

Health & Safety

Report

Worker Health and Safety Branch

HS-1779

**EXPOSURE AND ILLNESS FOLLOWING  
EARLY REENTRY INTO A CARBOFURAN-  
TREATED FIELD**

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## Executive Summary

On July 31, 1998, the Department of Pesticide Regulation (DPR) Worker Health and Safety Branch (WH&S) received notice that several field workers became ill while working in a treated cotton field. Thirty-four field workers began weeding a cotton field (plants about 4' tall) approximately 2 hours after the completion of an application of carbofuran, mepiquat chloride, and abamectin. The restricted entry interval for carbofuran on cotton is 2 days and posting is required. This incident was a result of miscommunication between grower, applicator, and farm labor contractor leading to early reentry and exposure of field workers to the toxic N-methyl carbamate, carbofuran. After weeding the treated cotton for 3.5 hours, the crew took a short break and moved to another cotton field to weed. The second field had been treated with cyfluthrin, dicofol, and mepiquat chloride 2 days previously. Approximately 10-15 minutes after entering the second field, the workers began feeling ill and stopped work. The resulting symptoms were typical of N-methyl carbamate overexposure. Thirty workers were transported to a local medical clinic; four did not seek immediate treatment and went home first. The incident could have been prevented with appropriate communication and adherence to existing regulations on restricted entry intervals and field posting.

Staff from DPR, the county agricultural commissioner's office and the California Department of Health Services interviewed the exposed workers. Symptoms experienced included headache, nausea, vomiting, diarrhea, eye irritation, tearing, respiratory problems, salivation, and muscle weakness. One worker experienced atrial fibrillation and was the only worker hospitalized. Ten workers had blood drawn and properly stored (chilled); red blood cell cholinesterase was below laboratory normal range in all 10 samples. Most of the exposed were decontaminated at the clinic and observed; only 4 received treatment with atropine. A physician collected urine samples from eight workers on the day of illness. Urine samples were collected from most of the other workers 8-19 days later, as some continued to suffer from illness symptoms. Investigators collected dislodgeable foliar residue samples about 6 hours after the workers became ill. In addition, the workers' clothing, originally removed as part of decontamination, was taken to the laboratory for analysis.

Foliage samples contained the following residues: carbofuran, 0.07-0.77  $\mu\text{g}/\text{cm}^2$ ; 3-hydroxy carbofuran, 0.007-0.01  $\mu\text{g}/\text{cm}^2$ ; and 3-keto carbofuran,  $<0.0025 \mu\text{g}/\text{cm}^2$ . Workers' (n=4) pants and shirts were analyzed for carbofuran (43.1-154.8 mg/worker), 3-hydroxy carbofuran (unable to quantify due to interferences caused by vomiting and diarrhea), and 3-keto carbofuran ( $<0.15 \text{ mg}$ ). These results essentially mirror those from the foliage samples.

Urine samples were analyzed for metabolites of carbofuran. Urine samples (n=8) collected the day of illness contained: 0.062-12 ppm carbofuran 7-phenol,  $<0.05\text{-}0.336 \text{ ppm}$  of carbofuran 3-keto-7-phenol, and  $<0.05\text{-}1.24 \text{ ppm}$  carbofuran 3-hydroxy-7-phenol. These metabolite levels dropped significantly in the urine samples collected 8-19 days later. Some workers either had very low foliar contact or wore gloves, T-shirt under the work shirt, coveralls, or plastic to protect them from the wet foliage in the morning. Most of these workers had lower metabolite levels than the other workers. A regression analysis of the relation between the urinary metabolites and the clothing residues (n=4) was significant ( $r^2 = 0.93$ ,  $p=0.04$ ).

Carbofuran is a cholinesterase-inhibiting insecticide used mainly for the control of soil-dwelling and foliar-feeding insects. It is a Toxicity Category I pesticide with reported oral  $\text{LD}_{50}$  of 5-13 mg/kg (rats), 2 mg/kg (mice) and 19 mg/kg (dogs). The dermal  $\text{LD}_{50}$  is  $>1000 \text{ mg}/\text{kg}$  in rabbits. The acute carbofuran toxic effects are usually short lived, as the N-methyl carbamate inhibition reaction is readily reversible.

## **Introduction**

On July 31, 1998, the Department of Pesticide Regulation (DPR) Worker Health and Safety Branch (WH&S) received notice that several field workers became ill while working in a treated cotton field. Thirty-four field workers began weeding a cotton field (plants approximately 4' tall) approximately 2 hours after the completion of an application of carbofuran, mepiquat chloride, and abamectin. The carbofuran restricted entry interval is 2 days for cotton and posting is required. Lack of communication between the grower, applicator, and labor contractor resulted in not posting the field and early entry. After weeding treated cotton for 3.5 hours, the crew took a short break and moved to another cotton field to weed. The second field had been treated with cyfluthrin, dicofol, and mepiquat chloride 2 days previously. Approximately 10-15 minutes after entering the second field, the workers began feeling ill and stopped work. Thirty workers were transported to a local medical clinic; four went home and did not seek immediate treatment.

Staff from DPR, the county agricultural commissioner's office and the California Department of Health Services interviewed the exposed workers. Symptoms experienced included headache, nausea, vomiting, diarrhea, eye irritation, tearing, respiratory problems, salivation, and muscle weakness. One worker was diagnosed with atrial fibrillation and was the only worker hospitalized. Most of the exposed were decontaminated at the clinic and observed; only 4 received treatment with atropine<sup>1</sup>. Blood samples for cholinesterase analyses were collected from 29 workers. All cholinesterase levels were within laboratory normal range, but the samples were not properly stored (refrigerated or chilled) between collection and analysis. Ten workers had a second sample drawn that was properly stored; red blood cell cholinesterase was below laboratory normal range in all 10 samples<sup>1</sup>.

Carbofuran (2,3-dihydro-2,2-dimethylbenzofuran-7-yl methylcarbamate) is a cholinesterase-inhibiting insecticide used mainly for the control of soil-dwelling and foliar-feeding insects. It is available only in a liquid formulation in the United States. Carbofuran is a Toxicity Category I pesticide with reported oral LD<sub>50</sub> of 5-13 mg/kg (rats), 2 mg/kg (mice), and 19 mg/kg (dogs)<sup>2</sup>. The dermal LD<sub>50</sub> is >1000 mg/kg in rabbits<sup>2</sup>. The acute carbofuran toxic effects are usually short lived, as the N-methyl carbamate inhibition reaction is readily reversible.

Carbofuran metabolism is similar in the rat, mouse, and cow<sup>2</sup>. Metabolism occurs via ring oxidation (3-hydroxy carbofuran and 3-keto carbofuran) and hydrolytic cleavage of the ester linkage (carbofuran 3-hydroxy-7-phenol, carbofuran 3-keto-7-phenol, and carbofuran 7-phenol).

This paper discusses the relationship between the carbofuran found on cotton foliage and the workers' clothing and the carbofuran metabolites found in urine samples collected from the exposed workers.

## **Materials and Methods**

WH&S followed applicable standard operating procedures related to sample identification, sample collection, record keeping, shipping, storage, report preparation, and data archiving. Since the study was conducted as part of an illness investigation, time did not allow researchers to follow procedures for protocol development. Research staff followed the Worker Health and Safety Cluster Illness Episode Action Plan<sup>3</sup> in response to this incident. Chain-of-custody forms were properly used for the DFR foliage samples and initial urine samples. However, the urine

samples collected in August were mistakenly shipped to another laboratory and then to our laboratory and did not have a chain-of-custody. Clothing samples were initially collected as part of decontamination and intended for disposal, but were brought to the laboratory for analysis without a chain-of-custody form. The study consisted of dislodgeable foliar residue sampling, analysis of clothing collected at the medical clinic and single urinary voids collected from the workers who became ill as a result of pesticide exposure.

#### *Study Dates*

Study initiation date:	July 31, 1998
Experimental start date:	July 31, 1998
Experimental termination date:	August 19, 1998
Study completion date:	November 1999

#### *Application*

The carbofuran application was completed around 4 a.m. on July 31, 1998, the day the workers entered the field. The product used to treat the field was Furadan 4F Insecticide-Nematicide, EPA# 279-2876-ZC, containing 44% carbofuran. This product carries the signal word "Danger" and has a two-day restricted entry interval. The application rate was 8 ounces of product in ten gallons of water per acre (0.25 lbs. carbofuran/acre). The tank mix also included:

- 0.0094 lbs./acre abamectin, (Zephyr 0.15 EC, EPA# 618-97 AA)
- 0.0437 lbs./acre mepiquat chloride, (Mepichlor 4.2% Liquid, EPA# 51036-188-AA)
- 0.04 lbs./acre RNA Bupher (EPA# 1050990-50015-AA) containing 7% trisodium phosphate, 6.3% propylene glycol and 8.55% phosphoric acid
- 0.89 lbs./acre cottonseed oil (RNA Cotton Oil Surfactant, EPA# 1050990-50014-AA)

#### *Dislodgeable Foliar Residue (DFR)*

Sample collection - County Agricultural Commissioner's staff assisted researchers in locating the carbofuran-treated field in western Fresno County where the illness occurred. (No samples were collected from the second field in which the workers were weeding.) Dislodgeable foliar residue sampling was conducted according to applicable standard operating procedures, Gunther et al.<sup>4</sup> and Edmiston et al.<sup>5</sup>. Foliar samples were collected using a Rabbit<sup>®</sup> leaf punch, which cut a leaf disk of 1.78 or 2.54 centimeters in diameter. Samples collected with the 1.78-cm punch consisted of 80 leaf disks and those collected with the 2.54-cm punch consisted of 40 leaf disks. All samples totaled 400 cm<sup>2</sup> of surface area for both sides of the leaf. Six samples were collected from the 30 acres located in the west fifth of the NE<sup>1</sup>/<sub>4</sub>, S18, T17S, R15E Mt. Diablo Base Meridian. Samples were collected in such a manner that they were representative of the entire 30 acres. Staff performing the sampling wore goggles, a half-face respirator, coveralls with a hood, and chemical-resistant gloves and boots. Samples were taken from the cotton approximately three feet from the ground. Sampling started at 5:30 p.m. July 31, 1998, and was completed within one hour. Samples were collected in labeled four-ounce glass jars, capped with a Teflon-lined lid, bagged, and placed on ice in an insulated chest (chilled, not frozen). A chain-of-custody form was completed and submitted to the laboratory with the samples. Leaf samples were transported to the California Department of Food and Agriculture, Center for Analytical Chemistry (CDFA) laboratory and extracted within 15 hours of sample collection.

Analytical method - Carbofuran analyses were performed by the CDFA laboratory. The samples were initially analyzed for carbofuran, 3-hydroxy carbofuran, and 3-keto carbofuran. At a later time, samples were also analyzed for abamectin and run through a pesticide screen which detected dicofol from a previous application. (Abamectin and screening methods are available upon request.)

Three sequential washings removed residues, each consisting of a 30-minute rotation on a mechanical shaker with 50 mL distilled water and 4 drops of sodium dioctyl sulfosuccinate solution. The solution was decanted between washings and the combined wash extracted with ethyl acetate. The organic extract was then dried by anhydrous sodium sulfate. The samples were analyzed on a Hewlett-Packard 1050 liquid chromatograph equipped with HP 1046A programmable FL detector. The conditions for carbofuran and its metabolites were:

- Pickering Laboratories analysis column, 5 $\mu$ , C<sub>18</sub>, 4.6 mm x 250 mm
- HPLC pump gradient: acetonitrile/H<sub>2</sub>O 1mL/min, stoptime = 23 min, posttime = 5 min
- 1050 ALS Injector program: 40  $\mu$ L drawn from sample
- Post column parameters: heated reactor temperature=100° C,
- Column temperature=42° C
- Fluorescence detector: excitation at 330 nm, emission at 464 nm.

Retention times were: carbofuran - 13.87 minutes; 3-keto carbofuran – 12.43 minutes; and 3-hydroxy carbofuran – 10.25 minutes.

Calculations - Analytical results were reported as micrograms per sample and recorded in Microsoft Access<sup>®</sup>. The results were then converted to micrograms/square centimeter ( $\mu\text{g}/\text{cm}^2$ ) by dividing the sample result by the sample surface area of 400  $\text{cm}^2$ .

### *Clothing Samples*

Sample collection – While at the medical treatment facility, researchers were picked up the workers' contaminated clothing to the laboratory for analysis of carbofuran residues. Each worker's clothing was in individual plastic bags and labeled with the workers' names. The bags of clothing were transported and stored frozen until analysis by the CDFA laboratory.

Analytical method – Each article of clothing was extracted with methanol in a large bottle and rolled for an hour. The extract was concentrated, if necessary. The extract was analyzed for the same compounds and in the same manner as the DFR samples.

### *Urine Samples*

Sample collection - After completion of the leaf sampling, one researcher drove to the medical treatment facility located in Fresno to pick up urine samples given by eight workers who were retained at the hospital for observation and then released later that day. These samples were collected from the field workers by the hospital early that day. The voids were in plastic sample containers and labeled with the workers' names. They were transported and stored frozen until analysis by the CDFA laboratory. Since some workers continued to experience symptoms in the days after the exposure, the original treating physician requested all workers to return to give urine for additional analyses. Workers submitted samples 8-19 days later; some worker submitted two samples in that later time period.

Analytical method - The urine samples were acid hydrolyzed with 0.25 N hydrochloric acid and passed through SCX and Bond-Elut cartridges for preliminary cleanup. The phenols were eluted from the cartridge with ethanol in dichloromethane, and exchanged to sodium hydroxide. A multi-step pentafluoro derivatization followed by ethyl derivatization scheme was used to prepare the sample extract for GC/MS analysis. The metabolites were 2,3-dihydro-2,2-dimethyl-7-benzofuranol (carbofuran 7-phenol), 2,3-dihydro-2,2-dimethyl-7-hydroxybenzofuran (carbofuran 3-keto-7-phenol), and 2,3-dihydro-2,2-dimethylbenzofuran-3,7-diol (carbofuran 3-hydroxy-7-phenol).

GC conditions:

- DB-17 column, 15m x 0.25 mm x 0.25 micron @ 10 psi
- 60° C/0.4 min, 40° C/min to 150° C, 10 C/min to 200° C, 15° C/min to 240° C, hold 2 min (12.3 min total time)
- S/S injector at 220° C, splitless injection, valve opens at 0.5 min
- Transfer line 240° C

ITD conditions:

- ITD analysis file - FUR\_METS
- 100-450 amu scan, 2 scans/sec, SIS method, 3 min acquisition ( 5-8 min)
- Manifold temp 220° C
- 5 min multiplier delay

Retention times were: carbofuran 7-phenol – 5.82 minutes; carbofuran 3-keto-7-phenol – 7.05 minutes; and carbofuran 3-hydroxy-7-phenol – 7.19 minutes.

Results are reported as parts per billion (ppb). Recoveries for the carbofuran 7-phenol run from 86% at 10 ppb to 104% at 4 ppm; the carbofuran 3-keto-7-phenol from 96% at 10 ppb to 135% at 0.4 ppm; and the carbofuran 3-hydroxy-7-phenol 37% at 10 ppb to 73% at 2 ppm. Metabolite residues range up to 12 ppm of the carbofuran 7-phenol, 0.25 ppm of carbofuran 3-keto-7-phenol, and 1.75 ppm of the carbofuran 3-hydroxy-7-phenol. A complete analytical reference is available upon request.

## **Results**

### *Worker/Work Demographics*

All 34 members of the weeding crew were male. The average age was 34.6 with a range of 13 to 64 years old. Thirty workers were questioned about the clothing worn the day of exposure; all workers reported wearing long pants. Seventy-three percent wore a long-sleeved shirt while 27% wore a short-sleeved shirt or T-shirt and 17% wore a T-shirt under their outer shirt. Fifty-seven percent wore work boots while the others wore other types of shoes (e.g. tennis shoes) and 83% wore socks. All 30 wore a hat of some type and 33% also wore a bandana under their hat. Only 30% of the workers wore gloves while weeding the cotton.

During interviews several workers reported that the cotton plants were wet. One worker wore a plastic bag over himself to protect from the dampness and told county investigators that he was not as sick as many of the other workers. Another worker wore cloth coveralls to protect from the wet foliage. In addition, some workers reported pulling weeds with their hands because the weeds were large and it was easier than using hoes. When the workers finished the carbofuran-treated field, they stopped for a food break. Since wash water and towels were ½ mile away,

only 7 workers (23%) reported washing their hands prior to eating; all used drinking water to wash. Thirteen workers did not wash prior to eating because the water was too far away and the wash status of the remaining 14 is unknown.

#### *Dislodgeable Foliar Residue Samples*

Table 1 contains the average results of the six DFR samples collected. All samples were collected the day of the exposure, approximately 14 hours after application. The DFR sample with the highest carbofuran residue contained 0.767 µg/cm<sup>2</sup>.

**Table 1: Dislodgeable Foliar Residue (DFR) Found Approximately 14 Hours after Application**

Analyte	Average DFR (µg/sample)	Average DFR (µg/cm <sup>2</sup> )	DFR Range (µg/cm <sup>2</sup> )	Notes
Carbofuran	182.4	0.456	0.069 - 0.767	High and low sample confirmed by GC-ITD
3-Hydroxy carbofuran	3.7	0.009	0.007 - 0.010	
3-Keto carbofuran	ND <sup>1</sup>	ND <sup>1</sup>	ND	
Avermectin	1.5	0.004	0.001 - 0.009	
Dicofol <sup>2</sup>	82.4	0.206	0.028 - 0.582	

<sup>1</sup> – None detected; limit of detection = 1.0 µg/sample (0.0025 µg/cm<sup>2</sup>)

<sup>2</sup> – Dicofol applied on July 20, 1998 at 1.5 lbs. active ingredient/acre (Kelthane MF, EPA # 707-202-AA)

#### *Clothing Residues*

Many of the exposed workers were very sick with vomiting and diarrhea. Thus, much of the clothing was contaminated and contained too many interferences for analyses. Chemists analyzed clothing samples from four workers. Table 2 presents the results of the clothing analyses completed. Interferences prevented analysis of the 3-hydroxy carbofuran. No 3-keto carbofuran was found on the clothing analyzed, which corresponds with the DFR results.

**Table 2: Carbofuran Residues on Worker Clothing Samples**

Worker ID	Matrix	Carbofuran (mg/sample)	3-Hydroxy carbofuran (µg/sample)	3-Keto carbofuran (µg/sample)
17	Shirt	NS <sup>1</sup>	NS <sup>1</sup>	NS <sup>1</sup>
	Pants	71.1	NS <sup>1</sup>	NS <sup>1</sup>
	<i>Worker Total</i>	<i>71.1</i>		
28	Pants	35.8	NS <sup>1</sup>	ND <sup>2</sup>
	Shirt	7.28	NS <sup>1</sup>	ND <sup>2</sup>
	<i>Worker Total</i>	<i>43.1</i>		
36	Pants	26.6	NS <sup>1</sup>	NS <sup>1</sup>
	T-shirt	0.34	NS <sup>1</sup>	NS <sup>1</sup>
	Outer shirt	18.3	NS <sup>1</sup>	NS <sup>1</sup>
	<i>Worker Total</i>	<i>45.24</i>		
40	Pants	91.4	NS <sup>1</sup>	ND <sup>2</sup>
	Shirt	63.4	NS <sup>1</sup>	ND <sup>2</sup>
	<i>Worker Total</i>	<i>154.8</i>		

<sup>1</sup> – No sample; too much interference for analysis

<sup>2</sup> – None detected; MDL = 0.150 mg/sample

Worker #36 wore a T-shirt under his work shirt. Less than 2% of the carbofuran residue on the upper body penetrated the work shirt to the T-shirt. This same person had relatively low urinary metabolite levels (Table 3). For workers 36 and 40, the shirt contained 41% of the total residue found while the pants contained 59%. Worker #28 had only 17% of the total residue on the shirt and 83% on the pants. Carbofuran residues on the clothing averaged 78.5 mg/worker (range, 43.1-154.8 mg/worker).

### *Urine Sample Results*

Urine samples were collected from eight workers on the day of the exposure (July 31, 1998). Physicians collected follow-up urine samples from six (worker ID 17, 28, 7, 8, 16, 35) of those eight workers. All six showed significant reduction in urine metabolite levels 8-13 days later with metabolite levels at or below the analytical limit of detection (Table 3). For the eight workers, initial urinary concentrations of carbofuran 7-phenol averaged 4.09 ppm (0.062-12 ppm) while carbofuran 3-keto-7-phenol averaged 0.113 ppm (ND-0.336) and carbofuran 3-hydroxy-7-phenol averaged 0.553 ppm (ND-1.24). Worker #16 had very low concentration of metabolites in his urine; he experienced very minimal symptoms. He reportedly worked on an outside row with little to no foliar contact and wore gloves. Worker #36 also had low initial metabolite levels; he reportedly wore a plastic bag over his clothing to protect him from the wet foliage. Workers #7, 17, 35 and 40 had the highest urinary metabolite levels. Workers 7, 17, and 40 all wore short-sleeved shirts and did not wear gloves; worker 35 did not wear gloves or socks. Workers 8 and 28 had intermediate urinary metabolite levels; #8 washed at break time and #28 wore gloves (Appendix 2).

### **Discussion**

No previous reports of carbofuran field worker poisoning were found in the public literature. The California Pesticide Illness Surveillance Program reveals that from 1982 through 1996 only two field workers reported ill effects following separate exposure incidents to carbofuran<sup>6</sup>.

In the samples collected following the 1998 early reentry incident, clothing residues mirrored DFR chemicals detected; no 3-keto carbofuran was detected on DFR or clothing. The between-worker differences in clothing residue detected probably reflect differences in activities and resulting foliar contact. Some workers apparently pulled weeds by hand (no hoe, even though it was provided) without wearing gloves, thus increasing foliar contact. The foliage was reportedly wet when workers first entered the field at 6:00 a.m., which may also affect dermal transfer. One man stated he worked an outside row with little foliar contact and wore gloves; he had the lowest urinary metabolites found in the group of eight tested the day of exposure. However, the limited data collected during the worker interviews does not fully explain the differences in initial urinary metabolites found for eight workers who submitted samples on the day of exposure.

**Table 3: Results of Urine Samples Collected from Workers Exposed to Carbofuran Residues**

Worker ID	Sample Date	Carbofuran 7-phenol (ppm)	Carbofuran 3-keto-7-phenol (ppm)	Carbofuran 3-hydroxy-7-phenol (ppm)	Total Carbofuran Equivalents (ppm)
17 <sup>1</sup>	31-Jul-98	5.48	0.13	0.84	8.58
	11-Aug-98 <sup>2</sup>	ND <sup>5</sup>	ND	ND	-
28 <sup>1</sup>	31-Jul-98	2.26	0.029	0.311	3.46
	08-Aug-98	0.01	ND	ND	0.01
36 <sup>1</sup>	31-Jul-98	0.205	ND	0.011	0.38
40 <sup>1</sup>	31-Jul-98	7.12	0.262	1.24	11.44
7 <sup>2</sup>	31-Jul-98	4.31	0.124	0.774	6.91
	11-Aug-98 <sup>3</sup>	0.01	ND	ND	0.01
	13-Aug-98 <sup>3</sup>	ND	ND	ND	-
8 <sup>2</sup>	31-Jul-98	1.28	0.014	0.144	1.92
	13-Aug-98 <sup>2</sup>	ND	ND	ND	-
16 <sup>2</sup>	31-Jul-98	0.062	ND	ND	0.08
	11-Aug-98 <sup>2</sup>	0.01	0.01	ND	0.02
35 <sup>2</sup>	31-Jul-98	12	0.336	1.1	17.94
	08-Aug-98	0.012	ND	ND	0.02
1	19-Aug-98 <sup>3</sup>	ND	ND	ND	-
2	19-Aug-98 <sup>3</sup>	ND	ND	ND	-
3	14-Aug-98 <sup>3</sup>	ND	ND	ND	-
4	08-Aug-98 <sup>4</sup>	0.055	ND	ND	0.07
	13-Aug-98 <sup>4</sup>	ND	ND	ND	-
5	08-Aug-98 <sup>4</sup>	ND	ND	ND	-
	13-Aug-98 <sup>4</sup>	ND	ND	ND	-
6	08-Aug-98 <sup>4</sup>	0.032	ND	ND	0.04
	13-Aug-98 <sup>4</sup>	ND	ND	ND	-
9	08-Aug-98 <sup>4</sup>	0.01	ND	ND	0.01
	13-Aug-98 <sup>4</sup>	ND	ND	ND	-
10	13-Aug-98 <sup>3</sup>	ND	ND	ND	-
12	11-Aug-98 <sup>3</sup>	0.01	ND	ND	0.01
13	11-Aug-98 <sup>3</sup>	ND	ND	ND	-
14	11-Aug-98 <sup>3</sup>	0.232	0.01	ND	0.32
18	11-Aug-98 <sup>3</sup>	ND	ND	ND	-
19	11-Aug-98 <sup>3</sup>	0.019	ND	ND	0.26
20	11-Aug-98 <sup>3</sup>	0.157	ND	ND	0.21
21	11-Aug-98 <sup>3</sup>	ND	ND	ND	-
22	11-Aug-98 <sup>3</sup>	ND	ND	ND	-
23	11-Aug-98 <sup>3</sup>	0.036	ND	ND	0.05
24	08-Aug-98	ND	ND	ND	-
25	08-Aug-98	ND	ND	ND	-
27	08-Aug-98	0.01	ND	ND	0.01
29	08-Aug-98	0.065	ND	ND	0.09
32	08-Aug-98	ND	ND	ND	-
34	08-Aug-98	ND	ND	ND	-
<b>31-Jul-98</b>	<b>Average</b>	<b>4.09</b>	<b>0.113</b>	<b>0.553</b>	<b>6.34</b>
	Range (n=8)	0.062-12	ND -0.336	ND-1.24	0.08-17.94
<b>08-Aug-98</b>	<b>Average</b>	<b>0.016</b>	<b>ND</b>	<b>ND</b>	<b>0.02</b>
	Range (n=12)	ND-0.065	ND	ND	ND-0.09
<b>11-Aug-98</b>	<b>Average</b>	<b>0.040</b>	<b>ND</b>	<b>ND</b>	<b>0.07</b>
	Range (n=12)	ND-0.232	ND-0.01	ND	ND-0.32
<b>13,14-Aug-98</b>	<b>Average</b>	<b>ND</b>	<b>ND</b>	<b>ND</b>	<b>ND</b>
	Range (n=8)	ND	ND	ND	ND

<sup>1</sup> - Urine sample collected day of incident and worker's clothing analyzed for carbofuran and metabolites.

<sup>2</sup> - Urine sample collected day of incident (no clothing analyzed)

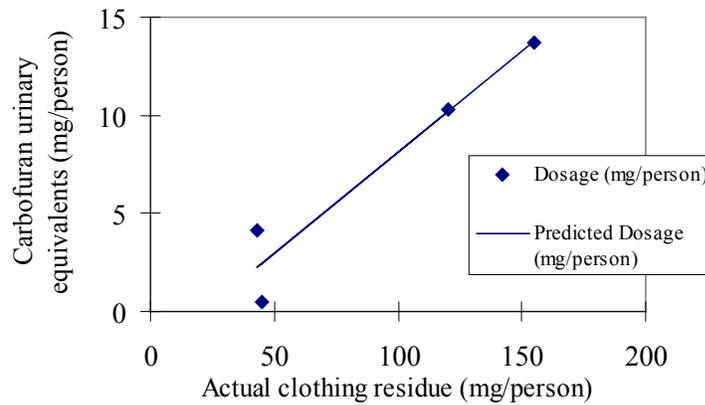
<sup>3</sup> - Assume log date on lab printout is equal to collection date.

<sup>4</sup> - Two samples collected for this individual. Sample results didn't distinguish between the sample collected on 8/8 (or 8/11) and those collected on 8/13

<sup>5</sup> - None detected; limit of detection was 0.01 for the 7-phenol and 3-keto-7phenol and 0.05 for the 3-hydroxy-7-phenol.

Assuming that worker #17's pants contained 59% of the total clothing residue (as it did for 2 other workers), the total for his shirt and pants would be 120.3 mg. Using that value for worker #17, a linear regression (Figure 1) of clothing residues vs. urine metabolites (n=4) was significant ( $r^2 = 0.93$ ,  $p=0.04$ ). This regression does not take into account the contribution of carbofuran residues on areas not protected by the shirt and pants (primarily hands, head and feet).

**Figure 1: Actual clothing residue vs. urinary metabolites**



Shah *et al* (1987)<sup>7</sup> found a dermal penetration rate of 18% for carbofuran in adult rats. In addition, Brodberg and Sanborn<sup>8</sup> found that the clothing penetration for harvesters averaged 25%. Using those two values and the urinary metabolite data, one can estimate the residue expected on the clothing.

$$\begin{array}{l} \text{carbofuran equivalents } (\mu\text{g/ml}) \text{ from urine metabolites} \times \text{urine volume (ml)} \times 18\% \text{ dermal absorption}^7 = \text{calculated dermal dose } (\mu\text{g}) \\ \text{(amount on skin, including under clothes)} \\ 11.4 \mu\text{g/ml} \times 1200 \text{ ml} \div 0.18 = 76,000 \mu\text{g} \\ \text{(from worker \#40; Table 3)} \end{array}$$

$$\begin{array}{l} \text{calculated dermal dose } (\mu\text{g}) \times 81\% \text{ of body covered by shirt \& pants}^9 \div 25\% \text{ clothing penetration}^8 = \text{carbofuran residues on clothing } (\mu\text{g}) \\ 76,000 \mu\text{g} \times 0.81 \div 0.25 = 246,000 \mu\text{g} \end{array}$$

The estimated clothing residue ranges from 9-262 mg/person. These values compare fairly well to the residues found in the clothing samples analyzed, given the uncertainty of the animal (vs. human) dermal absorption rate, the fact that hand exposure was not measured, and the urine samples were single urinary voids. The contribution of hand exposure to total dermal exposure during harvest of tomatoes and lettuce ranged from 8-35% (Schneider *et al.* (1988)<sup>10</sup>, Rech *et al.* (1989)<sup>11</sup>, Blewett *et al.* (1989)<sup>12</sup>). Since hand exposure was not measured here, the contribution to the adsorbed dosage cannot be accurately determined. However, some of the sample results suggest that wearing gloves and long-sleeved shirts with T-shirts underneath can help reduce

exposure and thus illness. Work practices to limit foliar contact, such as use of hoes when weeding, will also help reduce exposure.

This incident was a result of miscommunication between grower, applicator, and farm labor contractor leading to early reentry and exposure of field workers to the toxic N-methyl carbamate, carbofuran. The resulting symptoms were typical of N-methyl carbamate overexposure. The incident could have been prevented with appropriate communication and adherence to existing regulations on restricted entry intervals and field posting.

### **Quality Assurance Statement**

Since this study was conducted in response to an illness episode investigation, a protocol was not written and a sample collection audit could not be performed. The work followed the Worker Health and Safety Cluster Illness Episode Action Plan. The resulting data and study report were audited on August 3-5, 1999, and reported to the study director and branch management on August 6, 1999.

[original signed by K. Orr]

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Kathy Orr, Quality Assurance Officer  
Worker Health and Safety Branch

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Date

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Appendix 1: Dislodgeable Foliar Residue (DFR) Sample Results

WHS Sample ID	Analyte	DFR (µg/sample)	DFR (µg/cm <sup>2</sup> )	Notes
FS07-1	carbofuran	27.4	0.069	Confirmed by GC-ITD
FS07-2	carbofuran	143.0	0.357	
FS07-3	carbofuran	307.0	0.767	Confirmed by GC-ITD
FS07-4	carbofuran	145.0	0.362	
FS07-5	carbofuran	278.0	0.695	
FS07-6	carbofuran	194.0	0.485	
	Average	182.4	0.456	
FS07-1	carbofuran, 3-OH	2.8	0.007	
FS07-2	carbofuran, 3-OH	3.8	0.010	
FS07-3	carbofuran, 3-OH	3.5	0.009	
FS07-4	carbofuran, 3-OH	3.9	0.010	
FS07-5	carbofuran, 3-OH	4.1	0.010	
FS07-6	carbofuran, 3-OH	4.1	0.010	
	Average	3.7	0.009	
FS07-1	carbofuran, 3-keto	ND	ND	
FS07-2	carbofuran, 3-keto	ND	ND	
FS07-3	carbofuran, 3-keto	ND	ND	
FS07-4	carbofuran, 3-keto	ND	ND	
FS07-5	carbofuran, 3-keto	ND	ND	
FS07-6	carbofuran, 3-keto	ND	ND	
FS07-1	avermectin	0.5	0.001	
FS07-2	avermectin	1.3	0.003	
FS07-3	avermectin	3.7	0.009	
FS07-4	avermectin	1.2	0.003	
FS07-5	avermectin	1.1	0.003	
FS07-6	avermectin	1.0	0.002	
	Average	1.5	0.004	
FS07-1	dicofol	150.0	0.375	
FS07-2	dicofol	76.0	0.190	
FS07-3	dicofol	233.0	0.583	
FS07-4	dicofol	11.1	0.028	
FS07-5	dicofol	12.7	0.032	
FS07-6	dicofol	11.3	0.028	
	Average	82.4	0.206	

## Appendix 2: Exposure Factors Determined from Worker Interviews

<b>Worker ID</b>	<b>Clothing Worn</b>	<b>Personal Protective Equipment Used</b>	<b>Wash Hands</b>	<b>Pulled Weeds by Hand</b>
7	Long pants, <i>short-sleeved shirt</i> , work boots, <i>no socks</i>	Hat, bandana, <i>no gloves</i>	Unknown	Unknown
8	Long pants, long-sleeved shirt, shoes, socks	Hat, bandana, <i>no gloves</i>	Yes	Unknown
16	Long pants, long-sleeved shirt, work boots, socks	Hat, bandana, gloves	No	No, minimal foliar contact; worked outside row
17	Long pants, <i>short-sleeved shirt</i> , work boots, socks	Hat, <i>no gloves</i>	No	Unknown
28	Long pants, long-sleeved shirt, work boots, socks	Hat, gloves	No	Unknown
35	Long pants, long-sleeved shirt, shoes, <i>no socks</i>	Hat, <i>no gloves</i>	Unknown	Unknown
36	Long pants, long-sleeved shirt, T-shirt, work boots, socks	Hat, bandana, used plastic bag in AM, <i>no gloves</i>	Unknown	Unknown
40	Long pants, <i>short-sleeved shirt</i> , work boots, socks	Hat, <i>no gloves</i>	Unknown	Unknown