Health and Safety Report

Worker Health and Safety Branch

HS-1877

Pesticide Exposure to Cotton Irrigators using Sprinkler and Furrow Irrigation Systems in the Central San Joaquin Valley, Project 0301

By

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Study Report Approvals

(original signed by L. Ross) — *March 11, 2013*
Lisa Ross, Acting Chief, Worker Health and Safety Branch — Date

(original signed by B. Hernandez) — *March 4, 2013*
Bernardo Hernandez, Research Scientist I — Date

(original signed by S. Yanga) — *March 4, 2013*
Saturnino "Nino" Yanga, Research Scientist III — Date

(original signed by S. Fredrickson) — *March 5, 2013*
Scott Fredrickson, Staff Chemist — Date

Quality Assurance Audits

A. Field Activities

Date of Audit	*Phase*	*Notification Dates*	
		Study Director	*Management*
July 1, 2003	Ethical protocol approval*	July 1, 2003	July 1, 2003
The protocol was renewed the following three years and expired in June 2006			
July 17, 2003	Technical protocol approval	July 17, 2003	July 17, 2003
August 13,2003	In process field monitoring	August 13,2003	August 13,2003
June 30, 2006	In process field monitoring	June 30,2006	June 30,2006
Not Completed	QA Feld Monitoring	N/A	N/A
Not Completed	QA Raw Data Inspection	N/A	N/A
December 13, 2011	Final Report	December 13, 2011	April 3, 2012

* *The protocol detailing the study subject consent process was approved by the Independent Investigational Review Board, Investigational Ethics Committee on Human Research (IRB/IEC), Planation, FL. 33313*

B. Laboratory Activities

Date of Audit	*Phase*	*Notification Dates*	
		Study Director	*Management*
July 7, 2003	Method Verification - Chlorpyrifos	July 7, 2003	July 7, 2003
August 13, 2003	Sample Receipt - Chlorpyrifos	August 13,2003	August 13,2003
August 14, 2003	Sample Extraction/Analysis	August 14,2003	August 14,2003
July 15, 2005	Method Verification - Imidacloprid	July 15, 2005	July 15, 2005
July 14, 2007	Method Verification - Oxamyl	July 14,2007	July 14,2007
June 30, 2006	Sample Receipt - Oxamyl	June 30, 2006	June 30, 2006
June 30, 2006	Sample Extraction/Analysis	June 30, 2006	June 30, 2006
October 30, 2007	Completion Sample Analysis	October 30, 2007	October 30, 2007

Study Compliance Statement

Based upon all information supplied to me, including that provided by the California Department of Food and Agriculture, Center for Analytical Chemistry, (Laboratory Statements of Compliance), I hereby confirm that all aspects of this study, Project 0301, were conducted in compliance with the US Environmental Protection Agency, Good Laboratory Practice standards (GLP, 40 CFR 160), with the following exceptions:

- The test substance characterization was not documented before its use in the study as required in 40 CFR 160.105(a);
- The testing facility did not have procedures established for handling reference substances as required in 40 CFR 160.107:
- Quality assurance field monitoring and raw data audit was not conducted as stated in Standard Operating Procedure WHS-AD03

(original signed by B. Hernandez) *March 4, 2013*

Bernardo Hernandez, Study Director Date

Executive Summary

This study focused on potential exposure of workers to pesticide residues when irrigating crops. Based on chemical use patterns and crop height, cotton became the crop of choice. Scientists chose to monitor the pesticide oxamyl because its frequent use on cotton and chemical properties make it easy to detect. They monitored 18 irrigators as they performed their normal work tasks associated with either furrow or sprinkler irrigation. For each monitored irrigator, scientists recorded work tasks and the amount of time spent in contact with the foliage. They measured potential dermal exposure using sample dosimeters (hospital scrub pants, socks, long sleeve t-shirt, face and neck wipes, and hand-washes).

Scientists monitored twelve furrow irrigators and six sprinkler irrigators who moved and connected sprinkler pipes by hand. Furrow irrigators' experience and knowledge ranged from 15 days to 15 years. They worked an average of 7.5 hours per workday with only 2.1 hours involving foliar contact. Work tasks involving foliar contact included walking through the cotton field to check the water flow progress, removing obstructions in the rows and/or repairing breaks in the furrow bed. Non-foliar contact work tasks included tending ditches and moving tarps, siphon tubes, and/or gated main pipes. The sprinkler irrigators' work experience ranged from 2 to 5 weeks. They averaged 4.5 hours of their workday performing irrigator activities in the treated field, including 4.1 hours of foliar contact breaking pipe down from an irrigated section and resetting it in a dry section of the cotton field. Non-foliar contact work tasks included connecting the pipe to a valve outside of the field for the next sprinkler set. In a previous observation study, scientists documented that experienced furrow irrigators averaged only 1.4 hours per workday in contact with foliage and sprinkler movers averaged 2.7 hours per workday in contact with foliage. In this exposure study, furrow irrigators averaged 2.1 hours and sprinkler movers averaged 4.1 hours in contact with treated foliage.

Total body exposure per workday averaged about 10 milligrams (mg) for furrow irrigators and 4 mg for sprinkler irrigators. For furrow irrigators, 82.2% of the dermal exposure was on the lower body (below the waist) and 16.3% on the torso and arms. Their hand exposure was 1.42% and head exposure less than 1%. For sprinkler irrigators, 67.4% of the dermal exposure was on the lower body and 32.4% on the torso and arm exposure. Their hand and head exposure was less than 1%. The differences in the total body exposure and the amount of residue detected on the different areas of the body may be explained by the significant differences in the irrigation methods and how the water may wash off the residue from both the cotton plants and workers. In furrow irrigation, the water generally does not contact the cotton foliage. This does not dilute or wash off the pesticide residue from the leaves. In contrast, sprinkler irrigation applies water over the top of the plant, which dilutes or washes the pesticide residues off the leaves. When furrow irrigators enter the field they do not contact wet foliage. Whereas irrigators entering sprinkler irrigated fields have constant contact with wet foliage.

This study shows the relatively short foliar contact periods for furrow and sprinkler irrigators. In comparison, previous studies show many other field workers such as workers thinning or harvesting crops have continual contact with foliage for 7.0 to 9.5 hours per day in crops such as lemons, peaches, and greenhouse ornamentals. Department of Pesticide Regulation's Worker Health and Safety Branch toxicologists will use the information to evaluate the exposure potential of cotton irrigators. Scientists may use the information to guide future studies.

Introduction

The Department of Pesticide Regulation (DPR) provides regulatory oversight of pesticide use. DPR's mission is to protect human health and the environment from unreasonable risk resulting from the use of pesticides. DPR evaluates the effectiveness of the pesticide safety regulatory program through the Pesticide Illness Surveillance Program (PISP). The PISP database provides the means to identify circumstances of pesticide exposures that result in illnesses. From 1996 through 2004, the PISP database records 113 pesticide illness and injury cases involving irrigators (Mehler, 2006; Orr, 2002), Based on the number of cases involving irrigators, DPR's Worker Health and Safety Branch (WHS) scientists conducted an observation study of irrigator activities, specifically recording the amount of time irrigators spend contacting treated foliage (Hernandez, 2006). Based on their observations, the scientists conducted a dermal exposure study to characterize the extent that irrigator's extra clothing, wet working conditions, and time spent in foliar contact affect their exposure. The scientists also recorded the crop height in the field where each observed irrigator worked. The crop heights revealed that cotton plants would provide a worst case scenario for irrigator exposure to pesticide residue.

The scientists researched pesticide use on cotton and selected the pesticide oxamyl (DuPont™ Vydate® C-LV, Environmental Protection Agency (EPA) Registration Number 352-532) for this study because of the chemical properties and frequent use on cotton makes it easy to detect. Although the Vydate® C-LV label allows applications via ground, air, and chemigation, scientists only monitored irrigators after ground and aerial applications.

In 2006, WHS scientists conducted the study to measure oxamyl residue on cotton irrigators resulting from furrow irrigation and hand-moving of sprinkler irrigation pipes. They documented typical irrigator tasks during normal irrigation work practices, the amount of time spent on each irrigation task as well as the time spent in the field (i.e. enter fields, foliar contact, pipe contact) for a maximum of one workday. Scientists provided the irrigators with scrub pants, socks, and a long sleeve t-shirt to wear for the monitored workday. They collected the clothing as well as face and neck wipes, and hand-washes from the irrigators to measure the amount of dermal exposure. They did not interfere with the irrigator's work tasks. The scientists will use the information from this study to evaluate the exposure potential of irrigators and to guide future studies.

Background

Cotton is grown in regions where temperatures range from warm to hot. It provides both animal feed and clothing fiber. Crop reports show cotton grown in three California regions (southern desert valleys, San Joaquin Valley and Sacramento Valley). This study was conducted in the San Joaquin Valley where planting occurs in March and April with beds spaced 30 to 40 inches, measured center to center. Cotton is generally furrow irrigated, although other irrigation methods such as border-strip, sprinkler, and drip tape irrigation are used. Irrigation ceases in late August to allow the plants to dry out before mechanical harvesting. Cotton requires about 180 - 200 days to reach full maturity.

Although not a common practice, irrigators can enter a treated field during a restricted entry interval (REI) provided the employer assures they meet the requirements listed in 3CCR Section 6770(d). Growers generally schedule crop irrigation to avoid conflict with pesticide spray schedules.

Material & Methods

Project Duration

This study was initiated on July 17, 2003. The study began on August 1, 2003 and concluded on July 5, 2006.

Contacting Growers and Prospective Participant

Scientists approached cotton growers in California's San Joaquin Valley to obtain permission to conduct the irrigator pesticide exposure study. Scientists discussed irrigation practices, irrigator observations, and irrigator work tasks with the growers. Prospective study participants were cotton irrigators who either worked directly for the grower or worked for a labor contractor hired by the grower to perform irrigation work. Upon securing grower permission, the scientists approached the irrigators to present the focus of the study, explain expectations and answer any questions or concerns. Contact took place on the grower's property, at either the farm shop area or the field site. The irrigators were then asked for their voluntary consent to participate.

Selection of the Test Substance

Initially, scientists chose to monitor irrigators for chlorpyrifos exposure based on 2001 Pesticide Use Reporting (PUR) data that showed 1,193,861 pounds (lbs.) of chlorpyrifos applied to cotton (California Department of Pesticide Regulation, 2012). In the summer of 2003, scientists were only able to monitor two irrigators because the five cooperating growers planned no additional irrigation of their cotton fields.

During the subsequent analysis of the samples, the Principal Analytical Investigator (PAI) discovered a problem with the field spikes. As a result, the scientists conducted a spiking and storage study the following summer to evaluate the effects of sunlight and temperature on clothing samples, handwash solutions, and face/neck wipes weathered under conditions similar to those expected in the San Joaquin Valley cotton fields in late summer. The results from this study indicated chlorpyrifos was not stable under the study conditions and yielded less than acceptable results. The study suggested chlorpyrifos was not a good choice for an exposure monitoring study conducted in high temperature (Hernandez, 2005).

WHS scientists researched an alternative pesticide to monitor. To streamline the selection process, the study director surveyed five San Joaquin Valley cotton growers who participated in the irrigator observation study (Hernandez, 2006). He asked them to provide information on their expected spray schedule (Table 1).

Table 1. Expected Spray Schedule Timeline for Five Contacted Growers

Pesticide	Number of Growers Using the Pesticide				
	April/ May	June/ Early July	Late July/ Early August	Late August/ September	October
Abamectin	4	1	4	2	0
Chlorpyrifos	0	0	0	2	5
Imidacloprid	3	4	2	0	0
Oxamyl	1	4	5	5	0
Thiamethoxam	4	3	2	2	0

Although the scientists initially considered imidacloprid, its use occurs early in the growing season when the plants are small and significant foliar contact is not a problem. They instead chose oxamyl because the applications occur frequently at the time in the growing season when the irrigators would have significant contact with treated foliage. The study director consulted with the PAI who foresaw no storage and stability issues with oxamyl under field conditions.

Irrigators

The study population consisted of workers employed to irrigate cotton fields by either furrow or hand-moved sprinkler systems. Furrow irrigators work at the perimeter of the field, whereas sprinkler irrigators are in the field moving pipes from recently irrigated areas to dry areas. Scientists observed and documented the amount of time an irrigator spent doing each irrigation task (i.e. enter field, foliar contact, pipe contact etc.) for a maximum of one irrigation workday. A workday or work shift ended when an irrigator ceased performing irrigation tasks in the treated field for that day, or when the irrigator's participation ended for any reason.

Scientists monitored the irrigators for a minimum of 3.8 hours and a maximum of 10.5 hours, corresponding to a full workday for each irrigator. The scientists did not interfere with the irrigator's work tasks and provided all the necessary clothing matrices, face/neck wipes and wash solution to each participating irrigator. Each irrigator was identified by a unique worker identification (ID) number. They recorded the following information for each irrigator:

1. Work apparel,
2. Personal protective equipment (PPE) worn,
3. Each work task performed and the duration of each task,
4. Entry into treated fields prior to the REI expiration,
5. Foliar contact.

The scientists recorded one furrow irrigator entering an oxamyl treated cotton field prior the expiration of the REI. Due to insect pressure, the pest control advisor recommended the oxamyl application which occurred just prior to the scheduled irrigation of the field. This worker wore the required personal protective equipment.

Scientists took photographs to document crop maturity, cotton crop type (Pima or Acala) and any irrigator tasks showing potential pesticide exposure.

Crop Criteria and Field Information

Scientists obtained information about the ranch, irrigators and crop prior to monitoring the irrigators. They measured cotton crop height to ensure the crop met the minimum criteria of 24 inches. For the selected cotton fields, plant heights ranged from 54 to 70 inches with full leaf canopy. Scientists observed oxamyl (Vydate® C-LV) and other insecticides being loaded into the application equipment tanks, took tank-mix samples to confirm the presence of oxamyl in the tank, and observed the aerial application to the selected fields.

Irrigator Sample Matrices

1. Hand-wash samples (500 ml. of water with 0.002% sodium dioctyl sulfosuccinate).
2. White cloth face/neck wipes (sectioned from 100% flat fold cotton diapers; no dye color).
3. Long-sleeved white t-shirt (100% cotton; no dye color).
4. Knee-length white tube socks (80/20 acrylic/nylon blend; no dye color).
5. Hospital scrub pants (50/50 polyester/cotton blend with drawstring).

Irrigator Sample Collection Times

1. Hand-wash samples: at a minimum, at the end of the workday or work shift. Additional samples were collected prior to the irrigator's meal, smoking and/or water breaks, use of the bathroom facility, and anytime the irrigator desired to wash his hands.
2. Face/neck wipes: at a minimum, at the end of the workday or work shift. Additional samples were collected prior to the irrigator's meal breaks and any time the irrigator desired to use the wipes.
3. Clothing dosimeter samples: at the end of each workday or work shift.

Irrigator Sample Collection Procedures

Scientists collected samples at the end of the work day using a prescribed standard procedure to prevent cross-contamination. Samples were collected in the following order:

1. Hand-wash samples: Vigorous washing (rubbing) of the hands for approximately one minute, using approximately 500 ml of water with 0.002% sodium dioctyl sulfosuccinate, contained in a one-gallon track-seal bag. A scientist decanted the hand-wash sample into a pre-labeled 1-liter Nalgene bottle (with lid) to ensure no leakage during transit prior to analysis.
2. Face/neck wipes: The irrigator used a series of two wipes in succession to thoroughly wipe his face and neck; he placed each wipe into a pre-labeled one pint or larger wide-mouth canning jar.
3. Clothing
   For all clothing samples, two track-seal bags were used to prevent contamination, a pre-labeled sample bag placed inside the second bag. A scientist sealed each bag after the worker placed the clothing into the bag.
   a. T-shirt: The irrigator removed his t-shirt and placed it into a pre-labeled one-gallon track-seal bag.
   b. Socks: The irrigator donned a pair of vinyl, latex or nitrile gloves to remove his muddy tennis shoes or rubber boots. Once he removed the footwear, he removed the gloves and discarded them in a trash bag. He then removed the socks and placed them in a pre-labeled one-gallon track-seal bag.

c. Hospital scrub pants: The irrigator removed the scrub pants and placed them into a pre-labeled two-gallon track-seal bag.

Dislodgeable Foliar Residue (DFR)

Once the irrigators entered the cotton field and began working, scientists entered the same field and collected three DFR samples. The scientists used the DFR sample results to confirm the presence of oxamyl residue in the cotton fields. They also used the DFR results to calculate potential exposure for cotton scouts who typically enter treated fields to check the efficacy of the pesticide application. The scientists used a leaf cutting tool equipped with a 5.00 square centimeter (cm^2) cutting die cylinder punch (Precision Leaf Sampler) and fitted with a 4-ounce glass jar to collect 40 leaf discs per sample.

Sample Storage

While in the field, the scientists immediately froze the clothing, face/neck wipes, hand-wash, and tank-mix samples on dry ice. The DFR samples were immediately stored on ice and shipped overnight to the California Department of Food and Agriculture (CDFA) Center for Analytical Chemistry.

Laboratory

The CDFA Center for Analytical Chemistry performed all the laboratory analysis for the study pursuant to good laboratory practice standards. The analytical suitability of the residue matrix (i.e. cloth, leaves, etc.) determined which analytical instrument was used to evaluate the residues. To prevent potential loss of oxamyl, the chemist immediately extracted the DFR samples upon arrival at the laboratory, but analyzed the frozen samples (clothing, face/neck wipes, hand-wash, and tank-mix) at a later date upon thawing.

The chemist extracted oxamyl from the cloth matrices (pants, socks, and t-shirts) by washing them with methanol (MeOH) on a mechanical jar roller at 180 revolutions per minute for 30 minutes. The chemist used the following amounts of MeOH for each washing: 800 milliliters (mL) (pants), 650 mL (socks, orlon/nylon blend), and 1200 mL (t-shirts). The chemist concentrated, vortexed, and centrifuged the extract to settle any precipitation, then analyzed the clean extract. The LOQ ranged from 6.25 to 12.5 µg/sample.

The chemist extracted oxamyl from the face/neck wipes with 200 mL of MeOH by swirling them on a rotary table for 30 minutes. He then concentrated the extracts 10:1 on a rotary evaporator, brought them to a known volume, centrifuged, and analyzed them. The chemistry laboratory reported the LOQ as 0.56 µg/sample.

The chemist extracted each worker's combined hand-wash samples three times with methylene chloride, decanting the solution after each extraction. He then reduced the extract to near dryness with a rotary evaporator and brought the extract to a final volume of 5 mL with MeOH before he analyzed it. The chemistry laboratory reported the LOQ as 0.57 µg/sample.

To facilitate the removal of dislodgeable foliar residue from the leaf discs, each DFR sample went through three sequential washings. Each washing consisted of a 30-minute rotation on a mechanical shaker with 50 mL of a 0.02% dioctyl sodium sulfosuccinate solution added to the sample. The solution was decanted between washings. The chemist extracted the combined

washings with 50 mL methylene chloride, dried the extract in a rotary evaporator, and brought it to the final volume with ethyl acetate (EtAc). A comparison of a diluted water/dioctyl sodium sulfosuccinate extract to standard solutions determined the recovery rate. The chemistry laboratory reported the results as micrograms (µg) pesticide/sample. They reported the limit of quantitation (LOQ) as 0.13 µg/sample.

The chemistry laboratory can provide the analytical recoveries and equipment conditions upon request.

Data Treatment and Analysis

The scientists entered the raw data into a Microsoft Access® 2003 database. They analyzed the data separately for hand-moved sprinkler and furrow irrigation systems and used Microsoft Excel® 2003 to generate graphs.

For each worker, scientists summed the time spent on any one task (rounded to the nearest minute). For example, a furrow irrigator performed shovel work from 6:15 a.m. – 6:20 a.m. (5 minutes), 6:46 a.m. – 7:00 a.m. (14 minutes) and from 9:25 a.m. – 11:25 a.m. (120 minutes) for a total of 139 minutes.

Scientists grouped irrigator exposures based on the following:

1. Type of irrigation practiced at the study site (furrow or sprinkler),
2. Time the irrigator made contact with the foliage/irrigation pipes, and
3. The irrigator's work tasks in furrow or sprinkler irrigation during the exposure monitoring study.

Table 2 lists the irrigation tasks associated with foliar contact while Table 3 lists the irrigation tasks not associated with foliar contact.

Table 2
Irrigator Tasks Associated with Foliar Contact

Location	Irrigation Type	
	Furrow Irrigation	Sprinkler Irrigation
In field	• Field check (location of the water in the row) • Shovel work (clearing obstructions & directing flow)	• Moving irrigation pipe set: 1) within the field; or 2) removal from the field • Connecting pipe sprinkler valve to main[a] risers for next sprinkler move

[a] Main water supply line (Mains) that feed gated pipe or sprinkler pipe. Mains can either be located on the field edge or the middle of the field.

Table 3
Irrigator Tasks not Associated with Foliar Contact

Location	Irrigation Type	
	Furrow Irrigation	Sprinkler Irrigation
Field edge	• Handling siphon tubes, tarps and gated pipe[1] • Shovel work (clearing obstructions & directing flow)	• Connecting pipe sprinkler valve to main[a] risers for next sprinkler move
Not in field	• Breaks (morning, lunch, afternoon) • Checking on finished rows • Gathering siphon pipes for next irrigation set	• None

[a.] Main water supply line (Mains) that feed gated pipe or sprinkler pipe. Mains can either be located on the field edge or the middle of the field.

The scientists entered the DFR sample results (μg/sample) into a Microsoft Access® database. The sample results were divided by the sample surface area (400 cm^2) to provide the basic unit of DFR analysis (μg pesticide/cm^2 leaf area). A Microsoft Excel® query was used to generate summary data, including descriptive statistics.

Results

Using the recorded information on each irrigator's tasks (i.e. shovel work, tarp movement, etc.), the scientists calculated the amount of time each irrigator had contact with the treated foliage, converting minutes into hours for ease of data interpretation. Tables 4 and 5 show the time each furrow and sprinkler irrigator spent with and without foliar contact and the total time worked in the treated field. The average time for foliar contact and no foliar contact was also calculated. The 12 furrow irrigator's workday ranged from 5.3 to 10.5 hours (average = 7.5 hours). The six sprinkler irrigator's workday ranged from 3.8 to 5.1 hours (average = 4.5 hours). Although the protocol required monitoring of the cotton irrigators for a minimum of 4 hours in the treated field, one sprinkler irrigator completed his workday in less time (Worker FP104, 3.8 hours). This demonstrates the variation in task completion time for sprinkler irrigators. Since hand-move sprinkler irrigators work in groups of three or four, this irrigator completed his work in the field in a shorter amount of time with the assistance of his coworkers. This limited his foliar contact and decreased his potential pesticide residue exposure.

Table 4
Length of Workday with and without Foliar Contact, Furrow Irrigators (n=12)

Worker Identification	Foliar Contact		No Foliar Contact		Total Time	
	Minutes	Hours	Minutes	Hours	Minutes	Hours
FP0201	165	2.8	195	3.3	360	6.0
FP0202	215	3.6	270	4.5	485	8.1
FP0301	208	3.5	272	4.5	480	8.0
FP0302	212	3.5	229	3.8	441	7.4
WF0101	185	3.1	140	2.3	325	5.4
WF0201	195	3.3	435	7.3	630	10.5
WF0202	165	2.8	465	7.8	630	10.5
WF0203	80	1.3	445	7.4	525	8.8
WF0301	0	0.0	430	7.2	430	7.2
WF0302	0	0.0	390	6.5	390	6.5
WF0401	35	0.6	365	6.1	400	6.7
WF0402	47	0.8	268	4.5	315	5.3
Total	1507	25.1	3904	65.1	5411	90.2
Average	126	2.1	325	5.4	451	7.5

Table 5
Length of Workday with and without Foliar Contact, Sprinkler Irrigators (n=6)

Worker Identification	Foliar Contact		No Foliar Contact		Total Time	
	Minutes	Hours	Minutes	Hours	Minutes	Hours
FP0101	281	4.7	21	0.4	302	5.0
FP0102	266	4.4	37	0.6	303	5.1
FP0103	243	4.1	40	0.7	283	4.7
FP0104	209	3.5	16	0.3	225	3.8
FP0105	251	4.2	7	0.1	258	4.3
FP0106	242	4.0	18	0.3	260	4.3
Total	1492	24.9	139	2.3	1631	27.2
Average	249	4.1	23	0.4	272	4.5

Furrow irrigators performed work that required foliar contact an average of 2.1 hours (28 % of average work time). They performed work tasks that involved no-foliar contact an average of 5.4 hours (72 % of average work time) (Figure 1). Sprinkler irrigators averaged 4.1 hours (91% of average work time) in contact with foliage while performing work tasks involving water movement. They averaged 0.4 hours (9% of average work time) performing irrigation tasks without foliar contact (Figure 2).

Figure 1
Foliar vs. Non-Foliar Contact for Twelve Furrow Irrigators

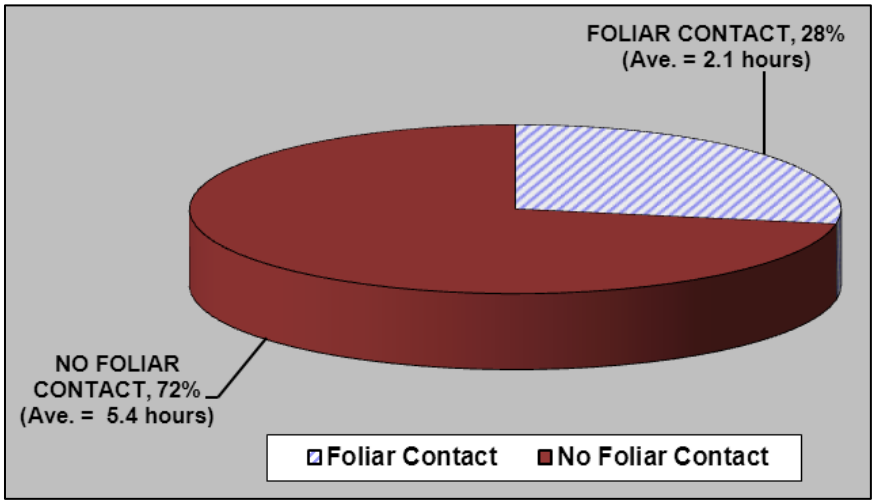
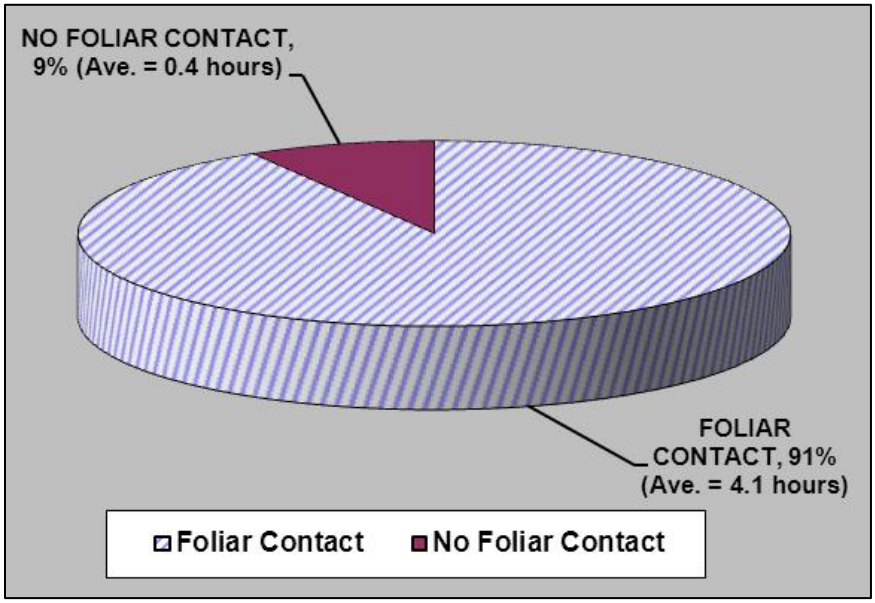


Figure 2
Foliar vs. Non-Foliar Contact for Six Sprinkler Irrigators



For each field where irrigators worked, Scientists collected three DFR samples to confirm an application of oxamyl occurred. Table 6 shows the calculated averages for DFR residue in these fields.

Table 6
Average Dislodgeable Foliar Residue (DFR) for Cotton Fields where Furrow and Sprinkler Irrigators Worked[a]

	DFR (µg/cm^2)[b]	
	Furrow	Sprinkler
Daily mean/field	0.357	0.362
	0.383	0.144
	0.237	0.111
	0.144	0.001
	ND[c]	
	0.006	
	0.094	
	0.310	
	0.273	
	0.401	
	0.151	
Average	0.214	0.154

a. Three DFRs represented two irrigators each; one in furrow irrigation and two in sprinkler irrigation,
b. micrograms per square centimeter,
c. 0.000 was used because ½ of the LOQ is indistinguishable from zero at the relevant level of precision (0.001 micrograms.cm-squared).

Table 7 and Figure 3 show the mean oxamyl recovery from the various matrices collected from the furrow irrigators. Assuming the mean recovery rates are representative of exposure, the majority of oxamyl exposure (82.2%) occurred on the lower extremities – legs (scrub pants, 81.4%) and feet (socks, 0.815%). The remaining exposure (17.8%) occurred on the upper body – torso and arms (t-shirt, 16.3%), face and neck (0.054%), and hands (1.42%).

Table 7
Amount of Oxamyl Recovered on Sample Matrices from Furrow Irrigators

Matrix	Mean (µg/sample)[a]	Percent of Total Exposure
Pants	8143	81.4
Socks	82	0.815
T-Shirt	1627	16.3
Wipes	5	0.054
Wash	142	1.42

a. micrograms per sample

Figure 3
Percent of Oxamyl Recovered on Sample Matrices from Furrow Irrigators

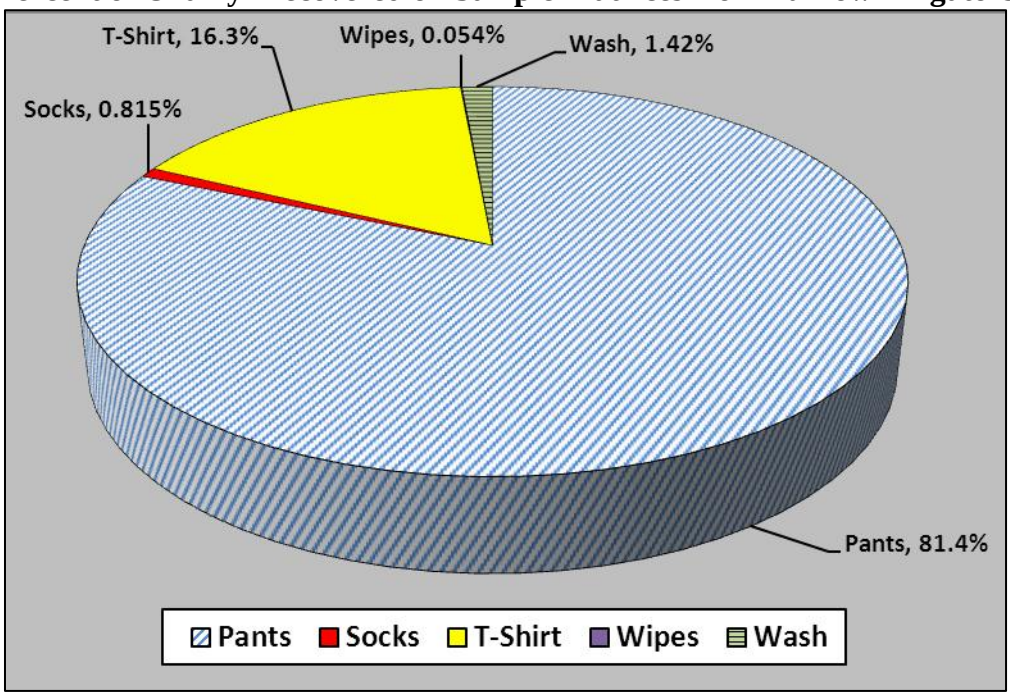


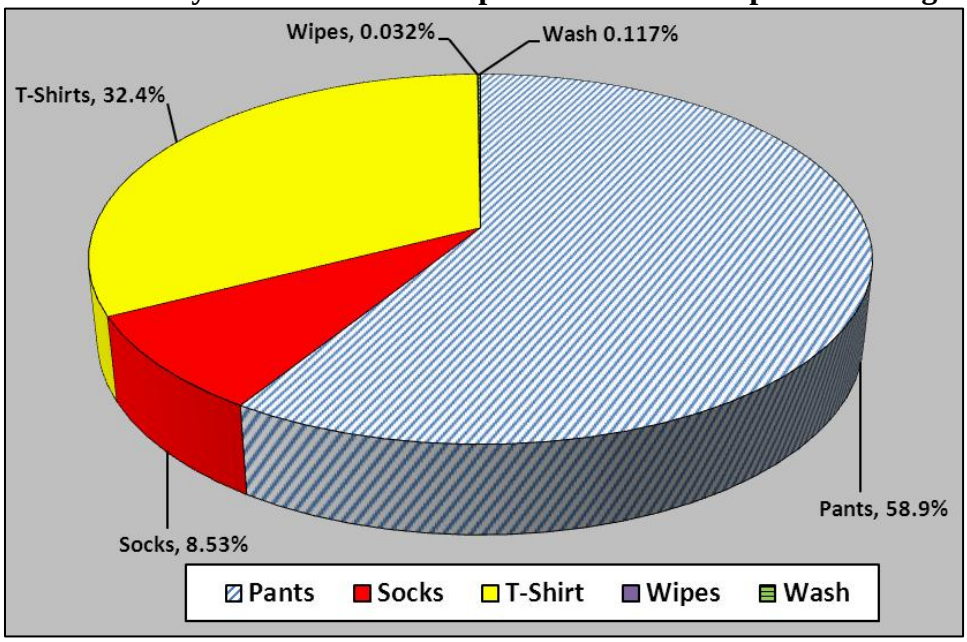
Table 8 and Figure 4 show the mean oxamyl recovery from the various matrices collected from the sprinkler irrigators. Assuming the mean recovery rates are representative of exposure, the majority of oxamyl exposure (67.4%) for sprinkler irrigators occurs on the lower extremities – legs (scrub pants, 58.9%) and feet (socks, 8.53%). The remaining exposure (32.5%) occurred on the upper body – torso and arms (t-shirt, 32.4%), face and neck (0.032%), and hands (0.117%).

Table 8
Amount of Oxamyl Recovered on Sample Matrices from Sprinkler Irrigators

Matrix	Mean (µg/sample)[a]	Percent of Total Exposure
Pants	2449	58.9
Socks	355	8.53
T-Shirt	1346	32.4
Wipes	1	0.032
Wash	5	0.117

[a.] micrograms per sample

Figure 4
Percent of Oxamyl Recovered on Sample Matrices from Sprinkler Irrigators



Discussion

Average Total Exposure Estimated for Workers in Study

The clothing matrices (pants, socks, and long-sleeved t-shirt) covered the legs, feet, arms and torso and represent exposure to these body parts. The hand-washes estimate the exposure to the hands while the face/neck wipes estimate the exposure to the head. However, face/neck wipes only represent half the head exposure (Thongsinthusak, 1998; U.S. EPA, 1997). To estimate the total exposure of an irrigator, the scientists doubled the mean exposure for the face/neck wipes and added it to the mean exposures of the other matrices (Figure 5).

Figure 5
Formula for Estimating Total Exposure in Irrigators

$$\text{Total Exposure} = \text{Mean Exposure}_{\text{pants}} + \text{Mean Exposure}_{\text{socks}} + \text{Mean Exposure}_{\text{t-shirt}} + [2\,(\text{Mean Exposure}_{\text{face/neck wipes}})] + \text{Mean Exposure}_{\text{hand washes}}$$

The scientists estimated the total exposure for furrow irrigators at 10,004 µg/day and for sprinkler irrigators at 4,157 µg/day.

Assuming a default body weight (BW) of 70 kg for field workers (Thongsinthusak et al., 1993), the scientists calculated the potential hourly exposure for both sprinkler and furrow irrigators by dividing the total exposure by the product of the number of hours worked and the default body weight.

The furrow irrigators worked an average of 7.5 hours (foliar contact and no foliar contact).

$$\text{Potential Hourly Exposure}_{\text{ Furrow Irrigators}} = \frac{10{,}004\ \mu g}{(7.5\ hr) \times (70\ kg)} = 19\ \mu g/kg/hr$$

The sprinkler irrigators worked an average of 4.5 hours (foliar contact and no foliar contact).

$$\text{Potential Hourly Exposure}_{\text{ Furrow Irrigators}} = \frac{4{,}157\ \mu g}{(4.5\ hr) \times (70\ kg)} = 13\ \mu g/kg/hr$$

Comparison of Average Exposure Calculated for Cotton Scouts

Greater contact with treated foliage along with higher pesticide foliar residues results in increased transfer of the pesticide to the worker's skin and clothing. Zweig (1984, 1985) expressed this relationship in the equation below.

$$\text{Potential exposure } (\mu g/kg/hr) = \frac{\text{DFR } (\mu g/cm^2) \times \text{TC } (cm^2/hr)}{\text{Body Weight (Kg)}}$$

The transfer coefficient (TC) is an estimate derived from studies that measured both DFR and dermal exposure. It estimates the rate of contact between the worker and the treated surface. The major route of pesticide exposure for field workers is through the dermal route; contact with treated surfaces, especially foliage, results in the transfer of pesticide residues to the skin. The TC is calculated by dividing the measured dermal exposure by the DFR from a treated crop.

$$\text{TC } (cm^2/hr) = \frac{\text{Dermal exposure } (\mu g/hr)}{\text{DFR } (\mu g/cm^2)}$$

Since the TC depends on the force of contact of the worker with the contaminated surface, it is task and surface-specific. However, TCs are only available for a limited number of tasks and crops. Scientists found no exposure data or TCs available for cotton irrigators, but found estimates available for cotton scouts. Cotton irrigators cut across the beds, whereas the cotton scouts walk in the furrows between the beds. The irrigators contact the foliage on the front and sides of their body, while cotton scouts mainly have contact on the sides of their bodies.

Dong (1990) derived a TC for cotton scouts from a series of studies involving several organophosphates applied to cotton (Ware *et al.*, 1973, 1974, 1975). Dong (1990) calculated the geometric mean potential transfer factors for bare hands (950 cm^2/hr), the upper body (1,020 cm^2/hr), and the lower body (9,640 cm^2/hr). He also calculated the potential dermal transfer factor for the whole body of cotton scouts (11,610 cm^2/hr) by summing the individual geometric mean transfer factors.

For fields where furrow and sprinkler irrigators worked, the average DFR residues were 0.214 µg/cm^2 and 0.154 µg/cm^2 respectively (Table 6). Using the TC of 11,610 cm^2/hr calculated by Dong (1990) for cotton scouts, scientists calculated the potential exposure for scouts in oxamyl treated fields to be 35.5 µg/kg/hr (furrow irrigated fields) and 25.5 µg/kg/hr (sprinkler irrigated fields). For irrigators, the potential exposures of 19 µg/kg/hr (furrow

irrigators) and 13 µg/kg/hr (sprinkler irrigators) averaged slightly above 50% of the averages estimated for cotton scouts.

Furrow irrigated fields:

$$\text{Potential Hourly Exposure}_{\text{cotton scouts}}: \frac{(0.214\ \mu g/cm^2)\ (11{,}610\ cm^2/hr)}{70\ kg} = 35.5\ \mu g/kg/hr$$

Sprinkler irrigated fields:

$$\text{Potential Hourly Exposure}_{\text{cotton scouts}}: \frac{(0.154\ \mu g/cm^2)\ (11{,}610\ cm^2/hr)}{70\ kg} = 25.5\ \mu g/kg/hr$$

Dislodgeable foliar residues sampled from sprinkler irrigated cotton fields averaged 0.060 µg/cm^2 lower than those taken from furrow irrigated fields. Sprinkler irrigation applies water to the plant leaves, which dilutes or washes the pesticide residues off the leaves. The sprinkler irrigators enter the field after completion of the irrigation. In contrast, the water in furrow irrigated cotton fields never exceeds six inches and does not contact the foliage, thus the water does not dilute or wash off the foliar residue.

A field worker's pesticide residue exposure depends on the amount of available foliar surface area, amount of residue on the foliar surface that is available for transfer to the skin and clothing, and the amount of time in contact with treated foliage. Irrigators work in field crops of varying height. Workers irrigating low growing crops (cantaloupes, lettuce, and sugar beets) contact less foliage (treated or otherwise) than workers irrigating taller growing crops (cotton, broccoli, and corn).

Furrow irrigators generally work alone and spend the majority of their time controlling water flow from the periphery of field, (preparing for the next water change, regulating water flow, etc. (Photos 1, 2, 3)). They typically wear rubber boots (knee or thigh high), rain pants, long sleeved shirts and/or a jacket (Photos 4, 5). They generally stay dry except for their hands, which are briefly immersed in water when setting each siphon pipe (Photo 6).

Sprinkler irrigation pipe movers work in teams of three or four workers thus limiting the duration of contact between treated foliage and the worker (Photo 7). They work in foliage that is continuously wet (Photo 8) and often wear various work attire such as pants, long sleeve shirts, jackets, and sweatshirts (Photos 9, 10). A sprinkler irrigator may get wet from his feet up to the mid-chest, depending on his own height, the height of the crop under irrigation and the type of work clothing worn. Hernandez *et al* (2006) observed that workers in the Salinas Valley sometimes wear rain pants and rubber gloves because of the cooler temperatures (Photo 11).

Furrow irrigators who participated in this study wore rubber boots which limited transfer of oxamyl residue to the sock dosimeters. In contrast, sprinkler irrigators who participated in this study wore tennis shoes, some with the toe cut out and no socks (Photo 9).

Sprinkler irrigators constantly have their hands wet as they work. Oxamyl recovery from the handwash samples show much lower exposure levels for sprinkler irrigators than furrow irrigators, most likely because the irrigation water washes the residue off of the sprinkler irrigators' hands.

Work experience may also help explain the difference in exposure between furrow and sprinkler irrigators. The concept of experience generally refers to know-how or knowledge gained through involvement or familiarity with an action or event. In this study, the furrow irrigator's knowledge and work experience ranged from 15 days to 15 years; whereas the work experience of sprinkler irrigators ranged from two to five weeks. An experienced irrigator limits his contact duration with treated surfaces, especially foliage. Furrow irrigators averaged 2.1 hours and sprinkler irrigators 4.1 hours in contact with treated foliage per workday. Hernandez *et al.* (2006) documented the amount of time per workday irrigators have contact with foliage – experienced furrow irrigators averaged 1.4 hours/workday and sprinkler irrigators averaged 2.7 hours/workday. Other field workers often have continual contact with foliage, from 7.0 to 9.5 hours/workday, performing cultural tasks such as picking fruit in lemon and peach orchards (Maddy *et al.*, 1981a, Maddy *et al.*, 1981b, Schneider *et al.*, 1992) or picking and disbudding flowers in greenhouses (Schneider *et al*., 2002).

Conclusion

This study demonstrates the relatively short foliar contact periods of furrow and sprinkler irrigators compared to field workers who are in constant contact with foliage during most of the workday (7.0 to 9.5 hours) while thinning or harvesting crops. While the irrigators may be potentially exposed to pesticide residue on the cotton plants, their exposure is mitigated by the amount of time in contact with foliage. Furrow irrigators worked an average of 7.5 hours per workday, but spent only 28% of their time (averaged 2.1 hours) in contact with the treated foliage. Sprinkler irrigators averaged slightly more than four hours within the treated field, but spent quite a bit of that time in recently irrigated areas where the irrigation water can wash off some of the available dislodgeable residue.

Photo 1: Furrow Irrigator Carrying Siphon Pipes Alone

Photo 2: Furrow Irrigator Working Alone with Irrigation Socks

Photo 3: Furrow Irrigator Conducting a Field Check Alone

Photos 4 and 5: Apparel Worn by a Furrow Irrigator

Photo 6: Irrigator Working with Siphon Tubes

Source:
http://www.livinghistoryfarm.org/farminginthe30s/water_20.html

Photo 7: Sprinkler Irrigators Working in Groups

Photo 8: Sprinkler Irrigation

Photos 9, 10, and 11: Sprinkler Irrigators Showing Varying Degrees of Wetness on Apparel

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