24 and 72 hours and typically accounted for 0.2% of the applied dose.

These data show that EPTC was rapidly absorbed and initially accumulated in the body. By four hours after application it was being rapidly eliminated, primarily in the urine. By 10 hours after application the dose was being eliminated more rapidly than it was being absorbed. After the dose was washed off at 24 hours elimination of the absorbed dosage was nearly complete. Fecal elimination was highest at and just after this time, and it accounted for at the most 5% of total elimination. This would seem to indicate that once the dose is removed from the skin surface there is no significant reservoir of bioavailability remaining in the skin or carcass and that elimination is essentially complete.

This absorption-elimination pattern validates the limited sample times used in the Knaak study (Knaak *et al.*, 1986). Sampling restricted to a 24 hour time point is adequate for the estimation of absorption because absorption was maximal and essentially complete at this time. Absorption at 24 hours for the doses used in this study was 9.3% (8740  $\mu\text{g}/\text{cm}^2$ ), 7.1% (890  $\mu\text{g}/\text{cm}^2$ ), 3.7% (190  $\mu\text{g}/\text{cm}^2$ ), and 6.4% (90  $\mu\text{g}/\text{cm}^2$ ) (see Table 2).

Table 2. Percutaneous absorption of EPTC in rats exposed for 24 hours<sup>a</sup>.

Dermal dose in $\mu\text{g}/\text{cm}^2$	% absorption <sup>b</sup>	% recovery
Knaak <i>et al.</i> (1986)		
36.1 (Experiment 2)	13.7	85.9
23.0 (Experiment 1)	20.9	76.6
21.5 (Experiment 3)	14.7	95.3
Jeffcoat (1988)		
8740	9.3	92.0
899	7.1	93.0
196	3.7	91.0
94	6.4	87.0

Brodberg, WH&S, 1989

<sup>a</sup> These data are for rats treated for 24 hours and then sacrificed.

<sup>b</sup> Total dermal absorption during a 24 hour time period. This includes residues bound to the skin.

When estimating percutaneous absorption in occupationally exposed workers it is most appropriate to use animal absorption from a similar exposure dose when human absorption is unknown. The dermal doses in both rat studies were greater than measured worker field exposures at the skin surface (see Table 3). The lowest dose used in the rat dermal absorption

studies is about 16X the mixer/loader/applicator dermal dose. The rat absorption data were statistically analyzed to determine if they could be used to extrapolate to a dose and absorption corresponding to the field dose. The data cannot be combined because the absorption rates are significantly different ( $p < 0.01$ ,  $t = 4.215$ ,  $df = 5$ ). In addition a significant regression line cannot be fit to either data set (analysis by one-way ANOVA). This is true for the regression of absorption on dose (Knaak *et al.* (1986) data:  $F = 0.514$ ,  $df = 1, 1$ ; Jeffcoat (1988) data:  $F = 3.567$ ,  $df = 1, 1$ ), and absorption on the log of dose (Knaak *et al.* (1986) data:  $F = 0.495$ ,  $df = 1, 1$ ; Jeffcoat (1988)  $F = 3.479$ ,  $df = 1, 1$ ).

Table 3. Comparison of rat dermal absorption study doses and field study dermal exposure doses.

Study	Applied dermal dose	Estimated field dermal dose <sup>a</sup>
Knaak <i>et al.</i> (1986)	36.1 $\text{mg}/\text{cm}^2$ 21.5 $\text{mg}/\text{cm}^2$	
Jeffcoat (1988)	8740 $\text{mg}/\text{cm}^2$ 890 $\text{mg}/\text{cm}^2$ 190 $\text{mg}/\text{cm}^2$ 90 $\text{mg}/\text{cm}^2$	
Ross <i>et al.</i> (1986)		
Mixer/loader		0.7 $\text{mg}/\text{cm}^2$
Applicator		0.3 $\text{mg}/\text{cm}^2$
Knarr and Iwata (1986)		
Mixer/loader/applicator		1.3 $\text{mg}/\text{cm}^2$
		Brodberg, WH&S, 1989

<sup>a</sup> Field exposure doses are given as the dose that would accumulate at the skin during 8 working hours averaged over the whole body surface area (21,110  $\text{cm}^2$ ).

The Jeffcoat (1988) study essentially represents 4 high doses with a mean absorption of 6.6%, and the Knaak *et al.* (1986) study represents two low doses (Experiments 2 and 3) with a mean of 14.2%. (Experiment 1 was eliminated because of low recovery.) From this simplified viewpoint the data agree with the expectation that percent of dose absorbed at high doses is less than that at low doses (Wester and Maibach, 1976). Since it is not possible to extrapolate from these data to the field dose, the lowest dose used in the rat studies will be used to estimate potential human absorption. Absorption at this dose is  $14.7 \pm 2.7$  (S.E.). By adding in the standard error and correcting for recovery a conservative estimate of the upper limit of absorption can be derived. This value (18.25%) will be used as the best available

estimate of worker absorption. No studies directly measuring the respiratory absorption of EPTC are available. A surrogate estimate of 50% of the inhalation exposure was proposed by one registrant (Ross *et al.*, 1986) based on studies of several chemicals in beagles (Raabe, 1986). A similar value from surrogate data has been reported in humans (Raabe, 1988). In general inhalation uptake of an organic vapor is less than 100% because not all of the vapor molecules reach the alveolar surfaces at which absorption occurs. The value of 50% uptake of the breathing zone exposure will be used as an estimate of potential human inhalation retention and absorption.

## **WORKER EXPOSURE**

### **A. Exposure to EPTC from use of liquid formulations**

Two worker exposure studies have been done on field crops. The exposure data from both studies have been recalculated by Worker Health and Safety Branch (WH&S) to reach standard exposure values based on the same surface area and as few additional assumptions as possible. From this starting point various factors estimating clothing penetration and dermal or inhalation absorption can be applied to each data set. After this standardization these studies yield similar exposure estimates as outlined below.

Ross *et al.* (1986) measured exposure during the broadcast spray application and mechanical incorporation of a liquid concentrate (87.8% a.i.) to red kidney beans. In this case a single person acted as the mixer/loader, applicator, and incorporator. Application and incorporation were done simultaneously using a tractor outfitted with both a boom sprayer and discing equipment. Monitoring of mixing and loading was separated from that of the application and incorporation phases by changing monitoring patches and collecting handwashes between these tasks. Fifteen replicates over 7 workdays were collected. Each replicate consisted of a mixer/loader sample and an applicator/incorporator sample. Applicator activity also included unplugging of spray nozzles and subsequent handwashes. These handwashes were monitored and included in the total handwash values. Application was performed at 3 lbs a.i./acre (3.5 pints/acre). This is the maximum recommended rate for beans. EPTC was used in a tank mix with ethalfluralin, another preemergent herbicide. Mixing was by open pouring. Protective clothing worn during the study were boots, jeans, a flannel shirt with the sleeves rolled up, and a cap. Long rubber gloves were worn only during mixing and loading. Sunglasses were worn at all times.

This study measured both potential dermal and inhalation exposure and used urine samples for biological monitoring. Potential exposure was monitored using 23.75 cm<sup>2</sup> gauze patches. These were attached on the surface of the worker's clothing at the back, shoulders, thighs, and shins. Forearm patches were on bare skin and chest patches were under the shirt. Hand exposure was monitored by collecting handwashes in surfactant. Each hand was washed two times in 200 mL of a 2% dioctyl sodium sulfosuccinate solution in a 0.5 gallon polyethylene

bag. Each hand was shaken 50 times in the bagged solution. Inhalation monitoring was by air sampling in the breathing zone using a personal air sampling pump drawing air through a charcoal filter at 1 L/min. Charcoal filter and patch samples were extracted and analyzed on a gas chromatograph equipped with a sulfur specific detector. Handwash samples were analyzed using liquid chromatography. The cysteine and N-acetyl cysteine conjugates of S-(DPC) present in urine samples were acetylated and methylated to convert them to S-(N,N-DPC)-N-acetylmethylcysteine. This compound was quantified using gas chromatography with a flame photometric detector in the sulfur mode. S-(N,N-DPC)-N-acetylmethylcysteine values were converted to EPTC equivalents for use in biological estimates of exposure.

Field fortifications and quantification standards were run for all samples. The mean recovery for patches was  $78 \pm 20\%$ , with  $80 \pm 10\%$  for handrinse solutions, and  $91 \pm 5.3\%$  for inhalation samples. Recovery of the two EPTC metabolites from urine averaged 81%. These daily recoveries have been used by WH&S to normalize the data to 100% recovery and to recalculate the exposures derived from this study.

The surface areas used by the registrant to calculate exposure values are somewhat different than those in the U.S. EPA Pesticide Assessment Guidelines (U.S. EPA, 1987). The U.S. EPA surface area values were used by WH&S during recalculations. In this study chest exposures were from patches placed under the shirt. This is a direct measure of dermal exposure but all other patches were positioned externally to directly measure potential dermal exposure. To standardize exposure data to a uniform work and monitoring situation (potential dermal exposure on the shirt surface), the patch data for the chest was multiplied by a factor of 2.13 ( $1/0.47 = 2.13$ ). This factor is derived from the next study (Knarr and Iwata, 1986) in which it was demonstrated that 47% of the external dose penetrated a long-sleeved work shirt. The inhalation exposure values were also normalized using a respiration rate of 29 L/min. rather than the 25 L/min. originally used in the study. The resultant average dermal exposure estimates as recalculated by WH&S are presented in Table 4.

Knarr and Iwata (1986) also measured worker exposure to a liquid concentrate formulation of EPTC (87.8% a.i.). In this case a post-emergent application to Kennebec potatoes was monitored over 8 working days. The maximum recommended rate of 3.9 lbs a.i./acre (4.5 pints) was used. A single worker performed the mixer/loader/applicator functions, and samples were not collected in a manner so that mixer/loader exposure could be separated from applicator exposure. This same worker also did the mechanical incorporation at the same time as spray application. The worker wore a long-sleeved shirt, long-legged pants and rubber boots at all times. Mid-forearm length gloves and a hard hat with a protective face shield were worn during mixing/loading operations. An open pour system was used for mixing.

Both potential dermal and inhalation exposure were monitored in this study. Potential dermal exposure was monitored using Durham and Wolfe-type patches supplied by Western Paper Box Company. The collection medium was polyurethane foam rather than gauze. Foam was used because a fortified control study showed that it retained volatile EPTC better than gauze (about 10X as much over 8 hours). It was hoped that this modification would more closely

represent the retentive qualities of skin. Patches were placed on the hat, shoulder, forearms, chest, back, thighs, and shins. Each patch had an exposed surface area of 23.75 cm<sup>2</sup>. (There is internal inconsistency concerning the exposure area in this study. To resolve this problem the surface area for cardboard holders supplied by Western Paper Box Company has been calculated as 23.75 cm<sup>2</sup> by WH&S.) Patches placed outside the shirt on the chest and under the shirt on a tee shirt were used to measure clothing penetration of EPTC. The detergent handrinse method was used to collect samples for estimation of hand exposure. A 0.1% sodium dodecyl sulfate solution (200 mL) in a one gallon bag was used for a single rinse of each hand. Each handrinse was done by shaking a single hand 50 times in a collection bag.

A personal air-sampling pump was used to collect samples to monitor inhalation exposure. Air was drawn through an XAD-2 resin cartridge in the worker's breathing zone at a rate of 200 mL/min. Sampling began before work commenced and ended after all cleanup was done.

Table 4. Normalized average dermal exposure to EPTC derived from field studies<sup>a</sup>.

Body region	Exposure in $\mu\text{g}/8\text{-hr day}$		
	mixer/loader <sup>b</sup>	applicator <sup>b</sup>	mixer/loader/applicator <sup>c</sup>
Hands	7176 <sup>d</sup>	4072	25
Unprotected skin <sup>e</sup>	130 <sup>d</sup>	134	1351
Protected skin <sup>f</sup>	7358 <sup>g</sup>	2038	26,252
Inhalation	1200	532	2480
Total	15,865	6,777	30,109

Brodberg, WH&S, 1989

<sup>a</sup> Dermal exposures were calculated by WH&S from raw patch and handwash data. U.S. EPA surface areas were used to extrapolate from the patch data to body regions. A clothing penetration factor of 47% was applied by WH&S to protected areas of the torso and trunk to estimate the exposure at the skin surface. Inhalation values from each study were normalized to a respiration rate of 29 L/min. from those originally assumed in each study. Calculated exposures have been corrected for recovery by WH&S.

<sup>b</sup> Recalculated from Ross *et al.* (1986) by WH&S.

<sup>c</sup> Recalculated from Knarr and Iwata (1986) by WH&S.

<sup>d</sup> Number of replicates is 14. One is excluded due to loss of a sample set.

<sup>e</sup> Includes the face and front and back of the neck.

<sup>f</sup> Includes the head, back, chest/stomach, upper arm, forearm, thigh, lower leg and feet. In Ross *et al.* (1986) the worker wore boots, jeans, a flannel shirt with the sleeves rolled up, a cap, and sunglasses. Long rubber gloves were worn during mixing and loading. In Knarr and Iwata (1986) the worker wore a long-sleeved shirt, long-legged pants, and rubber boots. Mid-forearm length gloves and a hard hat with a protective face shield were worn during mixing and loading.

<sup>g</sup> Number of replicates is 13 after rejection of a sample set that had a documented spill on a patch and due to loss of a sample set.

Sample analysis was by gas chromatography using either a N-P flame ionization (thermionic) detector or a flame photometric detector in the sulfur mode. Resin and patch samples were extracted with toluene, and aqueous wash samples were run over an XAD-2 resin column and then extracted prior to analysis by gas chromatography.

Untreated and fortified control samples were prepared in the field for patches, skin wash, and air samples to correct for recovery. Recoveries varied from 63-120%. Once again daily

recoveries have been used by WH&S to normalize the data to 100% in the recalculated exposures derived from this study. Fortified foam patches were set out in the field to follow the potential extent of EPTC loss during a sampling period. In a typical 5-hour work period 80-85% of the EPTC was observed to volatilize. This is similar to the volatilization of EPTC from the skin in dermal absorption studies.

The data for dermal exposure from this study were recalculated by WH&S so that the surface areas correspond to those used in U.S. EPA Subdivision U (U.S. EPA, 1987). Calculated dermal and inhalation exposure values are shown in Table 4. Inhalation exposure was also normalized by WH&S to a respiration rate of 29 L/min. from that assumed in this study (20 L/min.). A clothing penetration factor of 47% was derived by the registrant by comparison of patch residues inside and outside the shirt. This high penetration may be due to the volatility of EPTC. In this case exposure of protected skin may be from the vapor phase as well as liquid penetrating the clothing.

A comparison of the exposure data from these two studies is shown in Table 4. When mixing and loading is separated from application, the exposure to hands, protected skin, and via inhalation is greatest for the mixer/loader task. In the Ross *et al.* (1986) study, mixing and loading accounted for 10% of work time and application 90%. County agricultural personnel surveyed also estimated that time spent mixing and loading would be 10% and application 90% (Acosta, 1989; Perry, 1989; Gruenberg, 1989). The combined mixer/loader/applicator potential exposure calculated by WH&S for Ross *et al.* (1986) is 7686  $\mu\text{g}/8$  hr. This was less than observed in Knarr and Iwata (1986) (30,109  $\mu\text{g}/8$  hr). This difference may derive from the higher application rate in Knarr and Iwata (1986). Normalizing for the difference in pounds of a.i. applied, total mixer/loader/applicator exposure would be 24,633  $\mu\text{g}/8$  hr from Ross *et al.* (1986) versus 30,109  $\mu\text{g}/8$  hr from Knarr and Iwata (1986). (Normalizing factor = 1032 lbs Knarr and Iwata/322 lbs Ross *et al.* multiplied by the Ross *et al.* (1986) exposure.) This difference might be due to the use of the more retentive foam patches in Knarr and Iwata (1986).

Another difference between these studies is seen for hand exposure values. The values in Knarr and Iwata (1986) are lower than measured by Ross *et al.* (1986) (25 and 4072  $\mu\text{g}/8$  hrs., respectively). Since rubber gloves were used in both studies only during mixing and loading this should not be the source of the difference. Differences in handwash sampling between these studies may account for this difference. Ross *et al.* (1986) collected handwash samples by washing each hand twice in a fresh solution and then summing the values. They also used 20 times more surfactant in their handwash solution, and their protocol resulted in more frequent sampling. This is because they took samples each time the worker changed tasks between mixing/loading and application, and because they took handwash samples following maintenance cleaning of plugged nozzles. Some maintenance occurs in a typical work situation. Maintenance was done with bare hands which might increase hand exposure.

These estimates of potential dermal exposure can also be compared to an estimate of mixer/loader/applicator exposure derived from the biological monitoring reported by Ross *et al.* (1986). They reported EPTC-equivalents in urine samples normalized to a 1200 mL daily

void volume and corrected for percent measured metabolites eliminated in the rat metabolism studies. Based on their measurement the total absorbed dose calculated by WH&S was 136 µg/8 hrs. This would be roughly equivalent to a dermal exposure of 1586 µg/8 hrs. (To arrive at this estimate of dermal exposure the dosage above was corrected for the 47% clothing penetration and 18.25% dermal absorption used in calculating absorbed dosages in Table 5. This correction multiplies the inverse of these percentages by the internal dosage measured by biological monitoring. In this calculation, it was assumed that 100% of the absorbed dose was excreted in urine). This is about five times less than the dermal exposure derived from patches (7686 µg/hr) from Ross *et al.* (1986). This is a reasonable value since biological monitoring often yields an exposure estimate up to 50 times less than patch data (Maddy *et al.*, 1989).

### Exposure Assessment Recommendations

The exposure values derived from these two studies describe a range of worker exposure to EPTC. For regulatory purposes the mixer/loader/applicator value is deemed to be the most appropriate for work conditions prevailing in California. When applying EPTC the mixer/loader and applicator tasks are typically done by the same individual. This will frequently be a farmer doing his own application. The mixer/loader/applicator values derived by WH&S from Knarr and Iwata (1986) are an acceptable estimate of EPTC exposure during work performed at the maximal label rate of EPTC application of liquid formulations. If separate values are desired for mixer/loader and applicator exposure, the values for these exposures from Ross *et al.* (1986) should be used as an acceptable estimate. The data from Knarr and Iwata (1986) cannot be used to estimate separate mixer/loader and applicator exposure.

Table 5 shows dermal and inhalation Absorbed Daily Dosage (ADD) for different workers occupationally exposed to EPTC. These values have been calculated by WH&S based on the potential dermal exposure values derived from the Ross *et al.* (1986) and Knarr and Iwata (1986) studies. The clothing penetration factor (47%) used in these calculations was derived from Knarr and Iwata (1986). The dermal absorption factor (18.25%) was derived from Knaak *et al.* (1986) as an upper-bound based on the dose closest to the measured field exposure dose. The factor for surrogate inhalation uptake (50%) is from Raabe (1988). Workers spraying EPTC are likely to be exposed for 8 hours per day. Simultaneous broadcast spraying and mechanical incorporation are slow procedures and would require about 8 hours to complete a 50 acre application.

There is no definitive period for a use season of EPTC in California. For the major use crops, use reporting indicates applications are made throughout the year with maximum use during approximately one month for each crop. Time to toxic effect is the most desirable time frame over which to amortize dosage to estimate seasonal exposure. Lacking this we utilize estimates of the season which are climatically determined for a particular crop. This is 17 days for EPTC in any given location. Supporting this estimate of the season is the length of the toxicology study. The default time to effect was 17 days (the first interim sacrifice time),

and the first time the effects were observed after sequential daily dosing of laboratory animals.

The majority of EPTC applications are done by growers because major crops in which EPTC was used to control weeds are low value crops and EPTC products are Category III pesticides. This is supported by a report by Hunter (1995) on assessment of EPTC usage. For commercial application by PCOs, workdays per year are up to 15 days (Ross *et al.*, 1986). For the purpose of exposure estimation, it was assumed that a PCO applied EPTC eight days per season and 16 days per years.

Table 5 also shows ADD, Seasonal Average Daily Dosage (SADD), and Annual Average Daily Dosage (AADD). Eight workdays per 17-day use season were employed to calculate SADD. This number of workdays was based upon information from two submitted exposure studies. The first study involved ground-spray application which was done prior to planting of red kidney beans at the Nichols Ranch of Chico, California (Ross *et al.*, 1986). The application of EPTC was done over a 7-day period. The second study was conducted using ground-spray application to potato fields in the Salinas Valley of California (Knarr and Iwata, 1986). The total application period was eight days. These two studies were conducted at two big ranches and the number of application days are considered the upper end. Selection of big fields for the studies was to ensure an adequate number of replicates. For the exposure estimation, eight workdays per season was used to calculate SADD for ground as well as application by other methods, except for chemigation employing the center-pivot irrigation system. Six workdays per season were used instead of eight because this irrigation system has not become well established in California.

Table 5. Normalized average daily dosages of EPTC for occupationally exposed workers<sup>a</sup>.

work task	exposure		normalized dosage		
	Dermal <sup>b</sup> (µg/kg/day)	Inhalation <sup>c</sup> (µg/kg/day)	ADD <sup>d</sup> (µg/kg/day)	SADD <sup>e</sup> (µg/kg/day)	AADD <sup>f</sup> (µg/kg/day)
Mixer/loader <sup>g</sup> (n=14)	209.5	17.1	46.8	22.0	1.03
Applicator <sup>g</sup> (n=14)	89.2	7.6	20.1	9.45	0.44
M/L/A <sup>h</sup> (PCO) (n=8)	394.7	35.4	89.8	42.2	3.94

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<sup>a</sup> Daily dosages reported here includes both absorbed dermal and inhaled dosages. Dermal absorption = 18.25%. Inhalation uptake/absorption was 50% (Raabe, 1988).

<sup>b</sup> Dermal exposure is given for a 70 kg worker at the skin surface for an 8 hour work day after a 47% penetration factor is applied to protected body regions.

<sup>c</sup> Inhalation exposure is given at the worker's breathing zone.

- <sup>d</sup> ADD is calculated based on 18.25% percutaneous absorption and 50% respiration uptake.
- <sup>e</sup> SADD is calculated based on 8 working days of EPTC exposure per 17-day season.
- <sup>f</sup> AADD is calculated based on 8 working days of EPTC exposure per year, except for M/L/A which is 16 days.
- <sup>g</sup> Derived from Ross *et al.* (1986).
- <sup>h</sup> Derived from Knarr and Iwata (1986).

## **B. Exposure to EPTC from use of granular formulations**

Exposures of persons to EPTC were estimated during application of EPTC granular formulations for weed control in flowers and ornamentals, and aerial application of granular formulations in agriculture. There were no EPTC exposure studies available for these uses. Consequently, surrogate data obtained from exposure studies using chlorpyrifos, molinate and diazinon were utilized to estimate the exposure of persons to EPTC. These surrogate chemicals were selected because of their similarities in application methods and formulations. The surrogate exposure data were adjusted where appropriate to reflect factors associated with EPTC, including clothing penetration, application rate, application time, and dermal absorption value. The exposure estimates were reported as the arithmetic mean.

### **B.1 Flowers and ornamentals: application of EPTC granules**

There are several granular products of EPTC that are intended for use in flowers and ornamentals. Home gardeners can also use smaller bags of EPTC granular products in their home gardens and landscapes. The exposure for home gardeners to EPTC is expected to be lower than that for professional landscapers or workers who apply EPTC granules for weed control in flowers and ornamentals. Granular products for commercial uses are in larger size bags, e.g., 50 pounds.

A worker exposure study using an EPTC granular formulation was not available. A study using 14-G diazinon (Weisskopf *et al.*, 1988) was used as a surrogate for EPTC. Dermal and inhalation exposures were monitored for 6 workers by using patches, handwashes, and air sampling. These workers applied diazinon granules to eradicate Medfly larvae primarily in residential areas. The application rate was 40 pounds of product per acre (5.6 lbs a.i./acre). Types of application equipment were spreaders of three designs and a hand-held shaker. Only the exposure from the use of a belly grinder was used as a surrogate. The exposure from the use of a belly grinder was higher than that using other types of application equipment, namely coffee can applicator, Gandy spreader, and Lesco spreader. Also, a belly grinder is more appropriate for the application of Eptam<sup>®</sup> granules in the commercial production of flowers or ornamentals. After the application, diazinon was incorporated into the soil by a process called “watering in.” This type of application is similar to that for EPTC granules which requires either soil or water incorporation.

Table 6 shows exposure estimates for workers to diazinon according to body regions. These exposure estimates were then adjusted to reflect an application rate of EPTC at 5.0 lbs a.i. per acre. The EPTC labels do not require applicators to wear coveralls during application. Therefore, adjustment of leg exposure was made as noted in the footnote (<sup>b</sup>) of Table 6. The estimated absorbed dosages ( $\mu\text{g}/\text{kg}/\text{day}$ ) for workers loading and applying EPTC granules to flowers/ornamentals are shown in Table 7. The maximum label rate of 15 lbs a.i. per acre, which is used for the control of mugwort (*chrysanthemumweed*), was not employed in the estimation of exposure. Although this kind of weed is widely distributed in California, growing along streams, irrigation ditches, railroads, highways, and in moist pasture lands (Robbins *et al.*, 1941), it does not appear to be a common pest in gardens. Use of EPTC to control mugwort should not constitute a significant amount in California.

Table 6. Exposure of workers during application of EPTC granules.

	Mean exposure (mg)					Total
	Anterior head & neck	Posterior head & neck	Legs	Hands	Air	
Diazinon at 5.6 lbs a.i./A	3.66	1.04	0.14	0.06	0.27	5.17
	<u>Dermal exposure</u> = 4.90				<u>Inhalation</u>	
<u>exposure</u> = 0.27						
EPTC at 5.0 lbs a.i./A <sup>a</sup>	3.27	0.93	0.13	0.05	0.24	4.62
EPTC at 5.0 lbs a.i./A	3.27	0.93	0.59 <sup>b</sup>	0.05	0.24	5.08
	<u>Dermal exposure</u> = 4.84				<u>Inhalation</u>	
<u>exposure</u> = 0.24						

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<sup>a</sup> Diazinon exposure was adjusted to reflect an application rate of EPTC at 5.0 lbs a.i./A.

<sup>b</sup> EPTC product labels do not require coveralls to be worn during application of EPTC granules. Therefore, exposure of legs to EPTC was adjusted as follows:  $0.13 \times \text{clothing penetration of EPTC (47\%)} / \text{clothing penetration of diazinon (10\%)}$

## B.2 Agriculture: aerial application of EPTC granules

Exposures of pilots, flaggers, and loaders to EPTC during aerial application were estimated from two studies using molinate 10-G. Maddy *et al.* (1982) conducted the first study in Colusa County, California, using an application rate of 4 lbs a.i./acre. The second study was conducted by Knarr (1980) in Arkansas using an application rate of 3 to 5 lbs a.i./acre. The results of both exposure studies were reviewed and summarized by Formoli and Fong (1995); the geometric mean was employed in the estimation of exposure from a four-hour exposure

per day for pilots, flaggers and loaders. In order to be consistent with exposure estimates for other work tasks, the authors of this exposure document recalculated the exposures in terms of the arithmetic mean. The dermal and inhalation exposures were adjusted to reflect an application rate of EPTC at 3 lbs a.i./acre which is the maximum application rate for alfalfa. The mean absorbed dosages ( $\mu\text{g}/\text{kg}/\text{day}$ ) observed for pilots, flaggers, and loaders are shown in Table 7. The ground application of EPTC granules by tractors was assumed insignificant in terms of the amount of a.i. usage. From the use report in 1992, Eptam<sup>®</sup> 10-G accounts for 21,355 lbs a.i. or 3.2% of the total EPTC usage (Hunter, 1995). Aerial applications would constitute a major use of granular formulation. Therefore, the exposure of workers to EPTC during the ground application of granules was not estimated.

Table 7. Exposure of workers to EPTC during aerial and ground applications of granules<sup>a</sup>.

	Unadjusted surrogate exposure (mg/person/day)		Adjusted EPTC exposure (mg/person/day)		ADD (µg/kg/day)	SADD (µg/kg/day)	AADD (µg/kg/day)
	Dermal	inhalation	Dermal	inhalation			
B.1 Flowers and ornamentals: application of EPTC granules							
Loader/Applicator <sup>b</sup> (n=6)	4.90	0.27	4.84	0.24	14.3	6.75	0.32
B.2 Agriculture: Aerial application of EPTC granules <sup>c</sup>							
Pilots (n=5)	0.50	0.15	0.34 <sup>d</sup>	0.11	1.67	0.79	0.04
Flaggers (n=8)	5.62	0.09	2.89 <sup>e</sup>	0.12	8.40	3.95	0.18
Loaders (n=12)	32.0	5.57	21.2 <sup>f</sup>	4.18	85.1	40.1	1.86

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<sup>a</sup> Workers were assumed to be wearing long-sleeved shirts, long pants, shoes plus socks, and rubber gloves. These factors are applied: dermal absorption = 18.25%; inhalation uptake/absorption was 50% (Raabe, 1988); adult male body weight = 70 kg; clothing penetration of EPTC = 47%.

<sup>b</sup> The daily exposure was obtained from a study using diazinon 14-G at a rate of 5.6 lbs a.i./acre. The exposure was adjusted to reflect an application rate of 5 lbs a.i./acre for weed control in flowers and ornamentals. The number of workdays are 8 in a 17-day season. Percent of dermal exposure: Head and neck (86.8%), legs (12.2%), hands (1.0%)

<sup>c</sup> The surrogate data were from a study using molinate 10-G applied at an average rate of 4 lbs a.i./acre. Clothing penetration of molinate was 53%. The exposure data were adjusted to reflect an application rate of EPTC 10-G at 3 lbs a.i./acre. Eight workdays/17-day season.

<sup>d</sup> Pilots - Percent of dermal exposure: Body (83.9%), head and neck (11%), hands (5.1%). Clothing worn: long-sleeved shirts, long pants, shoes plus socks.

<sup>e</sup> Flaggers - Percent of dermal exposure: Body (94.7%), head and neck (4.4%), hands (0.9%). Same as pilots plus rubber gloves.

<sup>f</sup> Loaders - Percent of dermal exposure: Body (88.8%), head and neck (8.0%), hands (3.2%). Same as pilots plus rubber gloves.

### **C. Exposure to EPTC During Chemigation**

Liquid formulations of EPTC, Eptam<sup>®</sup> 7-E and Eptam<sup>®</sup> 6.7-E, may be applied and soil incorporated by using a chemigation system. A liquid formulation can be metered into the irrigation water at a constant flow rate. For flood, furrow, or sprinkler irrigation, liquid EPTC is metered into the water during the entire period. For sprinkler irrigation, liquid Eptam<sup>®</sup> may be metered into sufficient water to penetrate to a soil depth of 3 to 4 inches.

#### **C.1 Water-run of liquid formulations**

A worker exposure study for EPTC during a water-run irrigation (flood or furrow) was not available from the registrant. Therefore, exposure data generated for sodium tetrathiocarbonate (Haskell, 1994a, 1994b) was used as a surrogate. Sodium tetrathiocarbonate (Enzone<sup>®</sup>) was applied to grapes and citrus at three sites. The study design called for two applications per site at three sites utilizing three different irrigation systems: flood with furrows, drip and mini-sprinklers. The first application utilizing the nurse tank filled with water only and irrigation injection system was made with water from the nurse tank to generate background samples. The second application utilizing the same equipment, was made with Enzone<sup>®</sup> from the nurse tank. The long underwear dosimeters were worn underneath the worker's clothing and urine samples were collected before and after the application.

At each application site, one worker loaded the nurse tank with water for the pretreatment water application. The same worker also loaded Enzone<sup>®</sup> at the storage site into another nurse tank and transported it to the application site. These workers wore protective coveralls over normal work clothing, rubber boots, rubber gloves, and face shields or goggles. Two other workers, acting as applicators, attached the nurse tank to the irrigation system with hoses, pumps, and metering devices. They applied the Enzone<sup>®</sup> by injection into the irrigation system, then rinsed the nurse tank and injected the rinsate into the irrigation system. The workers then detached the pumps and hoses from the nurse tank. Injection of sodium tetrathiocarbonate into an irrigation system was done *using a closed system*. These applicators wore work clothing, rubber boots, and rubber gloves. The workers did not enter the treated area during the application at any of the sites. Under the work clothing, the workers wore long underwear which served as the dermal sampling matrix. The application time ranged from 5.75 to 11.33 hours averaging 8.31 hours per day. The average application rate for these sites was 136 lbs a.i. per acre.

Sodium tetrathiocarbonate is unstable in the environment after application. Collection of active ingredient residue samples for analysis was not practical, if not impossible. Therefore, a surrogate chemical, cesium ion in the form of cesium chloride, was added to the product before application at a rate of 0.0975% by weight. Estimation of dermal exposure per day was based on the amount of sodium tetrathiocarbonate that was proportional to the amount of detected cesium ion. Almost all samples collected for analysis showed that residues of cesium ion were either below the limit of detection (LOD) or the limit of quantitation (LOQ). When cesium was not detected in the underwear sample, the value observed was considered

1/2 LOD and values that were above the LOD but were too low to be quantified were expressed as 1/2(LOD+LOQ). All handwash sample results were estimated using the LOD. Dermal exposure was determined to be 2.27 mg/person/day, either for mixer/loaders or applicators. Standard deviation was not presented because of nondetection of residues by methods used in the estimation. Exposure of workers to EPTC was then estimated based on the label rates of 3 lbs a.i./acre for alfalfa (Tables 8 and 9). Inhalation exposure of mixer/loaders to Enzone<sup>®</sup> or its metabolite, CS<sub>2</sub>, was not directly monitored. Instead, exposure of workers to CS<sub>2</sub> was estimated from its urinary metabolite. This is not appropriate to be used as a surrogate for EPTC inhalation exposure. Therefore, EPTC inhalation exposure of 1,200 µg/person/day for M/L (Ross *et al.*, 1986) was employed. It was assumed that the application of liquid EPTC for a water-run used a closed system. Therefore, inhalation exposure would be 5% x 1,200 µg/person/day = 60 µg/person/day.

For weed control in alfalfa using a water-run application, the product label states “Meter 2 1/4 to 3 1/2 pints Eptam<sup>®</sup> 7-E (87.8%) per acre into the irrigation water applied to established stands prior to weed emergence.” It was assumed that the system used to dispense this product is a *closed system*, similar to that used for sodium tetrathiocarbonate.

Table 8. Dermal exposure estimates for EPTC loaders during a water-run application<sup>a</sup>.

<u>Sodium tetrathiocarbonate</u>				<u>EPTC</u>	
Rate (lbs a.i./acre)	DE (mg/person/day)	Adjusted DE <sup>c</sup> (mg/person/day)	Adjusted DE <sup>d</sup>	Rate (mg/person/day)	Adjusted DE <sup>e</sup> (lbs a.i./acr
136	2.27 <sup>b</sup>	22.7	107	3	2.35

DE = Dermal Exposure

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<sup>a</sup> Product label requires workers to wear long-sleeved shirt, long pants, chemical-resistant gloves, shoes plus socks, and protective eyewear.

<sup>b</sup> From Haskell (1994a, 1994b).

<sup>c</sup> Adjusted to reflect protection provided by one layer of clothing or (c) = (b) x 100%/10%.

<sup>d</sup> Adjusted to reflect 47 percent clothing protection of EPTC or (d) = (c) x 47%/10% (default).

<sup>e</sup> Adjusted to reflect the difference in the application rates or (e) = (d) x 3 lbs a.i./acre ÷ 136 lbs a.i./acre.

## C.2 Center-pivot irrigation system

For the potential worker exposure to EPTC during chemigation, it is anticipated that a center-pivot irrigation system would give a higher exposure than flood and furrow irrigation due to

potential contacts of workers to EPTC during handling of containers, pouring, mixing, calibration and application of EPTC products. Therefore, the exposure to EPTC during chemigation using the center-pivot irrigation system should represent an extreme exposure scenario.

A chlorpyrifos exposure study in corn using the center-pivot irrigation system (Byers *et al.*, 1992) was used as a surrogate. This study monitored both dermal and inhalation exposures. Three-layer pads, each composed of a bottom layer of glassine, middle layer of tagboard, and top layer of 12-ply surgical gauze, were used for dermal exposure monitoring. The hand exposure was monitored using 100% cotton beauty gloves worn over protective polyvinyl chloride gloves. Inhalation exposure was measured by employing a portable air sampler which was calibrated at a flow rate of 2 L/min. Polyurethane foam plugs were used for trapping the insecticide residues in the ambient air near the worker's breathing zone. The application rate for chlorpyrifos was 1 lb a.i. per acre.

The dermal exposure estimate was calculated to reflect the clothing worn by the worker which consisted of long-sleeved shirt, long pants, and rubber gloves. The EPTC labels require this same clothing for handlers, with the addition of protective eyewear. The dermal exposure data were adjusted to reflect EPTC clothing penetration of 47% and protection provided by rubber gloves of 90% (Thongsinthusak *et al.*, 1993b). The exposure data were also adjusted to represent the application rate of EPTC for alfalfa at 3 lbs a.i. per acre. It was assumed that the exposure period for a worker was 2 hours per day. Eight workdays in a 17-day season was also assumed. These default values were based on a survey which indicated that use of the center-pivot irrigation systems has not been well established in California (Thongsinthusak *et al.*, 1993a). The estimated absorbed dosages ( $\mu\text{g}/\text{kg}/\text{day}$ ) are shown in Table 9.

Table 9. Exposure of workers to EPTC during chemigation, aerial and ground applications of granules.

	Unadjusted surrogate exposure (mg/person/day)		Adjusted EPTC exposure (mg/person/day)		ADD (µg/kg/day)	SADD (µg/kg/day)	AADD (µg/kg/day)
	Dermal	inhalation	Dermal	inhalation			
<u>C.1 Water-run (chemigation)</u>							
Applicator <sup>a</sup> (n=9)	2.27	1.20	2.35	0.06	5.34	2.51	0.12
<u>C.2 Center-pivot sprinkler irrigation</u>							
M/L/A <sup>b</sup> (n=9)	14.1	0.05	84.4	0.14	221	78.0	3.64

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<sup>a</sup> Based on a 70-kg adult male body weight, except for surrogate dermal exposure which was based on an average body weight of 87.5 kg (actual body weight). Dermal absorption = 18.25%. Inhalation uptake/absorption was 50% (Raabe, 1988). The number of workdays per 17-day use season is eight. The number of workdays per year is also eight.

<sup>b</sup> Based on the chlorpyrifos application rate of 1 lb a.i./acre. Exposure time per workday = 2 hours; the exposures were adjusted based on the EPTC application rate of 3 lbs a.i./acre (for alfalfa); eight workdays per 17-day season. Adjusted dermal exposure (mg/2 hours): gloved hands 13.3, unclothed areas 8.9, clothed area 62.3.

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