Health & Safety Report

Worker Health and Safety Branch

HS-1700

EXPOSURE OF HERBICIDE HANDLERS IN THE CALTRANS VEGETATION CONTROL PROGRAM

- 1993-1994 -

April 27, 1995
Amended June 1, 1995
Amended June 2, 2004

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Exposure Of Herbicide Handlers In The Caltrans Vegetation Control Program

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Sponsor: California Department of Transportation
Division of Maintenance
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Sacramento, California 95814

Testing Facility: California Environmental Protection Agency[1]
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Worker Health and Safety Branch
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Study Director: Susan Edmiston, Senior Environmental Research Scientist

Analytical Laboratories: California Department of Food and Agriculture[2]
Center for Analytical Chemistry
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Principal Investigator: Sheila Margetich, Agricultural Chemist II

	North Coast Laboratory, Ltd.	University of California, Davis
	5680 West End Road	Department of Entomology
	Arcata, CA 95521	Davis, California 95616-8584
	(Glyphosate analyses)	(Simazine urine analyses)
Principal Investigator:	J. Paige Noon	Shirley Gee

Final Archives:

California Environmental Protection Agency
Department of Pesticide Regulation
Worker Health and Safety Branch
1020 N Street, Room 200
Sacramento, California 95814

(All raw data related to sample collection and glyphosate analyses. NCL will retain test/reference substances.)

California Department of Food and Agriculture
Center for Analytical Chemistry
3292 Meadowview Road
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(All raw data related to sample analysis and test/ reference substances, simazine urine analysis)

Study Dates:

Study Initiation:	March 30, 1993
Field Monitoring Start:	April 7, 1993
Lab Sample Analysis Start:	April 28, 1993
Field Monitoring Completion:	November 15, 1994
Lab Sample Analysis Completion:	March 21, 1995
Study Completion:	April 27, 1995
Report Amendment 1:	June 1, 1995
Report Amendment 2:	June 2, 2004

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APPROVALS

Approved by: *[original signed by J. Donahue]* _____
John Donahue, Branch Chief — Date

[original signed by S. Edmiston] _____
Susan Edmiston, Senior Environmental Research Scientist — Date
Study Director

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QUALITY ASSURANCE STATEMENT: Project No. 9302

The Caltrans VCP Worker Exposure Study was audited at the following intervals:

Audit Date	Phase	Date Reported To Study Director	Date Reported To Management
03/29/93	Protocol	03/29/93	03/29/93
05/25/93	Field monitoring	05/27/93	05/27/93
06/15/93	Field monitoring	06/16/93	06/16/93
01/27/94	Field monitoring	01/28/94	02/24/94
04/12/95	Draft report	04/12/95	04/12/95
04/20/95	Final report	04/20/95	04/27/95
06/01/95	Amended final report	06/01/95	06/01/95

[original signed by D. Meinders] _____
Dana Meinders, Quality Assurance Officer

*Audits of some laboratory procedures are contained in the individual laboratory reports and are located in the WH&S archives.

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AMENDED STUDY COMPLIANCE STATEMENT

Based on the information supplied to me by North Coast Laboratory, Ltd. (Certification of GLP) concerning the laboratory analyses of glyphosate and by the California Department of Food and Agriculture, Center for Analytical Chemistry (Laboratory Statements of Compliance), I hereby confirm that the study was conducted in compliance with the Environmental Protection Agency, Good Laboratory Practice standards (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). One lot of oryzalin used in the study was not characterized. One lot of oryzalin and one lot of oxyfluorfen were not identified and may not have been characterized.

The testing facility did not have procedures established for handling reference substances as required in 40 CFR 160.107.

The analyses of simazine urinary metabolites were not conducted in compliance with GLP standards.

The test substance containers used in this study were not retained for the duration of the study as required in 40 CFR 160.105.

Supplemental and support data, such as weather data, were not collected in compliance with GLP.

All SOPs required by the regulations may not have been in place at the time of study conduct.

Analytical reference standards were not characterized under GLP, with the exception of oxyfluorfen. Reference standards for field fortifications, except oxyfluorfen, were not characterized under GLP.

With the exception of approving the method validation reports, there was no Quality Assurance Unit involvement in the analytical portion of the study (except glyphosate analyses).

Protocol and SOP deviations were documented and can be found in Appendix A (available upon request).

[original signed by S. Edmiston]

Susan Edmiston, Senior Environmental Research Scientist
Study Director
Worker Health and Safety Branch

Date

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Signatures of Study Personnel

Name	Position	Signature
John Donahue	WH&S Branch Chief	*[original signed by J. Donahue]*
Susan Edmiston	Study Director	*[original signed by S. Edmiston]*
Janet Spencer	Study Scientist	*[original signed by J. Spencer]*
Cathy Cowan	Study Scientist	*[original signed by C. Cowan]*
Kathy Orr	Study Scientist	*[original signed by K. Orr]*
Dana Meinders	Testing Facility QA Audits	*[original signed by D. Meinders]*
Dave Conrad	Laboratory Supervisor	*[original signed by D. Conrad]*
Sheila Margetich	Principle Laboratory Investigator	*[original signed by S. Margetich]*
Carolinda Benson	Chemist, Diuron urine metabolites	*[original signed by C. Benson]*
Marvin Wroe	Lab Assistant	*[original signed by M. Wroe]*
Terry Jackson	Laboratory QA audits	*[original signed by T. Jackson]*

Date_____

*Signatures of North Coast Laboratory personnel are in the NCL report and are maintained in the archives of Worker Health and Safety.

Exposure Of Herbicide Handlers In The Caltrans Vegetation Control Program
- 1993-1994 -

EXECUTIVE SUMMARY

Objectives: The objective of the study was to estimate exposure of California Department of Transportation (Caltrans) mixer/loader/applicators and other application personnel to six herbicides used in their Vegetation Control Program (VCP). The exposure estimates were compared to estimates, developed from surrogate data, used in the Environmental Impact Report (EIR) prepared for the Caltrans VCP by Jones and Stokes Associates in May 1992.

Background: Caltrans is responsible for the management of over 15,000 miles of highways and 230,000 acres of rights-of-way throughout the state of California. Excessive vegetation growth along these highways can interfere with travel, can catch fire and can pose a threat to the safety of motorists. The VCP depends primarily on the use of chemical control and mowing or manual cutting. A number of herbicides are used, depending on the time of year, weeds to be controlled, surrounding vegetation, etc.

The Caltrans EIR stated that monitoring would be conducted to verify that the worker protection measures are effective in minimizing worker exposure to herbicides. Under contract with Caltrans, this worker exposure study was completed as a result of the Caltrans EIR assertion.

Methods: Exposure of Caltrans VCP employees to six herbicides was monitored while mixing, loading and applying. The six herbicides were bromacil, diuron, glyphosate, oryzalin, oxyfluorfen and simazine. For each herbicide, a minimum of 18 worker-days of exposure was measured. Monitoring involved the use of full-body dermal dosimetry, hand wipes, face/neck wipes and breathing zone samples. In addition, 24-hour urine samples were collected following diuron and simazine exposure to measure absorbed dosage. Other information collected included, but was not limited to, verification of the concentration of the test substance and the tank mix, amount of time spent handling the pesticide, amount of pesticide mixed and sprayed per day, etc.

Major Findings: In general, the absorbed dosages calculated from this study are below or within the ranges (average to maximum) estimated in the EIR. The calculated absorbed dosages exceeded the maximum dosage predicted by the EIR estimates for only one exposure/herbicide scenario - a mixer/loader/applicator applying simazine via a truck with a boom and a spray nozzle (hand gun) from the window of the cab. The measured exposures for simazine were similar to those for the other herbicides. However, in the study calculations, the dermal absorption for simazine is much higher than for the other herbicides monitored. Based upon the information provided in the EIR, the safety measures employed by the Caltrans VCP, if followed, are generally adequate to protect employees from excessive exposure with the exception of the three scenarios. For simazine, the Caltrans Vegetation Control Program may need to reevaluate its use. General exposure reduction may be possible by eliminating the use of the hand gun from spray truck windows for all herbicides, ensuring employees are wearing clean gloves (clean inside and out or new each day as required in California regulations), ensuring that employees wash and remove their gloves and wash their hands before entering the trucks, wearing gloves while handling the hoses, keeping the handling of hoses to a minimum and ensuring that landscape employees using hand-held wands keep the wand height at a low level to avoid spray mist.

INTRODUCTION

The California Department of Transportation (Caltrans) is responsible for maintaining over 230,000 acres of rights-of-way along 15,000 miles of highways. The Caltrans Vegetation Control Program (VCP) provides for management of plant growth along these highways and rights-of-way for safety of motorists, fire hazard reduction, control of noxious weeds and protection of the paved roadways. Mowing or manual vegetation removal and herbicide applications are employed to obtain clear strips along shoulders and medians, to keep bases of safety hardware (signs, guard rails, etc.) clear of weeds, to keep drainage ditches clean and to maintain landscaped areas.

An Environmental Impact Report (EIR) developed for Caltrans identified several areas of concern for employees in the VCP[10]. Some of the issues to be resolved included further evaluation of the dermal absorption rate for diuron and verifying the efficacy of Caltrans' protective measures. During the development of the EIR, actual monitoring data were unavailable for the six herbicides evaluated, and thus surrogate data were used to estimate worker exposure. Under contract with Caltrans, this worker exposure study was undertaken to evaluate the EIR assertions.

In the EIR, to estimate exposure of mixer/loaders, the results of a study by Nash *et al*. (1982)[18] were used. In this study, urine was collected from seven mixer/loaders (for aerial application) of 2,4-D for six days following one day of work. Nash *et al*. found that a single mixer/loader handled an average of 20 lb active ingredient (ai) per day (40 lb maximum). Results from several other studies were evaluated for use as surrogate data in the EIR[1, 12, 13], but the exposure scenario in the Nash *et al*.[18] study was determined to most closely represent that of Caltrans mixer/loaders and the data could be easily normalized to lb ai handled[10] for extrapolation of exposure.

Exposure of applicators using backpack sprayers and hand wands was estimated, in the EIR, from the work of Harris *et al*. (1990)[9]. Harris *et al*. monitored absorbed dosage (urinary excretion) of 11 "home applicators" spraying 2,4-D. The applicators wore protective clothing similar to that required of Caltrans applicators. Other studies have also monitored hand applicator exposure to herbicides[1, 11, 13, 14], but the exposure scenario in the work of Harris *et al*. was selected as that most closely representing the exposure of Caltrans workers.

Exposure to spray truck drivers was estimated in the EIR from studies conducted by Carmen *et al*. (1984)[3] and Maddy and Richmond (1987)[17]. Carmen *et al*. measured exposure of spray truck drivers using a rig with an oscillating boom while treating citrus orchards with parathion. Maddy and Richmond (1987) measured potential applicator exposure inside and outside enclosed cabs. By using the results of both studies, exposure inside the closed truck cab could be estimated. Exposure to other spray truck drivers had been measured[6], but the application rate was not given and the data could not be used in the EIR.

The Caltrans EIR stated that monitoring would be conducted to verify that the worker protection measures are effective in minimizing worker exposure to herbicides. The objective of this study was to measure the exposure of mixer/loader/applicators and other application-related personnel to herbicides used in the Caltrans VCP. These measurements were used to calculate an estimated internal dosage and then compared to the dosages estimated in the EIR. The results from the study were also used to evaluate the Caltrans herbicide safety program.

AMENDMENT
June 2004

In June 2004, one value in Table 5 was amended. The absorbed dosage for the third exposure of worker 1 under "Boom application with hand gun use (did not mix/load)" was an error. It should read 1.58E-03 instead of 1.58-04.

Work Task	Worker ID No.	Adjusted Inhalation Exposure[1] (µg/person)	Adjusted Dermal Exposure[2] (µg/person)	Absorbed Dosage (µg/person)	Absorbed Dosage (mg/kg)	Amount Mixed (lb AI)	Amount Applied (lb AI)
Boom application with hand gun use (did not mix/load)							
	1	22.1	820.8	29.1	4.17E-04	0	40.2
	1	25.1	8824.9	30.7	4.40E-04	0	40.2
	1	74.5	3330.5	110.5	*1.58E-03*	0	48.2
	Average	**40.6**	**1658.7**	**56.8**	**8.14E-04**	**0**	**42.9**

[original signed by S. Edmiston]
Susan Edmiston, Study Director

Date

MATERIALS AND METHODS

Herbicide Applications: A minimum of eighteen worker-days of exposure of Caltrans mixer/loader/applicators and other VCP personnel were monitored for each of six herbicides used in the VCP program from April 1993 through November 1994. Monitoring was scheduled in conjunction with the spray crews' application schedules on an "as available" basis, as the opportunities for target herbicides presented themselves. Table 1 provides a description of the herbicides used in the study.

Table 1: Herbicides Used in the VCP Handler Monitoring Study

ACTIVE INGREDIENT	HERBICIDE PRODUCT	FORMULATION	EPA REGISTRATION NO.
Bromacil	Krovar I DF	Dispersible granule	352-505 AA
Diuron	Krovar I DF	Dispersible granule	352-505 AA
	Karmex DF	Dispersible granule	352-508 AA
Glyphosate	Roundup	Liquid	524-308 AA
Oryzalin	Surflan A.S.	Liquid	62719-113 AA
Oxyfluorfen	Goal 1.6 E	Emulsifiable liquid	707-174 AA
Simazine	Simazine 90	Water dispersible granule	2749-509 AA
	Sim-Trol 4L	Flowable liquid	35915-11-60063

Appendix 1 summarizes the application rate(s), area sprayed, amount of active ingredient handled, and the equipment used for each application monitored. All monitoring was conducted in Caltrans Districts 3 and 10, encompassing 19 California counties. All monitored applications were conducted in accordance with the herbicide label requirements, DPR regulations and Caltrans procedures.

Worker Exposure Monitoring: Approval was obtained from the Committee on Human Research and the University of California at San Francisco (approval number H7420-08804-01). Voluntary cooperation was sought and obtained from all cooperators. The purpose of the study, study methods and the role of the cooperating workers in the study were fully explained to each worker interested in participating in the study, and signed informed consent was obtained from each worker prior to his/her participation. Workers were informed that they could withdraw from the study at any time without penalty. No attempt was made to alter the normal clothing worn, personal protective equipment (PPE) used or work habits of the workers prior to or during exposure monitoring. In general, workers wore clean clothing to start each work day. Most workers wore eye protection and Tyvek® coveralls over their normal clothing during mixing/loading and application; the exception being workers #3 and #10 who wore the coveralls only during mixing/loading. Workers also usually wore chemical resistant boots and gloves while mixing and loading and during all hand-wand applications. Respiratory protection was used only while actually pouring the formulated herbicide product into the tank.

Prior to the initiation of monitoring, the following information was recorded for each worker: sex, height, weight, job and years of experience applying herbicides in the Caltrans VCP. Individual Caltrans herbicide handlers were monitored during the normal course of a day while handling herbicides used in the VCP. Whenever possible, workers were monitored for three consecutive application days.

During the course of the monitored workday, study field staff was in at least visual contact with the cooperating workers or their application vehicle. For many applications, field staff rode in the application vehicle with the Caltrans workers. Field staff recorded the following information: herbicides used, the total amount(s) handled, dilution and application rates, work activities and amount of time spent at each activity, work clothing and PPE used, anomalies that might influence the exposure, and sample collection times.

To measure dermal exposure, workers wore t-shirts and long johns, and used face/neck and hand wipes. Long-sleeved 100% cotton t-shirts and 100% cotton long johns were worn next to the worker's skin under normal work clothes and PPE for the entire work day. Full-body dosimetry worn under normal work clothing was chosen over patch dosimetry as no extrapolation of results for body surface area or clothing penetration is needed. Exposure to the hands and face/neck area was measured by wiping either area separately with a series of two pre-moistened towelettes anytime during the day when the workers would normally wash their hands or face/neck. As a minimum, wipes were collected after mixing and loading, at lunch break and at the end of the day. Wipes were chosen over the use of cotton or knit gloves for the hands, as gloves are thought to overestimate hand exposure[7]. The following materials were used for face/neck and hand wipes during the study: Simazine - Diaperenes® or 100% cotton diaper squares moistened with a surfactant/water solution; glyphosate - 100% cotton diaper squares moistened with distilled water; diuron, bromacil, oryzalin, oxyfluorfen - 100% cotton diaper squares moistened with a surfactant/water solution. Dermal dosimeters were collected at the end of the day in the following order to prevent cross contamination: hand wipes, face/neck wipes, and then t-shirt and long johns.

Inhalation exposure was measured by placing a cassette containing a type AE glass fiber filter in the breathing zone of each worker. The cassettes were attached via vinyl tubing to a personal air pump. The pumps, attached to the worker's belts, were set to operate at 2 L/min using a Kurz® Mass Flow Meter and the start time was recorded. Air was pumped through the filters for the duration of the monitoring period. To ensure continuous operation for the duration of the monitoring period, pumps (not the filter cassettes) were often changed (flow rates, start/stop times recorded) at the lunch break. At the end of the monitoring period, the air sampling equipment was removed and the flow rate and stop time of the pumps were recorded. The filters were then removed from the tubing, capped and prepared for storage and transportation.

Urine Samples: Workers applying diuron and simazine were also asked to collect 24-hour urine samples during the course of monitoring. Diuron and simazine were selected for biomonitoring because some information was available on metabolism and analytical methods were thought to be available. In addition, the EIR makes reference to a need for biomonitoring of workers exposed to diuron to verify the exposure estimate made in that document.

Samples were collected in 1-liter bottles and pooled into a single sample for each 24-hour period. The 24-hour period began the morning of the application and ended with the first void the next morning. The total volume collected was recorded, and then an aliquot of approximately 250 mL was taken from each 24-hour sample. Samples were collected on the days of application. Some follow-up samples were collected for 24 to 48 hours. The logistics of study staff obtaining samples during nonwork periods precluded nonexposure follow-up samples on a regular basis. As a pre-sample, a single void sample was collected following a period of no exposure (usually a weekend) and prior to handling of diuron or simazine. Study staff also provided a single void sample to be used as a blank each day urine was collected from Caltrans workers.

Test Substance and Tank Mix: Test substance samples were collected from each lot number of each herbicide used in the study (with the exception of one lot of oryzalin and one unidentified lot of both oryzalin and oxyfluorfen). A tank mix sample was collected from each tank mix sprayed during the monitoring effort. Samples, usually collected at the spray nozzles, were taken at 1-4 intervals while spraying from each tank mix.

Field Fortifications and Blanks: Each field shipment was accompanied by blank and spiked samples of each of the sampling media. The purpose of the blanks was to assess handling and shipping conditions, assuring that cross-contamination between samples did not take place and result in the generation of false positives. Field fortifications served as indicators of the stability of the active ingredients of interest during shipping and storage before extraction and analysis. Two of each of the dermal dosimetry media (t-shirt, long johns and 10 wipes) and two glass fiber filters (in plastic cassettes) were spiked in the field with a known amount of a standard for every batch of samples shipped to the laboratory. Samples were spiked at the beginning of the day with a standard solution of the herbicides to be applied at 250 µL/sample for t-shirts, long johns and diaper squares and at 5 µL/sample for filters. The spiked filter cassettes were attached via vinyl tubing to personal air pumps that were set to run at 2 L/min. The start time was recorded and the pumps were allowed to run for the duration of the worker monitoring. At the end of the monitoring period the pump flow and end time were recorded and the filters were removed from the tubing and capped. All quality control samples were stored and shipped to the laboratory in the same manner as the exposure samples (see below). The field blanks and fortifications were extracted and analyzed with the exposure samples, using the same methodologies. The results indicate that neither contamination nor storage stability was a factor in the study and that the methods were valid and rugged.

Spiking standards were prepared from the appropriate formulated product whenever feasible. Otherwise, an analytical standard was substituted. The formulation was diluted with the appropriate solvent to be able to prepare spikes at field exposure rates. The concentrations of the spiking standards were confirmed by comparison with analytical standards. The results were: (1) diuron:simazine - diuron 1043 µg/mL, simazine 995 µg/mL; (2) diuron:bromacil - diuron 1000 µg/mL, bromacil 1000 µg/mL; (3) oxyfluorfen 1166 µg/mL and (4) glyphosate 1000 µg/mL. A spiking solution for oryzalin was not available during the study period and thus field fortification of samples was not completed.

Sample Storage and Shipping: T-shirts and long johns were placed in 1-gallon track seal plastic bags, sealed and placed in an ice chest with dry ice. The face/neck wipe and hand wipe samples were stored in 1-quart glass jars that were sealed with aluminum foil, capped and placed on dry ice. Glass fiber filter cassettes were capped, placed in track seal plastic bags and put in an ice chest containing dry ice. Urine aliquots were capped and stored on dry ice (separate from other exposure samples). All samples remained on dry ice until arrival at the analytical laboratory where they were checked in and the storage location was noted.

Test substance and tank mix samples were stored on dry ice separately from exposure and QC samples during field storage, shipment to the laboratory and storage in the laboratory. Once the samples arrived at the laboratory they were logged in and the storage location was noted on the chain of custody.

Analytical Method Validation: All analytical methodologies (except for the simazine urine metabolite urine analyses) utilized in this study were validated in the lab prior to usage on field samples. Method validation was performed on either cotton wipes or Diaperenes®, t-shirts, long johns and glass fiber filters for each herbicide. Method validation was conducted according to laboratory standard operating procedures. For each chemical/sample media combination, the method was validated by analyzing 5 replicates at 3 fortification levels including the limit of detection (LOD), 5 times the LOD and 20 times the LOD, except for glyphosate. Glyphosate validations were performed on cotton wipes, t-shirts and glass fiber filters only. The fortification levels for glyphosate were 3 replicates at 50 µg/sample, 250 µg/sample and 500 µg/sample for the wipes and t-shirts. Glyphosate method validation for glass fiber filters consisted of 2 replicates performed at 5 µg and 10 µg per filter. Data from these validation studies indicate acceptable recoveries for all analytes in all matrices. Recoveries for all analytes were within 70-120 percent of the expected value (see Table 2 for mean analytical recoveries). Detection limits are as follows (in µg/sample): bromacil, diuron and oryzalin - filter 2.0, cloth wipes 5.0, long johns 20, t-shirt 25; glyphosate - filter 5.0, cloth wipes 50, long johns 50, t-shirts 50; oxyfluorfen - filter 0.25, cloth wipes - 6.25, long johns 25.0, t-shirt 31.25; and simazine - filters 2.0, cloth wipes 8.0, long johns 20, t-shirt 25.

Table 2: Mean Analytical Recoveries (in percent of expected)

	Face/neck/hand wipes			GF filters			T-Shirts			Long johns		
Herbicide	LOD	5X LOD	20X LOD	LOD	5X LOD	20X LOD	LOD	5X LOD	20X LOD	LOD	5X LOD	20X LOD
Bromacil	105.32	91.97	80.00	97.07	90.95	104.95	88.30	103.86	104.30	95.41	98.79	92.69
Diuron	97.75	91.66	84.64	106.00	98.80	106.88	89.38	109.64	93.49	96.48	109.15	90.08
Oryzalin	91.04	102.99	90.28	99.38	105.34	90.58	97.24	95.38	105.81	98.67	89.21	103.75
Oxyfluorfen	93.41	106.88	85.97	101.92	94.65	104.97	95.31	113.08	100.01	104.12	100.93	107.10
Simazine	100.57	95.21	97.13	99.38	103.56	102.23	100.46	96.65	84.88	112.44	108.75	101.60
Glyphosate*	103.57	108.00	106.00	75.40	78.67	---	101.60	105.33	103.00	---	---	---

* - Glyphosate method validation completed at LOD, 5X LOD and 10X LOD for dermal media, and at LOD and 2X LOD for filters; long johns were assumed to give the same recovery as t-shirts.

Analytical Methods: Diuron and bromacil were extracted from all the matrices with methanol. Oryzalin was extracted with ethyl acetate and solvent-exchanged to methanol. These three compounds were analyzed with a Waters 600 E liquid chromatograph equipped with a Hewlett Packard 1050 UV
detector, and monitored at 254, 280 and 239 nanometers, respectively. The compounds were separated using an AllTech cartridge 15 centimeter C18 column with a flow rate of 1.0 milliliter (mL) per minute. A mobile phase of 65 percent deionized water and 35 percent acetonitrile under isocratic conditions was utilized for diuron and bromacil. Bromacil eluted at 5.38 minutes and diuron at 11.32 minutes. The mobile phase for oryzalin was comprised of 30 percent deionized water and 70 percent acetonitrile under isocratic conditions. The resulting retention time was 6.52 minutes. The column jacket was maintained at 28°C for each analyte.

Simazine and oxyfluorfen were extracted from all matrices with ethyl acetate. Simazine was analyzed on an HP5880 A gas chromatograph equipped with a nitrogen phosphorous detector. Separation was obtained with a 10 m x 0.53 mm x 2.65 µm HP-1 column with a flow rate of 20 mL per minute and a retention time of 2.79 minutes. The temperatures of the column, injector and detector were held constant at 225°C, 160°C and 250°C, respectively. Oxyfluorfen was analyzed on an HP5880 A gas chromatograph. This analysis was performed with an electron capture detector. Separation was achieved with a 12.5 m x 0.20 mm x 0.33 µm HP-1 capillary column resulting in a retention time of

6.52 minutes. The column temperature was held constant at 185°C with a back pressure of 20 psi. The injector was set at 250°C and the detector temperature held at 350°C.

Glyphosate was extracted from all matrices with 0.02M phosphoric acid. It was injected into a high pressure liquid chromatograph and separated on a 4.6 mm ID X 250 mm glyphosate column with a retention time of approximately 9 minutes. It was equipped with an o-phthaladehyde post-column reactor and detected with a fluorescence detector with excitation wavelength at 340 and emission at 455 nanometers.

A modification of the procedure described by Van Boven *et al*.[22] was developed and validated for the extraction and analysis of diuron and two of its primary metabolites, 3,4-dichlorphenylurea (DCPU) and 3,4-dichlorophenyl-3-methylurea (DCPMU) in urine. A 3 mL aliquot of urine was extracted without pH adjustment 3 times with 6 milliliters of dichloromethane (DCM) by rocking 3 minutes and pooling the lower DCM layer into a second test tube each time. The samples were solvent exchanged to methanol, filtered with a luer lock syringe through a 0.2 micron acrodisc and subsequently analyzed by HPLC/UV. The analysis was performed with a Hewlett Packard 1050 HPLC equipped with a UV detector set at 252 nanometers equipped with an auto-injector. A 10 microliter injection was separated under reverse phase conditions with an AllTech 150 mm x 4.6 mm 5µ Hypersil MOS-2 (C8) cartridge system. The system was equipped with a C8 guard column. The initial solvent mix was comprised of 20% acetonitrile:80% water changing to 65% acetonitrile:35% water over an 11-minute interval with a flow rate of 1.5 milliliters per minute; this solvent ratio was held for 4 minutes and then stepped to 90/10 acetonitrile/water mix and held for 6 minutes. The instrument was then returned to initial solvent ratios and allowed to equilibrate for 8 minutes between injections. Therefore the total run time was 21 minutes with a 29-minute cycle time.

Retention times for DCPU, DCPMU and diuron were 6.3, 7.1, and 7.6 minutes, respectively. The LOD for this analysis (10 times the signal to noise ratio) is 0.06 µg/sample (3 mL aliquot) or 20 ng/mL. Mean recoveries for the three compounds ranged from 92.02% to 100.18%. All methodologies were subjected to method validation consisting of fortifications at the LOD, 5X LOD and 20X LOD.

The methodology used to analyze simazine metabolites in urine is an enzyme-linked immunosorbent assay (ELISA) which has been successful for the detection of atrazine and its primary metabolites in human urine. This specific immunoassay is described by Lucas[16] *et al.* and Schneider and Hammock[19]. The data generated to date is considered preliminary a method to confirm that the ELISA is actually measuring simazine mercapturic acid is still under development. Efforts are continuing to lower the detection limit and to confirm identification of the metabolite.

Exposure Calculations: Field staff recorded the amount of time spent completing the daily activities required of the Caltrans employees during the course of the workdays monitored. These daily activities were grouped into the following categories:

Application	Time spent actually spraying herbicides to the target area.
Mix/load	Time spent completing mix/load activities, including pouring the formulated product into the tank, adding the proper amount of water and rinsing containers.
Equipment repair	Time spent repairing any part of the spray or mix/load equipment.
Driving	Time spent driving to and from the spray and/or mix/load sites. No herbicides are sprayed or handled.
Spray preparation	Time spent at the spray site preparing for the actual release of herbicide (moving booms into place, placing hand gun in reach of the operator, etc.).
Breaks/lunch	Time spent not conducting work-related activities.
Other	Time spent doing other activities that do not fit in the above categories (waiting for herbicides to be moved to the mix site, waiting for the early warning truck to arrive at the application site, etc.).

Work activities were categorized according to the observations made by study staff during the course of monitoring. The activities were broken down as follows:

Boom application	Operator of a spray truck with booms mounted below the cab included both the "batch" rig and injection rig and booms in front and behind the truck cab. No mixing/loading took place during the course of the monitoring period.
Boom application with hand gun use	Operator of a spray truck with booms mounted below the driver and a spray wand (hand gun) that was used by the applicator from inside the truck cab, included both the "batch" rig and injection rig and booms in front and behind the truck cab. No mixing/loading took place during the course of the monitoring period.
Hand application	The applicator sprayed with a hand-held wand that was attached via a long hose to a large tank mounted on a truck. No mixing/loading took place during the course of the monitoring period.
Mix/load	Mixed and loaded a tankful of spray mix, but did not actually apply any material. Worker usually drove to specified application site(s) prior to suspending the application for the day. (Applications were suspended or stopped for the day usually due to adverse environmental conditions.)
Mix/load/boom application	A combination of mix/load and boom application activities (see definitions above)
Mix/load/boom application with hand gun use	A combination of mix/load and boom application with hand gun use activities (see definitions above)
Mix/load/shadow vehicle driver	A combination of mix/load (see definition above) and shadow vehicle driver activities (see definition below)
Mix/load/spray rig driver	A combination of mix/load (see definition above) and spray rig driver activities (see definition below)
Shadow vehicle driver/spray rig driver	A combination of shadow vehicle driver and spray rig driver activities (see definitions below)
Shadow vehicle driver	Worker drove a shadow vehicle immediately behind the application rig. The shadow vehicle is used to protect the application rig occupants and has a "crash box" attached to the back of the vehicle.
Spray rig driver	Worker drove a spray truck, but did not operate spray equipment. This category included drivers for all types of applications (see above).
Spray rig driver handle hose	Worker drove a spray truck for the hand wand applications, but did not actually participate in spraying. Worker did assist the applicator in handling the long hoses.

Inhalation exposure calculations (in micrograms per person) assumed an inhalation rate of 14 liters/minute, inhalation uptake of 50% and inhalation absorption of 100%[20]. Dermal exposure (the amount that would land on the skin) was calculated by summing the results of the face/neck wipes, hand wipes, long johns and t-shirts. Since all dermal dosimetry was worn under normal work clothing, no corrections were necessary for clothing penetration. In cases where no residues were detected on the sample media, ½ the LOD was used in the exposure calculation. The glyphosate analytical results were reported as the glyphosate acid. In the EIR, glyphosate exposure was calculated as the isopropylamine salt of glyphosate. In the formulation used by Caltrans, 480 grams/liter of the isopropylamine salt is equivalent to 356 grams/liter of the acid, thus the analytical results were adjusted by a factor of 1.35 to make them equivalent to EIR exposure estimations.

Absorbed dosage estimates were calculated by adding to the inhalation dosage the measured dermal exposure times the appropriate dermal absorption factor. Dermal absorption estimates used are as follows: bromacil - 1%[10], diuron - 5%[10], glyphosate - 2.2%[24], oryzalin - 1.9%[15], oxyfluorfen - 22%[2], and simazine 32.1%[4]. Only the bromacil and diuron absorption factors are the same as those used in the Caltrans EIR. The absorption factors used for glyphosate, oryzalin, oxyfluorfen and simazine were obtained from actual dermal absorption studies conducted in rats and monkeys. Actual worker weights were used to calculate absorbed dosage in mg/kg.

RESULTS

Overall, 113 worker-days of Caltrans employee exposure to herbicides were monitored; 18 worker-days for each of five herbicides (bromacil, glyphosate, oryzalin, oxyfluorfen and simazine) and 23 worker-days for diuron. This was accomplished by measuring exposure to workers in 48 separate applications, 25 of which included two workers. In 26 of the applications, exposure to two herbicides in the tank mix was measured. Bromacil was always applied with diuron, as the only formulated product containing bromacil also contains diuron. All 18 worker-days of oryzalin and oxyfluorfen exposure were monitored when the compounds were applied together.

In this study, exposure of 13 different Caltrans employees was measured. Of the 13 employees, nine were male. Study cooperators had been employed as applicators in the VCP an average of 6.2 years (range: 1 to 12). Average weight for the females monitored was 164 lb (range: 138 to 208) while that of males was 173 lb (range: 150 to 190). Worker activity demographics are contained in Appendix 2. On the average, the monitored work day was almost 7 hours in length (including all breaks). Of that time, nearly 31% was spent applying herbicides and 28% driving to and from the application sites (Appendix 2). Average time spent driving to and from application sites was lowest for the landscape crews (hand wand applications). The remaining time was spent mixing/loading (7.5%), repairing equipment (1.7%), preparing to spray (6.5%), on breaks (17%) and conducting other activities (8.8%).

The results of the monitoring are presented in Tables 3-10 and summarized below:

<u>*Bromacil*</u> (Table 3). Average measured daily exposure to bromacil ranged from 0.18 mg/person for shadow vehicle drivers (n=3) to 1.2 mg/person for the mixer/loader/spray rig operator using a hand gun from the window of the truck cab (n=5). The average calculated absorbed daily dosage ranged from 6.70×10^{-5} mg/kg to 7.38×10^{-4} mg/kg, respectively, for the same activities. The maximum bromacil exposure measured was 2.37 mg/person/day (absorbed dosage of 1.19×10^{-3} mg/kg/day) for an application rig operator using a hand gun. For this application (and several others) residues on the hands were high. Study staff noted that the applicator wore a protective glove while using the hand

gun and driving the truck, thus potentially contaminating the inside of the cab and the ungloved hand. Workers mixed and loaded a daily average of 27.3 lb (0 - 60 lb) and sprayed an average of 30.3 lb (0 - 60 lb) of bromacil.

Diuron (Table 4). The diuron data shows a similar pattern to that of bromacil. Average measured daily diuron exposure ranged from 0.20 mg/person to 1.36 mg/person for the shadow vehicle driver (n=5) and mixer/loader/spray rig operator using a hand gun out the window (n=7), respectively. The average absorbed daily dosage ranged from $1.7x10^{-4}$ mg/kg for the shadow vehicle driver to $1.61x10^{-3}$ mg/kg for the mixer/loader/spray rig operator using a hand gun. Maximum measured exposure was 2.36 mg diuron/person/day (absorbed dosage of $2.6x10^{-3}$ mg/kg/day) measured while operating a spray rig and using the hand gun (same application as the high bromacil day). The VCP employees handled an average of 32.1 lb (0 - 89.6 lb) and 38.3 (0 - 89.6 lb) for mix/loading and spraying, respectively.

Glyphosate (Table 5). Monitored glyphosate activities included spray rig operators using a boom and a hand gun, landscape personnel using hand wands, and driving a truck and helping the applicator handle the hose (not actually applying). Workers using hand wand application equipment handled considerably less material than did those applying with truck-mounted booms (7.3 lb sprayed/day vs. 42.9 lb sprayed/day), but average measured daily exposure was more for the employees using hand wand application equipment (3.1 mg/person for the hand wand applicator vs. 1.7 mg/person for the boom applicator, using a hand gun). The maximum measured exposure was 5.5 mg/person/day, measured while applying glyphosate via a hand wand.

Oryzalin (Table 6). Just as for the glyphosate applications, workers mixing/loading and spraying landscaped areas with hand wands received higher average exposure (1.47 mg/person/day) than the mixer/loader/spray truck operators (0.16 mg/person/day). The truck operators did not use a hand gun during any monitored application involving oryzalin. Maximum measured mixer/loader/applicator exposure was 1.83 mg/person/day ($5.68x10^{-4}$ mg/kg/day absorbed dosage) for a handler using a hand-held wand. The higher exposure levels appear to be related to carelessness during mixing/loading and equipment repair without wearing gloves. Mixer/loader/applicators for boom applications mixed an average of 60.8 lb/day and applied 58.4 lb/day while hand wand handlers mixed and loaded 22.7 lb/day and sprayed 16 lb/day.

Oxyfluorfen (Table 7). In general, measured exposures to oxyfluorfen are low and are probably due to the small amounts used in the spray mix (about 5 times less chemical than oryzalin). Average measured daily exposure ranged from 0.04 mg/person for the shadow truck driver and spray rig driver (for landscape applicators, who did not handle hose or leave the truck) to 0.17 mg/person for the worker involved in mixing, loading and hand wand landscape applications. Absorbed daily dosages calculated for oxyfluorfen were generally a little higher than those calculated for oryzalin because of the higher dermal absorption rate for oxyfluorfen (22% vs. 1.9%).

Simazine (Table 8). Since the dermal absorption rate for simazine is higher than the other five herbicides, the absorbed dosages are proportionately higher. As noted for the other five herbicides monitored, the shadow vehicle driver had the lowest measured exposure (0.09 mg/person/day, absorbed dosage of $3.7x10^{-4}$ mg/kg/day). Average measured daily exposure for the spray truck operators using the hand gun was 2.10 mg/person (absorbed dosage of $9.57x10^{-3}$ mg/kg). The maximum calculated absorbed dosage was $2.61x10^{-2}$ mg/kg/day (measured exposure of 5.66 mg/person/day) for a spray rig operator using a hand gun. This high exposure is probably related to spilling simazine on the t-shirt. Other high exposures were related to frequent equipment repair,

handling the tank lid and other parts without gloves, and wearing gloves inside the truck cab, thus contaminating surfaces in the cab.

Biomonitoring. Results of the diuron urinalyses can be found in Table 9. None of the urine samples contained detectable levels of diuron or DCPMU. No pre-exposure sample, collected following a no exposure period of 3-4 days, contained detectable residues of any of the three metabolites measured. Eleven of 24 samples collected during or following exposure contained detectable (above the LOD) levels of DCPU. Of these 11 positive results all were at or near the limit of detection, indicating very low levels of metabolites.

Currently all the urine samples associated with the Caltrans project for simazine have undergone preliminary analysis. The results of this analysis can be found in Table 10. The values are reported as simazine mercapturic acid and are considered **preliminary**. This report will be amended once the analytical methods have been confirmed.

Field QC All handling/shipping blanks (123 samples) contained no detectable residues. Average field spike recovery was 96.0% (136) samples. Field fortification results can be found in Table 11. Exposure calculations were not adjusted for laboratory recoveries or field spike recoveries.

Sample Storage Information on sample storage can be found in Table 12. Sample storage ranged from six to 400 days with an overall study average of 140 days. The following are average (and range) storage times, in days, for the various herbicides studied: bromacil - 110 (43-252); diuron - 99 (20-252); glyphosate - 9 (6-22); oryzalin - 282 (238-316); oxyfluorfen - 282 (238-316); and simazine - 70 (20-400). The results of the field fortifications were not correlated to the storage time for any of the herbicides studied.

Test Substance Results of analysis for test substance samples were fairly consistent across lot numbers for each of the six herbicides. The results (and standard deviation) expressed as a percent of the theoretical formulation for each of the six herbicides are as follows: bromacil - 103.5$\pm$1.8%; diuron - 103.4$\pm$2.5%; glyphosate - 114.8$\pm$7.3; oryzalin - 112.4$\pm$13.8; oxyfluorfen - 99.9$\pm$2.5; simazine - 101.7$\pm$0.9%.

Tank Mix The tank mix samples showed extreme variation with an overall mean and standard deviation of 101.5$\pm$32.3 percent of the theoretical tank mix. The average percent of the theoretical tank mix found in the tank mix samples are as follows: bromacil - 76.0$\pm$23.1%; diuron - 85.4$\pm$27.6%; glyphosate - 133.4$\pm$29.6%; oryzalin - 90.9$\pm$18.3%; oxyfluorfen - 109.8$\pm$18.3%; simazine - 99.7$\pm$34.2%. No corrections were made in the worker exposure calculations based on the tank mix samples. Other research[21] has found considerable variation in tank mix samples following precise measurements of the amount added to the spray tank.

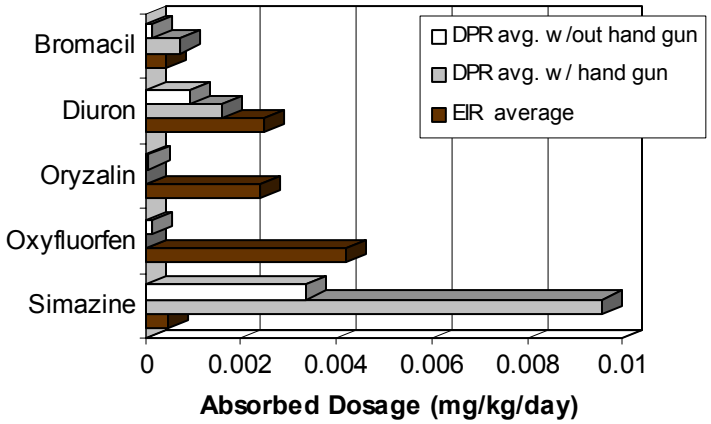
DISCUSSION

With the exception of simazine, the application rates monitored are within the range of those used in the EIR exposure assessment. The simazine applications monitored used rates approximately three times lower than those used in the EIR exposure estimates. However, regression analyses of total measured exposure vs. amount of herbicide handled by work task and chemical showed little to no correlation.

In the EIR, exposures were calculated for a person who mixes and loads or applies. For most of the applications monitored, it was normal practice for the same individual to complete the mixing/loading and applying. Two applications (4 herbicides) were monitored in which the VCP employee completed only the mix/load task. In both instances, the workers mixed and loaded and then drove to the scheduled application site only to have the application canceled due to unfavorable environmental conditions. For one of these operations, the air sample could not be analyzed and thus the exposure could not be calculated. In the other instance in which only mix/loading was monitored, the results were more than 100-fold less than the average absorbed dosage estimated in the EIR for oryzalin or oxyfluorfen[10]. Exposure to these two herbicides in this instance is notable in that the worker completing the mix/load task was being extremely careless while handling the herbicides on that occasion. Splashes of the formulated oryzalin product (Surflan®), a fairly thick orange liquid, were noted on the worker's PPE and on the t-shirt used as dermal dosimetry. By observation one would expect this exposure to represent a potentially maximum exposure scenario.

Eighteen worker-days of exposure were monitored when the mixing/loading activity did not take place during the course of the day (usually due to a combination of environmental factors and driving long distances to and from the application site that left mix in the tank from the previous day). Of the 18 days of monitoring, 4 involved hand wand application, 9 involved boom application from a truck and 5 involved boom application and the use of a hand gun. The average daily dosages as calculated from this study for bromacil (3 days), diuron (4 days), glyphosate (3 days) and simazine (1 day) were slightly higher for the boom application, both with and without the hand gun use, than the average calculated in the EIR. For the remainder of the boom applications where no mixing/loading took place (oryzalin - 1 day, oxyfluorfen - 1 day) and the hand applications (no mix/load) average exposures were below or approximately equal to those estimated in the EIR. At no time did any single monitored application (no mix/load) exceed the maximum dosage predicted in the EIR.

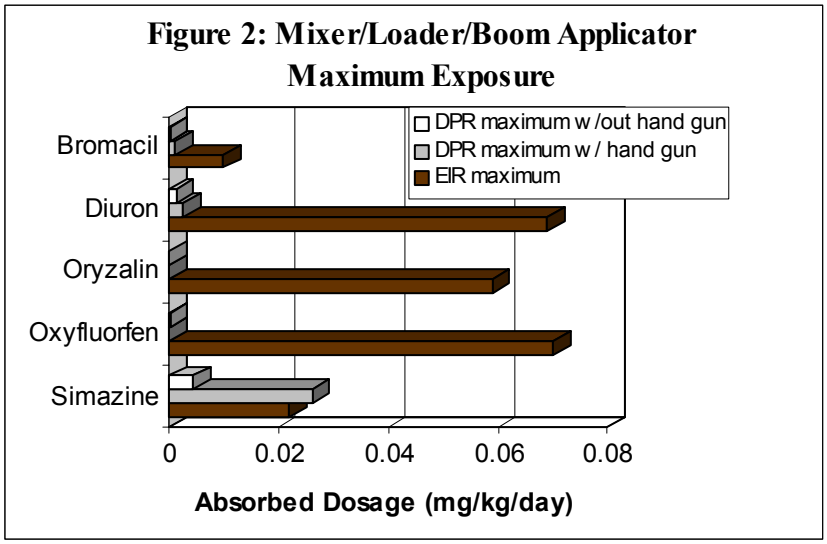
Figure 1: Mixer/Loader/Boom Applicator Average Daily Exposure



In order to compare the mixer/loader/applicator (M/L/A) exposure data to that calculated in the EIR, it was necessary to add the values calculated for mixer/loader exposure with those calculated for either the truck driver exposure or hand applicator exposure. In general, the average daily absorbed dosages calculated from the monitoring results fell below or within the range of dosages (average to maximum) estimated in the EIR[10]. Figures 1, 2, and 4 provide a comparison of the absorbed dosages estimated in the EIR and those calculated from data collected in this study for the average daily exposure and the maximum exposure potential.

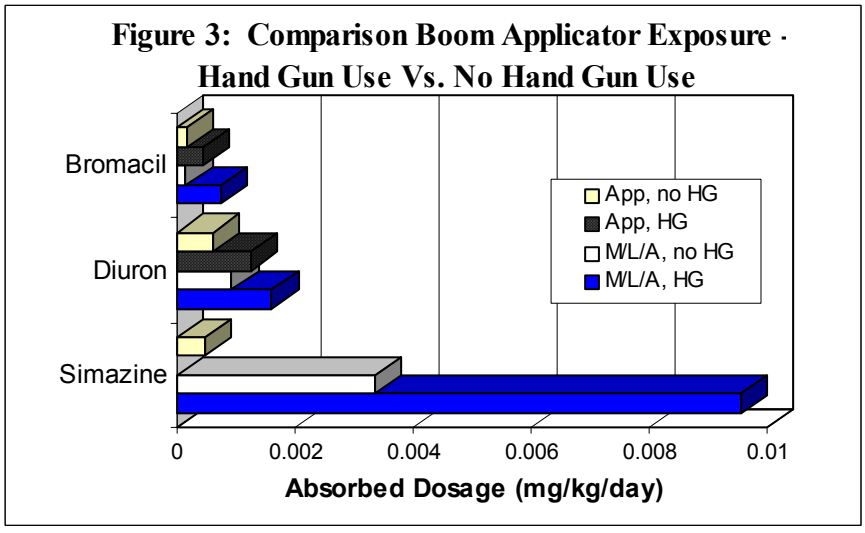
In Figure 1, calculated average absorbed dosages for all herbicides in this study, except bromacil and simazine, are below those estimated in the EIR. For simazine, the measured exposure is similar to that measured for the other herbicides, but the high dermal absorption rate translates to a much higher absorbed dosage. (The EIR used a dermal absorption rate of 1%.) The average daily absorbed simazine dosage calculated from monitoring results (truck driver using a hand gun) is more than an

order of magnitude greater than that estimated in the EIR. The maximum daily dosage (Figure 2) calculated for simazine from the study results is 2.26×10^{-2} mg/kg. The maximum simazine dosage estimated in the EIR is 2.2×10^{-2} mg/kg, essentially the same.



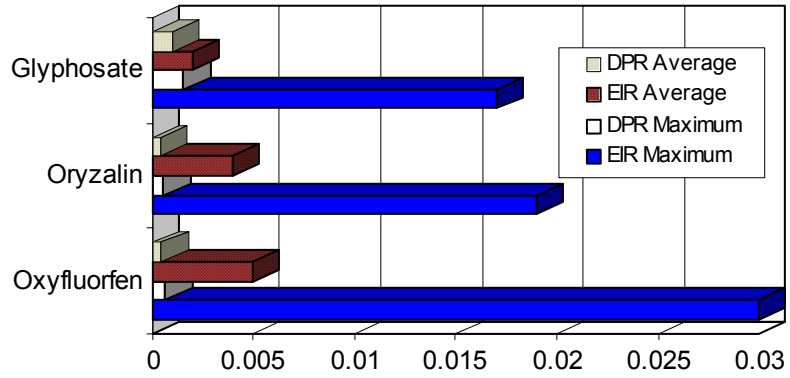
It appears as though mixing/loading bromacil, diuron and simazine (all dry formulations) may have added a fairly significant inhalation component to the potential exposure. Potential inhalation exposures where no mixing/loading took place were very low or no residues were detected; residues were detected much more often when the mixing/loading operation was monitored. Most, but not all, workers wore respiratory protection while actually pouring the herbicide into the spray tank. The use of this protection was not factored into the exposure calculation. Study staff noted dusty conditions on several occasions during the mixing of the diuron/bromacil product. Another situation that may lead to higher exposures is the use of open cab trucks for spraying. It was stated in the EIR that the Caltrans workers spraying via the trucks were using enclosed cabs because the application trucks have air conditioners and the windows of the trucks are closed during application. It was the observation of study staff that the air conditioners in the application rigs often worked poorly and that the windows were frequently open during application, thus they are not applying from an enclosed cab. In addition, for those applications in which the hand gun was used, it would not be possible to close the window while using this method of application. The applicator must stick his hand out the window to use the hand gun.

Of note is the general trend of the boom applicator exposure (Figure 3). For the three herbicides (bromacil, diuron, and simazine) in which both methods of boom application (hand gun vs. no hand gun) were monitored, the daily average (and the maximum exposure) was higher for those applicators who used a hand gun from the window of the application truck. On many occasions during the monitoring of Caltrans employees, the applicators using the hand gun commented that they could feel spray mist from the hand gun on their faces. The winds, etc., cause the spray mist to blow back into



the cab of the truck, exposing the occupants and contaminating the truck cab. Thus if the applicator is not wearing gloves while driving the truck, the hands can become contaminated and once gloves are put on, the inside of the gloves may then be contaminated. In addition, it was noted on several occasions that the applicator would wear a glove while using the hand gun and leave the glove on to drive the truck, potentially contaminating the steering wheel and transferring residues to the ungloved hand. Other situations, observed by study staff, that may have lead to higher exposures are frequent equipment repair without wearing gloves and handling of the lid and other parts of the tank without wearing gloves.

Figure 4: Mixer/Loader/Hand Wand Applicator Daily Average & Maximum Exposure



Only three of the six herbicides studied were applied using hand wands. Hand wand applications were generally used to treat landscaped areas. Figure 4 illustrates the comparison between the absorbed dosages estimated in the EIR and the absorbed dosages calculated from the monitoring results. None of the absorbed dosages calculated in this study approached those calculated (average or maximum) in the EIR. For oryzalin and oxyfluorfen, average dermal exposure and consequently average absorbed dosage were higher for those using hand wand application equipment when compared to the truck operators (no hand gun). The calculated absorbed dosage for glyphosate was similar for hand wand applicators and truck operators using a hand gun. As can be noted in Tables 4-6, hand wand applicators handled significantly less material than those operating the trucks (boom application).

Study staff noted in several instances that the hand wand applicators were not always careful about keeping the spray nozzle close to the ground. Raising the nozzle to reach spots that are difficult to walk to often exposed the applicator to significant spray drift. Difficult terrain (steep embankments on the sides of freeways) and heavy traffic offer plenty of distractions to take the applicator's mind off pesticide application safety. Applicators were often observed to walk into the area they just sprayed, instead of backward away from the spray mist. Again, steep embankments, heavy traffic and uneven ground make this safety practice very difficult to follow. Another factor possibly adding to the exposure of hand applicators is the potential for contamination inside the gloves and inside the cab of the truck. The applicators were always careful to wear gloves while applying and often rinsed the gloves prior to removing them. However, when just moving the hose around (assisting the applicator, not actually spraying), the use of gloves was much more inconsistent. The hoses are often inadvertently sprayed, then handled by ungloved workers (and often draped over the shoulder) who then climb back into the truck only to contaminate the interior of the cab and possibly the inside of the gloves once they are put back on. One worker wiped spray mist off the truck windshield with bare hands, resulting in a very high hand exposure for the day.

Current problems with the analytical methodology for the simazine urinary metabolites preclude much discussion, as the results can only be considered qualitative. Work on the methodology is continuing and the report will be amended once the methods are fully developed and the results are made available.

Human or laboratory animal metabolism studies following exposure to diuron are not available or are inadequate to determine the complete metabolism of diuron. Two papers are available in which urinary metabolites are characterized following massive overdoses. In one study, diuron and four metabolites were identified in postmortem plasma and urine[23]. In this study diuron was metabolized to DCPU and DCPMU; unchanged diuron was also found in small amounts. Van Boven[22] *et al*., found that the primary metabolites were DCPU and DCPMU; no unchanged diuron was detected. In the study of exposure to Caltrans workers, we found only DCPU in the urine samples (no diuron or DCPMU). Regression analyses performed on DCPU vs. measured exposure showed very poor correlation (r^2 ranged from 0.32 for cumulative DCPU vs. cumulative exposure to 0.10 for daily DCPU vs. daily measured exposure). However, urinary levels of DCPU were very low suggesting low exposure and/or low dermal absorption.

CONCLUSIONS

In general, the absorbed dosages calculated from this study are below or within the ranges (average to maximum) estimated in the EIR. The calculated absorbed daily dosages exceeded the maximum dosage predicted by the EIR estimates for only one exposure/herbicide scenario - a M/L/A applying simazine via a truck with a boom and using hand gun from the window of the truck. The average daily dosages predicted in the EIR were exceeded in three exposure herbicide scenarios - a M/L/A applying simazine via a truck with a boom and hand gun from the window of the truck, a M/L/A applying simazine via a truck with a boom and not using a hand gun from the window of the truck and a M/L/A applying bromacil via a truck with a boom and using a hand gun from the window of the truck. Based upon the information provided in the EIR, the safety measures employed by the Caltrans VCP, if followed, are generally adequate to protect employees from excessive exposure with the exception of the three scenarios mentioned above. The Caltrans Vegetation Control Program may need to reevaluate the use of simazine. General exposure reduction may be possible by eliminating the use of the hand gun from spray truck windows for all herbicides, ensuring employees are wearing clean gloves (clean inside and out or new each day as required in California regulations), ensuring that employees wash and remove their gloves and wash their hands before entering the trucks, wearing gloves while handling the hoses, keeping the handling of hoses to a minimum and ensuring that landscape employees using hand-held wands keep the wand height at a low level to avoid spray mist.

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Table 3: ESTIMATED ABSORBED DAILY DOSAGE - BROMACIL

Work Task	Worker ID No.	Inhalation Exposure[1] (µg/person)	Dermal Exposure[2] (µg/person)	Absorbed Dose (µg/person)	Absorbed Dosage (mg/kg)	Amount Mixed (lb AI)	Amount Applied (lb AI)
Boom application, no hand gun (did not mix/load)							
	3	7.5	455.1	8.3	1.06E-04	0	60.0
	3	6.7	1640.5	19.7	2.51E-04	0	50.4
	4	NS	NS	---	---	0	56.0
	Average	**7.1**	**1047.8**	**14.0**	**1.78E-04**	**0**	**55.5**
Boom application with hand gun use (did not mix/load)							
	1	31.3	1414.7	29.8	4.27E-04	0	20
Mix load drive to site (did not apply)							
	4	NS	465.9	---	---	44	0
Mix/load/boom application, no hand gun							
	3	16.3	667.2	14.8	1.88E-04	60	14.4
	3	7.0	519.5	8.7	1.10E-04	24	14.4
	12	7.2	NS	---	---	60	46.0
	Average	**10.2**	**593.4**	**11.8**	**1.49E-04**	**48**	**24.9**
Mix/load/boom application with hand gun use							
	1	26.2	1212.5	25.2	3.62E-04	16	16.0
	1	121.6	2243.9	83.2	1.19E-03	40	20.8
	1	134.5	1067.4	77.9	1.12E-03	NR	25.2
	2	7.1	496.3	8.5	1.05E-04	NR	19.2
	4	133.6	516.2	71.9	9.14E-04	56	52.0
	Average	**84.6**	**1107.3**	**53.4**	**7.38E-04**	**25**	**26.6**
Mix/load/spray rig driver (hand gun used from passenger side by other employee)							
	1	17.9	884.7	17.8	2.55E-04	NR	19.2*
	2	7.9	143.7	5.4	6.60E-05	NR	25.2*
	Average	**12.9**	**514.2**	**11.6**	**1.61E-04**	**---**	**22.2***
Shadow vehicle driver							
	10	7.0	100.2	4.5	5.75E-05	0*	50.4*
	10	7.2	386.2	7.5	9.52E-05	60*	14.4*
	10	7.0	27.5	3.8	4.83E-05	0*	60*
	Average	**7.1**	**171.3**	**5.2**	**6.70E-05**	**20***	**41.6***
Bromacil Averages		**34.1**	**765.1**	**25.8**	**3.53E-04**	**27.3**	**30.3**

1 - Inhalation Exposure: Actual inhalation measurements; for samples with none detected, ½ the LOD was substituted.

2 - Dermal Exposure: The sum of the results of analyses for hand wipes, face/neck wipes, long johns and t-shirts; for samples with none detected, ½ the LOD was substituted.

* - Not included in overall average as these amounts duplicate other entries in the table from the same day. The shadow driver and spray rig driver did not actually handle the amount of chemical recorded in the table. They were involved incidentally with the application of the herbicide.

NR - Not recorded

NS - No sample collected or sample collection incomplete as spray rig caught fire and monitoring equipment was destroyed.

Table 4: ESTIMATED ABSORBED DAILY DOSAGE - DIURON

Work Task	Worker ID No.	Inhalation Exposure[1] (µg/person)	Dermal Exposure[2] (µg/person)	Absorbed Dose (µg/person)	Absorbed Dosage (mg/kg)	Amount Mixed (lb AI)	Amount Applied (lb AI)
Boom application, no hand gun (did not mix/load)							
	3	7.5	502.2	28.9	3.67E-04	0	60.0
	3	6.7	218.6	14.3	1.81E-04	0	38.4
	3	6.7	1960.9	101.4	1.29E-03	0	50.4
	4	NS	NS	---	---	0	56.0
	Average	**7.0**	**893.9**	**48.2**	**6.12E-04**	**0**	**51.2**
Boom application with hand gun use (did not mix/load)							
	1	30.0	1455.7	87.8	1.26E-03	0	20
Mix/load, drive to site (did not apply)							
	4	NS	404.6	---	---	44	0
Mix/load/boom application, no hand gun							
	3	15.3	603.3	37.8	4.80E-04	60	14.4
	3	110.0	1080.1	109.0	1.38E-03	80	38.4
	Average	**62.7**	**841.7**	**73.4**	**9.32E-04**	**70**	**26.4**
Mix/load/boom application with hand gun use							
	1	123.9	1704.3	147.2	2.11E-03	NR	25.2
	1	15.6	1580.9	86.9	1.25E-03	16.0	16.0
	1	141.6	2216.9	181.7	2.60E-03	40.0	20.8
	2	7.1	625.9	34.9	4.28E-04	NR	19.2
	2	377.1	636.3	220.4	2.71E-03	NR	74.4
	4	34.0	1467.0	90.4	1.15E-03	89.6	89.6
	4	117.0	458.1	81.4	1.03E-03	56.0	52.0
	Average	**116.6**	**1241.3**	**120.4**	**1.61E-03**	**50.4**	**42.5**
Mix/load/spray rig driver (hand gun used from passenger side by other employee)							
	1	7.0	2364.6	121.7	1.75E-03	NR	74.4*
	1	15.1	1095.5	62.3	8.94E-04	NR	19.2*
	2	7.9	362.9	22.1	2.71E-04	NR	25.2*
	Average	**10.0**	**1274.3**	**68.7**	**9.70E-04**	**---**	**39.6***
Shadow vehicle driver							
	10	6.5	88.8	7.7	9.83E-05	0*	38.4*
	10	7.0	109.0	9.0	1.14E-04	0*	60.0*
	10	7.2	407.6	24.0	3.06E-04	60*	14.4*
	10	7.3	275.2	17.4	2.22E-04	80*	38.4*
	10	7.0	102.7	8.6	1.10E-04	0*	50.4*
	Average	**7.0**	**196.7**	**13.3**	**1.70E-04**	**28***	**40.3***
Diuron Averages		**50.4**	**896.4**	**71.2**	**9.52E-04**	**32.1**	**38.3**

1 - Inhalation Exposure: Actual inhalation measurements; for samples with none detected, ½ the LOD was substituted.

2 - Dermal Exposure: The sum of the results of analyses for hand wipes, face/neck wipes, long johns and t-shirts; for samples with none detected, ½ the LOD was substituted.

* - Not included in overall average as these amounts duplicate other entries in the table from the same day. The shadow driver and spray rig driver did not actually handle the amount of chemical recorded in the table. They were involved incidentally with the application of the herbicide.

NR - Not recorded

NS - No sample collected or sample collection incomplete as spray rig caught fire and monitoring equipment was destroyed.

Table 5: ESTIMATED ABSORBED DAILY DOSAGE - GLYPHOSATE

Work Task	Worker ID No.	Adjusted Inhalation Exposure[1] (µg/person)	Adjusted Dermal Exposure[2] (µg/person)	Absorbed Dosage (µg/person)	Absorbed Dosage (mg/kg)	Amount Mixed (lb AI)	Amount Applied (lb AI)
Boom application with hand gun use (did not mix/load)							
	1	22.1	820.8	29.1	4.17E-04	0	40.2
	1	25.1	8824.9	30.7	4.40E-04	0	40.2
	1	74.5	3330.5	110.5	1.58E-03	0	48.2
	Average	**40.6**	**1658.7**	**56.8**	**8.14E-04**	**0**	**42.9**
Mix/load/hand wand application							
	5	25.9	5094.5	125.0	1.55E-03	18.1	10.6
	6	59.4	4756.1	134.3	1.44E-03	9.0	11.3
	6	26.2	2963.3	78.3	8.37E-04	9.0	4.5
	7	26.8	2866.1	76.5	1.23E-03	12.1	9.0
	7	23.9	3704.4	93.5	1.50E-03	24.1	12.1
	7	23.6	1267.7	39.7	6.39E-04	9.0	12.1
	8	23.9	2158.4	59.4	8.80E-04	12.1*	9.0*
	8	24.4	1096.2	36.3	5.38E-04	9.0*	12.1*
	8	23.8	1277.1	40.0	5.92E-04	1.5	0.6
	9	22.6	2843.1	73.9	8.64E-04	3.0	4.2
	9	23.8	5517.5	133.3	1.56E-03	24.1*	12.1*
	9	24.9	2858.0	75.3	8.81E-04	3.0	1.8
	Average	**27.4**	**3033.5**	**80.5**	**1.04E-03**	**9.8**	**7.3**
Spray rig driver/handle hose for hand wand application (did not actually spray)							
	5	20.3	1501.2	43.2	5.36E-04	9.0*	11.3*
	5	25.5	477.5	23.3	2.89E-04	9.0*	4.5*
	6	24.7	926.0	32.7	3.50E-04	18.1*	10.6*
	Average	**23.5**	**968.2**	**33.1**	**3.91E-04**	**12.0***	**8.8***
Glyphosate Averages		**29.0**	**2460.2**	**68.6**	**8.96E-04**	**7.4**	**16.2**

1 - Inhalation Exposure: Actual inhalation measurements; for samples with none detected, ½ the LOD was substituted. The analytical results were reported as the glyphosate acid and were adjusted by multiplying by 1.35 to make them equivalent to those estimated for the salt.

2 - Dermal Exposure: The sum of the results of analyses for hand wipes, face/neck wipes, long johns and t-shirts; for samples with none detected, ½ the LOD was substituted. The analytical results were reported as the glyphosate acid and were adjusted by multiplying by 1.35 to make them equivalent to those estimated for the salt.

* - Not included in averages as these amounts duplicate other entries in the table from the same day. For most of the hand wand applications, handlers worked in teams of two, thus the amount of glyphosate handled per day is listed twice in the table. The spray rig drivers did not actually handle the amount of chemical recorded in the table. They were involved incidentally with the application of the herbicide.

Table 6: ESTIMATED ABSORBED DAILY DOSAGE - ORYZALIN

Work Task	Worker ID No.	Inhalation Exposure[1] (µg/person)	Dermal Exposure[2] (µg/person)	Absorbed Dosage (µg/person)	Absorbed Dosage (mg/kg)	Amount Mixed (lb AI)	Amount Applied (lb AI)
Boom application, no hand gun (did not mix/load)							
	3	8.0	27.5	4.5	5.74E-05	0	52
Hand wand application (did not mix/load)							
	9	15.1	958.5	25.8	3.02E-04	0	20
	11	7.6	1156.7	25.8	3.58E-04	0*	20*
	Average	**11.4**	**1057.6**	**25.8**	**3.30E-04**	**0**	**20**
Mix/load, drive to site (did not apply)							
	3	7.6	293.9	9.4	1.19E-04	100	0
Mix/load/boom application, no hand gun							
	3	7.1	260.0	8.5	1.08E-04	40	56
	3	7.4	188.5	7.3	9.23E-05	44	100
	3	6.9	155.0	6.4	8.13E-05	100	44
	10	7.0	100.0	5.4	6.90E-05	80	52
	10	7.3	75.0	5.1	6.47E-05	40	40
	Average	**7.1**	**155.7**	**6.5**	**8.3E-05**	**60.8**	**58.4**
Mix/load/hand wand application							
	8	7.4	1825.1	38.4	5.68E-04	20	20
	9	6.7	NS	---	---	32	12
	9	20.9	1299.1	35.1	4.11E-04	16	16
	9	7.4	1340.8	29.2	3.41E-04	20*	20*
	11	16.3	1377.2	34.3	4.76E-04	16*	16*
	Average	**11.7**	**1460.5**	**34.2**	**4.49E-04**	**22.7**	**16.8**
Shadow vehicle driver							
	10	6.9	27.5	4.0	5.08E-05	100*	44*
	10	7.6	150.9	6.7	8.49E-05	44*	100*
	10	7.4	27.5	4.2	5.37E-05	0*	52*
	Average	**7.3**	**68.6**	**4.9**	**6.32E-05**	**48***	**65.3***
Spray rig driver (drove truck while other employee sprayed with hand wand)							
	8	7.6	27.5	4.3	6.38E-05	32*	12*
Oryzalin Averages		**9.0**	**546.5**	**14.9**	**1.94E-04**	**42.9**	**37.5**

1 - Inhalation Exposure: Actual inhalation measurements; for samples with none detected, ½ the LOD was substituted.

2 - Dermal Exposure: The sum of the results of analyses of hand wipes, face/neck wipes, long johns and t-shirts; for samples with none detected, ½ the LOD was substituted.

* - Not included in averages as these amounts duplicate other entries in the table from the same day. For most of the hand wand applications, handlers worked in teams of two, thus the amount of oryzalin handled per day is listed twice in the table. The shadow drivers and spray rig driver did not actually handle the amount of chemical recorded in the table. They were involved incidentally with the application of the herbicide.

NS - No sample collected or sample collection incomplete.

Table 7: ESTIMATED ABSORBED DAILY DOSAGE - OXYFLUORFEN

Work Task	Worker ID No.	Inhalation Exposure	Exposure[2] (µg/person)	Absorbed Dosage (µg/person)	Absorbed Dosage (mg/kg)	Amount Mixed (lb AI)	Amount Applied (lb AI)
Boom application no hand gun (did not mix/load)							
	3	1.0	34.4	8.1	1.02E-04	0	10.4
Hand wand application (did not mix/load)							
	9	2.2	46.0	11.2	1.31E-04	0	4.0
	11	0.9	106.0	23.8	3.31E-04	0*	4.0*
	Average	**1.6**	**76.0**	**17.5**	**2.31E-04**	**0**	**4.0**
Mix/load, drive to site (did not apply)							
	3	0.9	39.8	9.2	1.17E-04	20	0
Mix/load/boom application, no hand gun							
	3	0.9	41.2	9.5	1.21E-04	8.8	20.0
	3	0.9	40.0	9.2	1.17E-04	20.0	8.8
	3	0.9	76.0	17.2	2.18E-04	8.0	11.2
	10	0.9	34.4	8.0	1.02E-04	16.0	10.4
	10	0.9	38.0	8.8	1.13E-04	8.0	8.0
	Average	**0.9**	**45.9**	**10.5**	**1.34E-04**	**12.2**	**11.7**
Mix/load/hand wand application							
	8	0.9	147.3	32.9	4.87E-04	4.0	4.0
	9	0.9	256.2	56.8	6.65E-04	4.0*	4.0*
	9	0.8	232.5	51.6	6.03E-04	6.4	2.4
	9	4.0	110.6	26.3	3.08E-04	3.2	3.2
	11	3.3	106.0	24.9	3.46E-04	3.2*	3.2*
	Average	**2.0**	**170.5**	**38.5**	**4.82E-04**	**4.5**	**3.2**
Shadow vehicle driver							
	10	0.9	34.4	8.0	1.02E-04	0*	10.4*
	10	0.9	34.4	8.0	1.02E-04	20.0*	8.8*
	10	0.9	34.4	8.0	1.02E-04	8.8*	20.0*
	Average	**0.9**	**34.4**	**8.0**	**1.02E-04**	**9.6***	**13.1***
Spray rig driver (drove truck while other employee sprayed with hand wand)							
	8	0.9	34.4	8.0	1.19E-04	6.4*	2.4*
Oxyfluorfen Averages		**1.3**	**80.3**	**18.3**	**2.33E-04**	**8.6**	**7.5**

1 - Inhalation Exposure: Actual inhalation measurements; for samples with none detected, ½ the LOD was substituted.

2 - Dermal Exposure: The sum of the results of analyses for hand wipes, face/neck wipes, long johns and t-shirts; for samples with none detected, ½ the LOD was substituted.

* - Not included in averages as these amounts duplicate other entries in the table from the same day. For most of the hand wand applications, handlers worked in teams of two, thus the amount of oxyfluorfen handled per day is listed twice in the table. The shadow drivers and spray rig driver did not actually handle the amount of chemical recorded in the table. They were involved incidentally with the application of the herbicide.

Table 8: ESTIMATED ABSORBED DAILY DOSAGE - SIMAZINE

Work Task	Worker ID No.	Inhalation Exposure[1] (µg/person)	Dermal Exposure[2] (µg/person)	Absorbed Dosage (µg/person)	Absorbed Dosage (mg/kg)	Amount Mixed (lb AI)	Amount Applied (lb AI)
Boom application, no hand gun (did not mix/load)							
	3	6.5	104.7	36.9	4.68E-04	0	21.6
Mix/load/boom application, no hand gun							
	3	21.6	524.9	179.3	2.28E-03	45	21.6
	13	7.4	1108.7	359.6	4.41E-03	45	54.0
	Average	**14.5**	**816.8**	**269.4**	**3.35E-03**	**45**	**37.8**
Mix/load/boom application with hand gun use							
	1	7.0	633.9	207.0	2.97E-03	3.6	1.8
	1	35.0	5627.5	1823.9	2.61E-02	NR	27.0
	1	7.1	992.5	322.2	4.62E-03	15.3	10.8
	1	7.5	625.7	204.6	2.93E-03	1.8	9.0
	1	18.9	1197.4	393.8	5.65E-03	NR	48.6
	1	7.9	3444.3	1109.6	1.59E-02	9.0	6.3
	2	461.7	2203.5	938.2	1.15E-02	NR	42.3
	4	226.7	1312.4	534.6	6.79E-03	50.4	50.4
	Average	**96.5**	**2004.7**	**691.7**	**9.57E-03**	**16.0**	**24.5**
Mix/load/spray rig driver (hand gun used from passenger side by other employee)							
	1	70.9	1101.0	388.9	5.58E-03	NR	42.3*
Shadow driver/spray rig driver (hand gun used from passenger side by other employee)							
	2	7.4	583.7	191.1	2.35E-03	9.0*	6.3*
Shadow vehicle driver							
	10	7.3	86.9	31.5	4.03E-04	45*	21.6*
	10	6.5	72.0	26.4	3.37E-04	0*	21.6*
	Average	**6.9**	**79.5**	**29.0**	**3.70E-04**	**22.5***	**21.6***
Spray rig driver (hand gun used from passenger side by other employee)							
	2	7.3	225.5	76.0	9.33E-04	1.8*	9.0*
	2	7.2	740.4	241.3	2.96E-03	15.3*	10.8*
	2	6.7	78.1	28.4	3.49E-04	3.6*	1.8*
	Average	**7.0**	**348.0**	**115.2**	**1.41E-03**	**6.9***	**7.2***
Simazine Averages		**51.1**	**1148.0**	**394.1**	**5.37E-03**	**21.3**	**26.7**

1 - Inhalation Exposure: Actual inhalation measurements; for samples with none detected, ½ the LOD was substituted.

2 - Dermal Exposure: The sum of the results of analyses for hand wipes, face/neck wipes, long johns and t-shirts; for samples with none detected, ½ the LOD was substituted.

* - Not included in averages as these amounts duplicate other entries in the table from the same day. For most of the hand wand applications, handlers worked in teams of two, thus the amount of oxyfluorfen handled per day is listed twice in the table. The shadow drivers and spray rig driver did not actually handle the amount of chemical recorded in the table. They were involved incidentally with the application of the herbicide.

NR - Not recorded

Table 9: DIURON URINALYSIS VS. TOTAL EXPOSURE

Worker No.	Study No.	Sample Type	Exposure Date	Sample Collection Date	Analysis (ng/mL)	Volume (mL)	Total DCPU[1] (µg/person)	Total Exposure[2] (ug/person)
1	SE15(1)	Pre-exposure (3 days clearance)	NA	11/2/93	ND	100	ND	None
1	SE15(1)	Exposure sample	11/2/93	11/3/93	26.67	1200	32.0	2371.6
1	SE16(1)	Exposure sample	11/3/93	11/4/93	66.67	1600	106.7	1828.2
1	SE17(1)	Exposure sample	11/4/93	11/5/93	26.67	1450	38.7	1110.6
1	SE23(1)	Pre-exposure (4 days clearance)	NA	11/8/93	ND	150	ND	None
1	SE23(1)	Exposure sample	11/8/93	11/9/93	33.33	1000	33.3	1596.5
1	SE24	Exposure sample	11/9/93	11/10/93	26.67	1300	34.7	2358.5
1	SE25	Exposure sample	11/10/93	11/11/93	30.0	1600	48.0	1485.7
2	SE15(1)	Pre-exposure (3 days clearance)	NA	11/2/93	ND	100	ND	None
2	SE15(1)	Exposure sample	11/2/93	11/3/93	30.0	1400	42.0	1013.4
2	SE16(1)	Exposure sample	11/3/93	11/4/93	33.33	1500	50.0	370.8
2	SE17(1)	Exposure sample	11/4/93	11/5/93	66.67	900	60.0	633.0
4	SE15(2)	Pre-exposure (3 days clearance)	NA	11/2/93	ND	250	ND	None
4	SE15(2)	Exposure sample	11/2/93	11/3/93	30.0	950	28.5	1501.0
4	SE16(2)	Exposure sample	11/3/93	11/4/93	20	600	12.0	575.1
4	SE17(2)	Exposure sample	11/4/93	11/5/93	ND	700	7.0	404.6
4	SE23(2)	Pre-exposure (3 days clearance)	NA	11/8/93	ND	600	ND	None
4	SE23(2)	Exposure sample	11/8/93	11/9/93	ND	750	Incomplete	Incomplete
3	SE18	Pre-study (no clearance time)	11/2/93	11/3/93	33.33	Unknown	Unknown	Unknown
3	SE18	Exposure sample	11/3/93	11/4/93	ND	500	5.0	509.7
3	SE19	Exposure sample	11/4/93	11/5/93	ND	1150	11.5	618.5
3	SE20	Exposure sample	11/5/93	11/6/93	ND	950	9.5	1967.6
3	SE21	Pre-exposure (3 days clearance)	NA	11/9/93	ND	Unknown	ND	None
3	SE21	Exposure sample	11/9/93	11/10/93	ND	1700	17.0	1190.1
3	SE22	Exposure sample	11/10/93	11/11/93	ND	600	6.0	225.2
3	SE22	Post-exposure	11/10/93	11/12/93	ND	850	8.5	None
10	SE18	Pre-study (no clearance)	11/2/93	11/3/93	ND	Unknown	ND	Unknown
10	SE18	Exposure sample	11/3/93	11/4/93	ND	1300	13.0	116.1
10	SE19	Exposure sample	11/4/93	11/5/93	ND	1050	10.5	414.8
10	SE20	Exposure sample	11/5/93	11/6/93	ND	1300	13.0	109.7
10	SE21	Pre-exposure (3 days clearance)	NA	11/9/93	ND	Unknown	ND	None
10	SE21	Exposure sample	11/10/93	11/10/93	ND	1000	10.0	282.5
10	SE22	Exposure sample	11/10/93	11/11/93	ND	1250	12.5	95.3
10	SE22	Post-exposure	11/10/93	11/12/93	ND	1200	12.0	95.3

1 - Calculated using the following formula: [(DCPU) X (Volume)]/1000 = Total DCPU (µg/person); use ½ LOD for ND
2 - From Table 4
NA - Not applicable; ND - None detected

Table 10: SIMAZINE URINALYSIS VS TOTAL EXPOSURE

Worker No.	Study No.	Sample Type	Exposure Date	Sample Collection Date	Analysis (ng/mL)	Volume (mL)	Total Sim. Mercap. [1] (µg/person)	Total Exposure [2] (ug/person)
1	SE01	Pre-study	4/6/93	4/7/93	0.16	125		NA
1	SE01	Exposure	4/7/93	4/8/93	11	1000	11.0	3452.2
1	SE01	Pre-exposure (3 days no exposure)	4/8/93	4/12/93	1.2	100		NA
1	SE02	Exposure	4/12/93	4/13/93	4.6	1000	4.6	999.6
1	SE03	Exposure	4/13/93	4/14/93	4.4	1000	4.4	633.2
1	SE04	Exposure	4/14/93	4/15/93	11.7	1200	14.0	640.9
1	SE15(1)	Pre-Exposure		11/2/93	1.12	100		NA
1	SE15(1)	Exposure	11/2/93	11/3/93	6.6	1200	7.9	1171.9
1	SE27	Pre-exposure		3/1/94	3.8	200		NA
1	SE27	Exposure	3/1/94	3/2/94	20	800	16.0	5662.5
1	SE39	Exposure	3/2/94	3/3/94	7.1	900	6.4	1216.3
2	SE01	Pre-study	4/6/93	4/7/93	3.4	125		NA
2	SE01	Exposure	4/7/93	4/8/93	1.4	1000	1.4	591.1
2	SE01	Pre-exposure (3 days no exposure)	4/8/93	4/12/93	2.4	50		NA
2	SE02	Exposure	4/12/93	4/13/93	4.6	900	4.1	747.6
2	SE03	Exposure	4/13/93	4/14/93	2.74	1400	3.8	232.8
2	SE04	Exposure	4/14/93	4/15/93	1.19	1500	1.8	84.8
2	SE15(1)	Pre-Exposure	-	11/2/93	2.5	100		NA
2	SE15(1)	Exposure	11/2/93	11/3/93	9.8	1400	13.7	2665.2
3	SE21	Pre-exposure	-	10/9/93	1.3			NA
3	SE21	Exposure	11/9/93	11/10/93	1.48	1700	2.5	546.5
3	SE22	Exposure	11/10/93	11/11/93	2.3	600	1.4	111.2
3	SE22	Post-exposure	11/**10**/93	11/12/93	2.4	850	2.0	
4	SE15(2)	Pre-Exposure	-	11/2/93	0.94	250		NA
4	SE15(2)	Exposure	11/2/93	11/3/93	11.5	950	10.9	1539.1
10	SE21	Pre-exposure	-	11/9/93	1.6			NA
10	SE21	Exposure	11/9/93	11/10/93	1.98	1000	2.0	94.2
10	SE22	Exposure	11/10/93	11/11/93	1.25	1250	1.6	78.5
10	SE22	Post-exposure	11/**10**/93	11/12/93	1.22	1200	1.5	

1 - Calculated using the following formula: $\frac{[(\text{Simazine mercapturate}) \times (\text{Volume})]}{1000}$ = Total Simazine Mercapturate (µg/person)

2 - From Table 8

NA - Not applicable

Table 11: Field QC Recovery Report

Analyte	Sample Matrix	Average Percent Recovery
Bromacil	Face/neck/hand wipe	95.3
	GF filter	109.7
	Long johns	93.3
	T - shirt	89.0
	Bromacil Average	**97.6**
Diuron	Face/neck/hand wipe	95.2
	GF filter	102.0
	Long johns	95.3
	T - shirt	92.3
	Diuron Average	**96.6**
Glyphosate	Face/neck/hand wipe	97.9
	GF filter	96.8
	Long johns	95.3
	T - shirt	96.8
	Glyphosate Average	**96.7**
Oxyfluorfen	Face/neck/hand wipe	72.7
	GF filter	107.0
	Long johns	109.0
	T - shirt	115.4
	Oxyfluorfen Average	**101.0**
Simazine	Face/neck/hand wipe	97.7
	GF filter	85.0
	Long johns	86.3
	T - shirt	87.4
	Simazine Average	**89.1**
	Overall Average	**96.0**

***** Field fortifications were not conducted for oryzalin as a spiking standard was not available during monitoring.

Table 12: SAMPLE STORAGE

Herbicide	Sample Type	No. of Samples	Average Storage Time (days)	Maximum Storage Time (days)	Minimum Storage Time (days)
Bromacil	GF filter	17	98	196	40
	Face/neck wipe	17	102	239	43
	Hand wipe	16	98	239	43
	Long johns	18	115	246	54
	T - shirt	18	121	252	61
Bromacil		69	110	252	43
Diuron	GF filter	22	80	196	13
	Face/neck wipe	22	89	239	20
	Hand wipe	22	89	239	20
	Long johns	23	104	246	35
	T - shirt	23	113	252	37
Diuron		90	99	252	20
Glyphosate	GF filter	18	10	23	8
	Face/neck wipe	18	9	22	7
	Hand wipe	18	9	22	7
	Long johns	18	9	21	6
	T - shirt	18	8	21	6
Glyphosate		72	9	22	6
Oryzalin	GF filter	18	257	316	231
	Face/neck wipe	18	266	316	238
	Hand wipe	18	266	316	238
	Long johns	18	292	316	267
	T - shirt	18	305	316	285
Oryzalin		72	282	316	238
Oxyfluorfen	GF filter	18	257	316	231
	Face/neck wipe	18	266	316	238
	Hand wipe	18	266	316	238
	Long johns	18	292	316	267
	T - shirt	18	305	316	285
Oxyfluorfen		72	282	316	238
Simazine	GF filter	18	52	156	13
	Face/neck wipe	18	59	162	20
	Hand wipe	18	59	162	20
	Long johns	18	88	400	22
	T - shirt	18	73	170	22
Simazine		72	70	400	20
Study Average		558	140	400	6

APPENDIX 1: APPLICATION INFORMATION

Study Reference No.	Active Ingredient	Application rate (lb AI/100 gal)	Total AI Mixed (lb)	Total AI Sprayed (lb)	Spray Mix Applied (gallons)	Treated Areas	Equipment Used
SE01	Simazine	1.8	9.00	6.30	350	4' median; 6' shoulder; 2' ramps	500 gallon tank; underbar, rear off-set & hand gun
SE02	Simazine	1.8	15.30	10.80	600	4' shoulder	500 gallon tank; underbar, rear off-set & hand gun
SE03	Simazine	1.8	1.80	9.00	500	4' & 2' shoulder	500 gallon tank; underbar, rear off-set & hand gun
SE04	Simazine	1.8	3.60	1.80	100	6' shoulder; 2' ramps	500 gallon tank; underbar, rear off-set & hand gun
SE06	Glyphosate	3.0	9.00	11.25	375	landscape	300 gallon tank; hand wand with ~100' hose
SE07	Glyphosate	3.0	18.00	10.50	350	landscape	300 gallon tank; hand wand with ~100' hose
SE08	Glyphosate	3.0	9.00	4.50	150	landscape	300 gallon tank; hand wand with ~100' hose
SE09(1)	Glyphosate	3.0	12.00	9.00	300	mostly landscape; shoulder	500 gallon tank; hand wand with ~130' hose
SE09(2)	Glyphosate	3.0	3.00	1.80	60	landscape	50 gallon tank; hand wand with ~20' hose
SE10(1)	Glyphosate	3.0	9.00	12.00	400	landscape; shoulder	500 gallon tank; hand wand with ~130' hose
SE10(2)	Glyphosate	3.0	3.00	4.20	140	landscape	50 gallon tank; hand wand with ~20' hose
SE11(1)	Glyphosate	3.0	24.00	12.00	400	shoulder; landscape	500 gallon tank; hand wand with ~130' hose
SE11(2)	Glyphosate	3.0	1.50	0.60	20	landscape	50 gallon tank; hand wand with ~20' hose
SE12	Glyphosate	4.0	0	40.00	1000	8' shoulder and spot treatments	3000 gal. batch rig; underbar, rear off-set & hand gun
SE13	Glyphosate	4.0	0	40.00	1000	8' median and spot treatment	3000 gal. batch rig; underbar, rear off-set & hand gun
SE14	Glyphosate	4.0	0	36.00	1200	8' shoulder and spot treatments	3000 gal. batch rig; underbar, rear off-set & hand gun
SE15(1)	Diuron	3.2	Unknown	74.40	1150	6' shoulder and spot treatments	3000 gal. batch rig; underbar, rear off-set & hand gun
SE15(1)	Simazine	1.8	Unknown	37.60	1150	6' shoulder and spot treatments	3000 gal. batch rig; underbar, rear off-set & hand gun
SE15(2)	Simazine	1.8	50.40	50.40	2800	8' median and spot treatment	3000 gal. batch rig; underbar, rear off-set & hand gun
SE15(2)	Diuron	3.2	89.60	89.60	2800	8' median and spot treatment	3000 gal. batch rig; underbar, rear off-set & hand gun
SE16(1)	Diuron	2.0	Unknown	25.20	500	4' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE16(1)	Bromacil	2.0	Unknown	25.20	500	4' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE16(2)	Bromacil	2.0	56.00	52.00	2200	4' median; 4' shoulder and spot	3000 gal. batch rig; underbar, rear off-set & hand gun
SE16(2)	Diuron	2.0	56.00	52.00	2200	4' median; 4' shoulder and spot	3000 gal. batch rig; underbar, rear off-set & hand gun
SE17(1)	Diuron	2.0	Unknown	19.20	900	4' & 8' shoulders	3000 gal. batch rig; underbar, rear off-set & hand gun
SE17(1)	Bromacil	2.0	Unknown	19.20	900	4' & 8' shoulders	3000 gal. batch rig; underbar, rear off-set & hand gun
SE17(2)	Bromacil	2.0	44.00	0	0	none	3000 gal. batch rig; underbar, rear off-set & hand gun
SE17(2)	Diuron	2.0	44.00	0	0	none	3000 gal. batch rig; underbar, rear off-set & hand gun
SE18	Bromacil	2.4	0	60.00	2500	6' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE18	Diuron	2.4	0	60.00	2500	6' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE19	Bromacil	2.4	60.00	14.40	600	6' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE19	Diuron	2.4	60.00	12.00	600	6' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE20	Diuron	2.4	0	50.40	2100	6' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE20	Bromacil	2.4	0	50.40	2100	6' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE21	Diuron	3.2	80.00	38.40	1200	shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE21	Simazine	1.8	45.00	21.60	1200	shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun

Study Reference No.	Active Ingredient	Application rate (lb AI/100 gal)	Total AI Mixed (lb)	Total AI Sprayed (lb)	Spray Mix Applied (gallons)	Treated Areas	Equipment Used
SE22	Simazine	1.8	0	21.60	1200	shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE22	Diuron	3.2	0	38.40	1200	shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE23(1)	Diuron	2.0	16.00	16.00	400	4' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE23(1)	Bromacil	2.0	16.00	16.00	400	4' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE23(2)	Bromacil	2.0	0	56.00	2800	4' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE23(2)	Diuron	2.0	0	56.00	2800	4' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE24	Bromacil	2.0	40.00	20.80	550	4' median; 4' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE24	Diuron	2.0	40.00	20.80	550	4' median; 4' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE25	Diuron	2.0	0	20.00	600	4' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE25	Bromacil	2.0	0	20.00	600	4' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE26	Bromacil	4.0	60.00	46.00	1100	4' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE27	Simazine	1.8	Unknown	27.00	1500	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE28	Oryzalin	4.0	20.00	20.00	500	landscape; shoulder	600 gallon tank; hand wand with ~150' hose
SE28	Oxyfluorfen	0.8	4.00	4.00	500	landscape; shoulder	600 gallon tank; hand wand with ~150' hose
SE29	Oxyfluorfen	0.8	6.40	2.40	300	mostly landscape; shoulder	600 gallon tank; hand wand with ~150' hose
SE29	Oryzalin	4.0	32.00	12.00	300	mostly landscape; shoulder	600 gallon tank; hand wand with ~150' hose
SE30	Oxyfluorfen	0.8	0	4.00	500	mostly landscape; shoulder	600 gallon tank; hand wand with ~150' hose
SE30	Oryzalin	4.0	0	20.00	500	mostly landscape; shoulder	600 gallon tank; hand wand with ~150' hose
SE31	Oryzalin	4.0	16.00	16.00	400	landscape	600 gallon tank; hand wand with ~150' hose
SE31	Oxyfluorfen	0.8	3.20	3.20	400	landscape	600 gallon tank; hand wand with ~150' hose
SE32	Oryzalin	4.0	80.00	52.00	1300	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE32	Oxyfluorfen	0.8	16.00	10.40	1300	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE33(1)	Oryzalin	4.0	40.00	56.00	1400	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE33(1)	Oxyfluorfen	0.8	8.00	11.20	1400	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE33(2)	Oxyfluorfen	0.8	8.00	8.00	500	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE33(2)	Oryzalin	4.0	40.00	40.00	500	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE34	Oxyfluorfen	0.8	20.00	8.80	1100	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE34	Oryzalin	4.0	100.00	44.00	1100	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE35	Oxyfluorfen	0.8	8.80	20.00	2500	6' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE35	Oryzalin	4.0	44.00	100.00	2500	6' median	3000 gal. batch rig; underbar, rear off-set & hand gun
SE36	Oryzalin	4.0	100.00	0	0	none	3000 gal. batch rig; underbar, rear off-set & hand gun
SE36	Oxyfluorfen	0.8	20.00	0	0	none	3000 gal. batch rig; underbar, rear off-set & hand gun
SE37	Oxyfluorfen	0.8	0	10.40	1300	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE37	Oryzalin	4.0	0	52.00	1300	6' shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE38	Simazine	3.0	45.00	54.00	2400	6’ shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE39	Simazine	1.8	Unknown	48.60	2700	8' median; shoulder	3000 gal. batch rig; underbar, rear off-set & hand gun
SE40	Bromacil	2.4	24.00	14.40	600	6' median	3000 gal. batch rig; underbar, rear off-set & hand gun

Appendix 2: Worker Activity Demographics

Worker Task	Worker ID No.	Total Time Monitored (minutes)	Application	Percent Mix/load	Percent Equipment Repair	Percent Driving (no spray)	Percent Spray Preparation	Percent Break Time	Other
Boom application, no hand gun (did not mix/load)									
	3	391	33.2	0.0	0.0	32.7	6.1	16.6	11.3
	4	390	38.5	0.0	9.5	20.0	1.8	11.0	19.2
	3	386	27.2	0.0	2.6	37.3	2.6	24.4	6.0
	3	359	22.6	0.0	10.6	31.8	4.7	17.8	12.5
	3	436	37.2	0.0	2.1	22.2	17.9	16.3	4.4
	Average	**392**	**31.7**	**0.0**	**4.9**	**28.8**	**6.6**	**17.2**	**10.7**
Boom application with hand gun use (did not mix/load)									
	1	385	30.1	0.0	0.0	23.4	25.7	15.6	5.2
	1	592	50.7	0.0	0.0	22.1	0.0	18.2	9.0
	1	483	37.5	0.0	0.0	29.0	1.2	14.5	17.8
	1	588	39.1	0.0	0.9	29.3	12.6	12.1	6.1
	Average	**512**	**39.3**	**0.0**	**0.2**	**25.9**	**9.9**	**15.1**	**9.5**
Hand wand application (did not mix/load)									
	9	458	48.3	0.0	0.0	23.8	0.0	17.2	10.7
	11	458	48.3	0.0	0.0	23.8	0.0	17.2	10.7
	Average	**458**	**48.3**	**0.0**	**0.0**	**23.8**	**0.0**	**17.2**	**10.7**
Mix/load, drive to site (did not spray)									
	3	200	0.0	11.0	0.0	55.0	0.0	10.0	24.0
	4	271	0.0	18.8	0.0	56.1	14.0	0.0	11.1
	Average	**236**	**0.0**	**14.9**	**0.0**	**55.5**	**7.0**	**5.0**	**17.5**
Mix/load/boom application, no hand gun									
	3	313	12.1	27.5	0.0	29.1	5.8	10.9	14.7
	3	378	20.4	8.7	16.4	25.1	4.8	18.5	6.1
	10	415	24.1	10.6	0.0	36.6	2.4	10.1	16.1
	10	428	22.0	14.7	0.0	31.5	4.2	18.5	9.1
	3	364	26.6	5.8	0.0	28.3	10.7	23.1	5.5
	13	332	38.3	10.8	0.6	16.0	5.1	12.3	16.9
	3	485	6.8	6.2	0.0	25.2	7.2	15.5	39.2
	12	375	43.2	13.3	0.0	12.5	12.3	17.6	1.1
	3	411	36.0	9.7	0.0	24.8	2.2	15.6	11.7
	3	375	21.1	23.7	0.0	33.6	0.5	12.0	9.1
	Average	**388**	**25.1**	**13.1**	**1.7**	**26.3**	**5.5**	**15.4**	**12.9**
Mix/load/boom application with hand gun use									
	1	465	25.4	14.0	8.6	31.6	6.5	7.5	6.5
	1	445	21.8	8.5	0.0	39.3	4.3	15.5	10.6
	1	553	21.7	6.7	0.0	42.9	6.1	11.0	11.6
	1	115	60.0	7.0	0.0	25.2	4.3	0.0	3.5
	1	548	14.8	8.6	0.0	34.9	17.5	10.6	13.7
	2	470	18.3	7.4	0.0	31.7	17.2	14.9	10.4
	1	541	14.8	15.0	5.4	37.7	4.8	22.4	0.0
	1	519	20.6	5.8	0.0	23.3	16.6	15.0	18.7
	2	597	28.8	14.2	0.0	24.1	7.2	12.6	13.1
	1	420	27.6	15.7	16.7	15.7	7.6	9.5	7.1
	1	430	30.9	19.8	0.0	33.0	2.3	12.8	1.2
	4	598	37.5	7.7	3.2	18.2	11.7	13.9	7.9
	4	570	34.9	6.7	0.0	22.8	12.6	16.3	6.7
	Average	**482**	**27.5**	**10.5**	**2.6**	**29.3**	**9.1**	**12.5**	**8.5**

Appendix 2: Worker Activity Demographics (con't)

Worker Task	Worker ID No.	Total Time Monitored (minutes)	Percent Application	Percent Mix/load	Percent Equipment Repair	Percent Driving (no spray)	Percent Spray Preparation	Percent Break Time	Percent Other
Mix/load/hand wand application									
	8	441	37.2	2.3	0.0	21.1	0.7	38.8	0.0
	11	435	45.7	4.6	0.0	16.6	3.0	23.4	6.7
	9	432	46.3	3.2	0.0	15.5	3.5	17.8	13.7
	9	448	35.0	6.7	0.0	16.7	3.8	37.3	0.4
	8	166	24.1	4.8	0.0	28.9	6.0	18.1	18.1
	9	408	44.4	5.6	0.0	35.0	0.0	11.0	3.9
	7	426	28.6	1.4	0.0	16.7	18.1	30.8	4.5
	9	435	32.6	10.6	0.0	23.0	7.6	18.4	7.8
	8	432	46.3	3.2	4.9	15.5	3.2	17.8	9.0
	8	426	28.6	1.4	0.0	16.7	18.1	30.8	4.5
	5	381	42.3	12.3	0.0	17.6	0.0	23.6	4.2
	9	435	45.7	4.6	0.0	16.6	3.0	23.4	6.7
	9	424	25.7	6.8	0.5	56.8	0.0	9.2	0.9
	7	441	37.2	2.3	0.0	21.1	0.7	38.8	0.0
	7	448	35.0	6.7	0.0	16.7	3.8	37.3	0.4
	6	436	46.1	6.9	0.0	25.9	0.0	20.6	0.5
	6	224	36.2	9.4	0.0	26.3	11.2	13.4	3.6
	Average	**402**	**37.5**	**5.5**	**0.3**	**22.7**	**4.9**	**24.1**	**5.0**
Mix/load/spray rig driver (other employee using hand gun from passenger side)									
	1	597	28.8	14.2	0.0	24.1	7.2	12.6	13.1
	1	470	18.3	7.4	0.0	31.7	17.2	14.9	10.4
	2	519	20.6	5.8	0.0	23.3	16.6	15.0	18.7
	Average	**529**	**22.6**	**9.2**	**0.0**	**26.4**	**13.7**	**14.2**	**14.1**
Shadow vehicle driver									
	10	411	36.0	9.7	0.0	24.8	2.2	15.6	11.7
	10	436	37.2	0.0	2.1	22.2	17.9	16.3	4.4
	10	378	20.4	8.7	16.4	25.1	4.8	18.5	6.1
	10	391	33.2	0.0	0.0	32.7	6.1	16.6	11.3
	10	375	21.1	23.7	0.0	33.6	0.5	12.0	9.1
	10	313	12.1	27.5	0.0	29.1	5.8	10.9	14.7
	10	359	22.6	0.0	10.6	31.8	4.7	17.8	12.5
	10	386	27.2	0.0	2.6	37.3	2.6	24.4	6.0
	Average	**381**	**26.2**	**8.7**	**4.0**	**29.6**	**5.6**	**16.5**	**9.5**
Shadow vehicle driver/spray rig driver (other employee using hand gun from passenger side)									
	2	460	17.4	0.0	6.3	44.3	5.7	26.3	0.0
Spray rig driver (other employee using hand gun from passenger side or hand wand outside truck)									
	2	445	21.8	8.5	0.0	39.3	4.3	15.5	10.6
	2	553	21.7	6.7	0.0	42.9	6.1	11.0	11.6
	2	115	60.0	7.0	0.0	25.2	4.3	0.0	3.5
	8	414	34.3	4.6	0.0	24.2	8.0	19.3	9.7
	Average	**382**	**34.4**	**6.7**	**0.0**	**32.9**	**5.7**	**11.5**	**8.8**
Spray rig driver/handle hose (no actual spraying)									
	6	381	42.3	12.3	0.0	17.6	0.0	23.6	4.2
	5	224	36.2	9.4	0.0	26.3	11.2	13.4	3.6
	5	436	46.1	6.9	0.0	25.9	0.0	20.6	0.5
	Average	**347**	**41.5**	**9.5**	**0.0**	**23.3**	**3.7**	**19.2**	**2.7**
Overall Average		**417**	**30.8**	**7.5**	**1.7**	**27.7**	**6.5**	**17.0**	**8.8**

Appendix 3: Inhalation Raw Data

Analyte	Study No.	Worker No.	Analysis (µg/sample)	Initial Flow Rate (pump 1)	End Flow Rate (pump 1)	Elapsed Time (pump 1)	Initial Flow Rate (pump 2)	End Flow Rate (pump 2)	Elapsed Time (pump 2)	Inhalation Exposure* (µg/person)
Bromacil	SE16(1)	1	17.24	2.0	1.5	256	2.0	1.7	205	134.5
Bromacil	SE16(1)	2	ND	2.0	1.4	226	2.0	1.8	145	7.9
Bromacil	SE16(2)	4	16.33	2.0	1.5	351	2.0	1.3	219	133.6
Bromacil	SE17(1)	1	2.48	2.0	1.8	240	2.0	2.0	150	17.9
Bromacil	SE17(1)	2	ND	2.0	2.0	255	2.0	1.8	150	7.1
Bromacil	SE17(2)	4	NS	2.0	2.0	271	0.0	0.0	0	
Bromacil	SE18	3	ND	2.0	1.9	274	2.0	1.5	161	7.5
Bromacil	SE18	10	ND	2.0	2.2	270	2.0	1.6	162	7.0
Bromacil	SE19	3	2.33	2.0	2.0	313	0.0	0.0	0	16.3
Bromacil	SE19	10	ND	2.0	1.9	311	0.0	0.0	0	7.2
Bromacil	SE20	3	ND	2.0	2.2	385	0.0	0.0	0	6.7
Bromacil	SE20	10	ND	2.0	2.0	391	0.0	0.0	0	7.0
Bromacil	SE23(1)	1	3.58	2.0	1.6	248	2.0	2.0	300	26.2
Bromacil	SE23(2)	4	ND	2.0	1.7	273	2.0		120	
Bromacil	SE24	1	17.0	2.0	2.0	265	2.0	1.8	200	121.6
Bromacil	SE25	1	4.47	2.0	2.0	275	2.0	2.0	110	31.3
Bromacil	SE26	12	ND	2.0	1.8	135	2.0	2.0	83	7.2
Bromacil	SE40	3	ND	2.0	2.0	255	2.0	2.0	185	7.0
Diuron	SE15(1)	1	ND	2.0	2.0	302	2.0	2.0	295	7.0
Diuron	SE15(1)	2	53.87	2.0	2.0	278	2.0	2.0	290	377.1
Diuron	SE15(2)	4	4.67	2.0	1.7	274	2.0	2.0	258	34.0
Diuron	SE16(1)	1	15.88	2.0	1.5	256	2.0	1.7	205	123.9
Diuron	SE16(1)	2	ND	2.0	1.4	226	2.0	1.8	145	7.9
Diuron	SE16(2)	4	14.31	2.0	1.5	351	2.0	1.3	219	117.0
Diuron	SE17(1)	1	2.09	2.0	1.8	240	2.0	2.0	150	15.1
Diuron	SE17(1)	2	ND	2.0	2.0	255	2.0	1.8	150	7.1
Diuron	SE17(2)	4	NS	2.0	2.0	271	0.0	0.0	0	
Diuron	SE18	3	ND	2.0	1.9	274	2.0	1.5	161	7.5
Diuron	SE18	10	ND	2.0	2.2	270	2.0	1.6	162	7.0
Diuron	SE19	3	2.18	2.0	2.0	313	0.0	0.0	0	15.3
Diuron	SE19	10	ND	2.0	1.9	311	0.0	0.0	0	7.2
Diuron	SE20	3	ND	2.0	2.2	385	0.0	0.0	0	6.7
Diuron	SE20	10	ND	2.0	2.0	391	0.0	0.0	0	7.0
Diuron	SE21	3	15.72	2.0	2.0	222	2.0	2.0	151	110.0
Diuron	SE21	10	ND	2.0	1.8	220	2.0	1.9	155	7.3
Diuron	SE22	3	ND	2.0	2.2	350	0.0	0.0	0	6.7
Diuron	SE22	10	ND	2.0	2.3	359	0.0	0.0	0	6.5
Diuron	SE23(1)	1	2.13	2.0	1.6	248	2.0	2.0	300	15.6
Diuron	SE23(2)	4	ND	2.0	1.7	273	2.0		117	
Diuron	SE24	1	19.8	2.0	2.0	265	2.0	1.8	200	141.6
Diuron	SE25	1	4.28	2.0	2.0	275	2.0	2.0	110	30.0
Glyphosate	SE06	5	ND	2.0	2.9	346	2.0	1.7	87	15.0
Glyphosate	SE06	6	6.24	2.0	2.0	449	2.0	1.8	86	44.0
Glyphosate	SE07	5	ND	2.0	1.6	286	2.0	1.8	95	19.2
Glyphosate	SE07	6	ND	2.0	1.9	271	2.0	1.6	89	18.3
Glyphosate	SE08	5	ND	2.0	1.7	224	0.0	0.0	0	18.9
Glyphosate	SE08	6	ND	2.0	1.6	222	0.0	0.0	0	19.4
Glyphosate	SE09(1)	7	ND	2.0	1.1	225	2.0	2.0	201	19.9
Glyphosate	SE09(1)	8	ND	2.0	2.0	330	2.0	1.8	92	17.7
Glyphosate	SE09(2)	9	ND	2.0	1.8	335	2.0	1.8	89	18.5
Glyphosate	SE10(1)	7	ND	2.0	2.0	290	2.0	2.0	140	17.5
Glyphosate	SE10(1)	8	ND	2.0	1.8	235	2.0	2.0	150	18.1
Glyphosate	SE10(2)	9	ND	2.0	2.2	316	2.0	2.1	91	16.8
Glyphosate	SE11(1)	7	ND	2.0	2.0	302	2.0	1.9	146	17.7
Glyphosate	SE11(1)	9	ND	2.0	2.0	282	2.0	1.9	164	17.7
Glyphosate	SE11(2)	8	ND	2.0	2.0	92	2.0	2.0	71	17.6
Glyphosate	SE12	1	ND	2.0	1.6	246	2.0	1.9	300	18.6
Glyphosate	SE13	1	ND	2.0	2.5	303	2.0	1.9	169	16.3
Glyphosate	SE14	1	7.70	2.0	1.7	264	2.0	2.2	224	55.2
Oryzalin	SE28	8	ND	2.0	1.8	432	0.0	0.0	0	7.4
Oryzalin	SE28	9	ND	2.0	1.8	430	0.0	0.0	0	7.4
Oryzalin	SE29	8	ND	2.0	1.7	410	0.0	0.0	0	7.6
Oryzalin	SE29	9	ND	2.0	2.7	220	2.0	1.6	205	6.7
Oryzalin	SE30	9	2.0	2.0	1.7	458	0.0	0.0	0	15.1
Oryzalin	SE30	11	ND	2.0	1.7	458	0.0	0.0	0	7.6

Appendix 3: Inhalation Raw Data

Analyte	Study No.	Worker No.	Analysis (µg/sample)	Initial Flow Rate (pump 1)	End Flow Rate (pump 1)	Elapsed Time (pump 1)	Initial Flow Rate (pump 2)	End Flow Rate (pump 2)	Elapsed Time (pump 2)	Inhalation Exposure* (µg/person)
Oryzalin	SE31	9	2.73	2.0	1.4	219	2.0	2.0	170	20.9
Oryzalin	SE31	11	2.24	2.0	1.9	219	2.0	1.8	165	16.3
Oryzalin	SE32	10	ND	2.0	2.0	428	0.0	0.0	0	7.0
Oryzalin	SE33(1)	3	ND	2.0	2.0	364	0.0	0.0	0	7.1
Oryzalin	SE33(2)	10	ND	2.0	2.0	236	2.0	1.6	179	7.3
Oryzalin	SE34	3	ND	2.0	2.0	372	0.0	0.0	0	6.9
Oryzalin	SE34	10	ND	2.0	2.0	375	0.0	0.0	0	6.9
Oryzalin	SE35	3	ND	2.0	1.8	398	0.0	0.0	0	7.4
Oryzalin	SE35	10	ND	2.0	1.7	411	0.0	0.0	0	7.6
Oryzalin	SE36	3	ND	2.0	1.7	200	0.0	0.0	0	7.6
Oryzalin	SE37	3	ND	2.0	1.5	382	0.0	0.0	0	8.0
Oryzalin	SE37	10	ND	2.0	1.8	386	0.0	0.0	0	7.4
Oxyfluorfen	SE28	8	ND	2.0	1.8	432	0.0	0.0	0	0.9
Oxyfluorfen	SE28	9	ND	2.0	1.8	430	0.0	0.0	0	0.9
Oxyfluorfen	SE29	8	ND	2.0	1.7	410	0.0	0.0	0	0.9
Oxyfluorfen	SE29	9	ND	2.0	2.7	220	2.0	1.6	205	0.8
Oxyfluorfen	SE30	9	0.29	2.0	1.7	458	0.0	0.0	0	2.2
Oxyfluorfen	SE30	11	ND	2.0	1.7	458	0.0	0.0	0	0.9
Oxyfluorfen	SE31	9	0.52	2.0	1.4	219	2.0	2.0	170	4.0
Oxyfluorfen	SE31	11	0.45	2.0	1.9	219	2.0	1.8	165	3.3
Oxyfluorfen	SE32	10	ND	2.0	2.0	428	0.0	0.0	0	0.9
Oxyfluorfen	SE33(1)	3	ND	2.0	2.0	364	0.0	0.0	0	0.9
Oxyfluorfen	SE33(2)	10	ND	2.0	2.0	236	2.0	1.6	179	0.9
Oxyfluorfen	SE34	3	ND	2.0	2.0	372	0.0	0.0	0	0.9
Oxyfluorfen	SE34	10	ND	2.0	2.0	375	0.0	0.0	0	0.9
Oxyfluorfen	SE35	3	ND	2.0	1.8	398	0.0	0.0	0	0.9
Oxyfluorfen	SE35	10	ND	2.0	1.7	411	0.0	0.0	0	0.9
Oxyfluorfen	SE36	3	ND	2.0	1.7	200	0.0	0.0	0	0.9
Oxyfluorfen	SE37	3	ND	2.0	1.5	382	0.0	0.0	0	1.0
Oxyfluorfen	SE37	10	ND	2.0	1.8	386	0.0	0.0	0	0.9
Simazine	SE01	1	ND	2.0	1.6	273	2.0	1.5	267	7.9
Simazine	SE01	2	ND	2.0	1.8	460	0.0	0.0	0	7.4
Simazine	SE02	1	ND	2.0	1.9	190	2.0	2.0	253	7.1
Simazine	SE02	2	ND	2.0	1.9	185	2.0	1.9	255	7.2
Simazine	SE03	1	ND	2.0	1.6	308	2.0	1.9	231	7.5
Simazine	SE03	2	ND	2.0	1.6	318	2.0	2.2	233	7.3
Simazine	SE04	1	ND	2.0	2.0	115	0.0	0.0	0	7.0
Simazine	SE04	2	ND	2.0	2.2	115	0.0	0.0	0	6.7
Simazine	SE15(1)	1	10.13	2.0	2.0	302	2.0	2.0	295	70.9
Simazine	SE15(1)	2	65.96	2.0	2.0	278	2.0	2.0	290	461.7
Simazine	SE15(2)	4	31.13	2.0	1.7	274	2.0	2.0	258	226.7
Simazine	SE21	3	3.09	2.0	2.0	222	2.0	2.0	151	21.6
Simazine	SE21	10	ND	2.0	1.8	220	2.0	1.9	155	7.3
Simazine	SE22	3	ND	2.0	2.3	350	0.0	0.0	0	6.5
Simazine	SE22	10	ND	2.0	2.3	359	0.0	0.0	0	6.5
Simazine	SE27	1	4.88	2.0	2.0	195	2.0	1.8	185	35.0
Simazine	SE38	13	ND	2.0	1.8	329	0.0	0.0	0	7.4
Simazine	SE39	1	2.60	2.0	1.9	175	2.0	1.8	205	18.9

* Inhalation Exposure calculated using the following formula:

[Analysis (µg/sample) / (((([End flow rate, pump 1 (L/min)]+[Initial flow rate, pump 1 (L/min)]) /2) * [Elapsed Time, pump 1 (min)])+((([End flow rate, pump 2 (L/min)]+[Initial flow rate, pump 2 (L/min)])/2)*[Elapsed Time, pump 2 (min)])] * (Ventilation Rate [14 L/min]) *([elapsed time 1 (min)]+[elapsed time 2 (min)])

or

$$\frac{\text{Analytical Results (µg)}}{\text{Average Flow Rate (L/min)} * \text{Elapsed Time (min)}} \times \text{Ventilation Rate (L/min)} \times \text{Elapsed Time (min)} = \text{Inhalation Exposure (µg/person)}$$

Appendix 4: Dermal Raw Data

Analyte	Study No.	No.	Face/neck wipe (µg/sample)	Hand wipe (µg/sample)	Long johns (µg/sample)	T - shirt (µg/sample)	Dermal Exposure* (µg/person)
Bromacil	SE16(1)	1	102.6	499.8	ND	455.0	1067.4
Bromacil	SE16(1)	2	15.7	49.9	ND	68.1	143.7
Bromacil	SE16(2)	4	50.0	217.0	ND	239.2	516.2
Bromacil	SE17(1)	1	16.8	602.3	ND	255.6	884.7
Bromacil	SE17(1)	2	49.8	253.2	38.4	155.0	496.3
Bromacil	SE17(2)	4	31.8	109.2	51.5	273.4	465.9
Bromacil	SE18	3	23.3	234.0	ND	187.8	455.1
Bromacil	SE18	10	ND	ND	ND	ND	27.5
Bromacil	SE19	3	77.7	190.5	ND	389.0	667.2
Bromacil	SE19	10	22.9	274.3	ND	78.9	386.2
Bromacil	SE20	3	60.7	1363.0	ND	206.8	1640.5
Bromacil	SE20	10	ND	ND	ND	85.2	100.2
Bromacil	SE23(1)	1	50.0	840.0	ND	312.5	1212.5
Bromacil	SE23(2)	4	NS	NS	ND	40.0	
Bromacil	SE24	1	156.9	720.0	28.0	1339.0	2243.9
Bromacil	SE25	1	129.7	999.0	36.0	250.0	1414.7
Bromacil	SE26	12	ND	NS	ND	ND	
Bromacil	SE40	3	45.0	175.0	ND	289.5	519.5
Diuron	SE15(1)	1	121.4	517.4	44.8	1681.0	2364.6
Diuron	SE15(1)	2	73.1	199.7	ND	353.5	636.3
Diuron	SE15(2)	4	84.1	548.9	ND	824.0	1467.0
Diuron	SE16(1)	1	118.6	630.4	47.3	908.0	1704.3
Diuron	SE16(1)	2	29.5	48.3	30.3	254.8	362.9
Diuron	SE16(2)	4	41.2	193.7	ND	213.2	458.1
Diuron	SE17(1)	1	15.9	684.9	36.4	358.3	1095.5
Diuron	SE17(1)	2	45.3	280.2	78.4	222.0	625.9
Diuron	SE17(2)	4	26.0	100.2	22.6	255.8	404.6
Diuron	SE18	3	25.8	250.7	ND	215.7	502.2
Diuron	SE18	10	ND	30.0	ND	66.5	109.0
Diuron	SE19	3	74.4	149.2	ND	369.7	603.3
Diuron	SE19	10	18.0	251.0	27.2	111.4	407.6
Diuron	SE20	3	42.2	1664.0	ND	244.7	1960.9
Diuron	SE20	10	ND	20.7	ND	69.5	102.7
Diuron	SE21	3	110.6	577.2	ND	382.3	1080.1
Diuron	SE21	10	ND	210.6	ND	52.1	275.2
Diuron	SE22	3	12.0	76.8	ND	119.8	218.6
Diuron	SE22	10	ND	63.8	ND	ND	88.8
Diuron	SE23(1)	1	37.5	1255.0	ND	278.4	1580.9
Diuron	SE23(2)	4	NS	NS	ND	43.8	
Diuron	SE24	1	152.8	788.6	25.5	1250.0	2216.9
Diuron	SE25	1	118.2	1057.0	33.7	246.8	1455.7
Glyphosate	SE06	5	79.0	89.0	ND	919.0	1112.0
Glyphosate	SE06	6	840.0	928.0	237	1518.0	3523.0
Glyphosate	SE07	5	1005.1	1658.3	35.0	1075.3	3773.7
Glyphosate	SE07	6	ND	412.6	52.3	196.0	685.9
Glyphosate	SE08	5	ND	278.7	ND	ND	353.7
Glyphosate	SE08	6	589.9	1000.3	ND	579.8	2195.0
Glyphosate	SE09(1)	7	956.0	322.0	ND	820.0	2123.0
Glyphosate	SE09(1)	8	61.0	628.0	72.8	837.0	1598.8
Glyphosate	SE09(2)	9	193.0	1312.0	ND	587.0	2117.0
Glyphosate	SE10(1)	7	111.0	179.0	ND	624.0	939.0
Glyphosate	SE10(1)	8	88.0	138.0	ND	561.0	812.0
Glyphosate	SE10(2)	9	233.0	1140.0	ND	708.0	2106.0
Glyphosate	SE11(1)	7	163.0	1036.0	ND	1520.0	2744.0
Glyphosate	SE11(1)	9	79.0	543.0	ND	299.0	946.0
Glyphosate	SE11(2)	8	317.0	3294.0	64	412.0	4087.0
Glyphosate	SE12	1	194.0	367.0	ND	ND	611.0
Glyphosate	SE13	1	192.0	325.0	ND	66.0	608.0
Glyphosate	SE14	1	665.0	1540.0	ND	237.0	2467.0
Oryzalin	SE28	8	ND	108.6	ND	1704.0	1825.1
Oryzalin	SE28	9	102.8	433.0	ND	795.0	1340.8
Oryzalin	SE29	8	ND	ND	ND	ND	27.5
Oryzalin	SE29	9	155.0	794.0	NS	1364.0	
Oryzalin	SE30	9	41.7	364.0	ND	542.8	958.5
Oryzalin	SE30	11	56.7	295.0	ND	795.0	1156.7

Appendix 4: Dermal Raw Data (con't)

Analyte	Study No.	Worker No.	Face/neck wipe (µg/sample)	Hand wipe (µg/sample)	Long johns (µg/sample)	T - shirt (µg/sample)	Dermal Exposure* (µg/person)
Oryzalin	SE31	9	114.0	629.0	ND	546.1	1299.1
Oryzalin	SE31	11	87.2	539.0	ND	741.0	1377.2
Oryzalin	SE32	10	ND	75.0	ND	ND	100.0
Oryzalin	SE33(1)	3	12.5	225.0	ND	ND	260.0
Oryzalin	SE33(2)	10	ND	50.0	ND	ND	75.0
Oryzalin	SE34	3	7.5	125.0	ND	ND	155.0
Oryzalin	SE34	10	ND	ND	ND	ND	27.5
Oryzalin	SE35	3	17.5	136.0	ND	25.0	188.5
Oryzalin	SE35	10	55.0	73.4	ND	ND	150.9
Oryzalin	SE36	3	27.3	85.1	ND	171.5	293.9
Oryzalin	SE37	3	ND	ND	ND	ND	27.5
Oryzalin	SE37	10	ND	ND	ND	ND	27.5
Oxyfluorfen	SE28	8	ND	6.7	ND	125.0	147.3
Oxyfluorfen	SE28	9	10.7	18.8	ND	214.3	256.2
Oxyfluorfen	SE29	8	ND	ND	ND	ND	34.4
Oxyfluorfen	SE29	9	9.7	28.5	ND	181.8	232.5
Oxyfluorfen	SE30	9	ND	14.8	ND	ND	46.0
Oxyfluorfen	SE30	11	ND	22.2	ND	68.2	106.0
Oxyfluorfen	SE31	9	15.2	41.2	ND	41.7	110.6
Oxyfluorfen	SE31	11	ND	48.7	ND	41.7	106.0
Oxyfluorfen	SE32	10	ND	ND	ND	ND	34.4
Oxyfluorfen	SE33(1)	3	ND	44.8	ND	ND	76.0
Oxyfluorfen	SE33(2)	10	ND	6.8	ND	ND	38.0
Oxyfluorfen	SE34	3	ND	8.8	ND	ND	40.0
Oxyfluorfen	SE34	10	ND	ND	ND	ND	34.4
Oxyfluorfen	SE35	3	ND	10.0	ND	ND	41.2
Oxyfluorfen	SE35	10	ND	ND	ND	ND	34.4
Oxyfluorfen	SE36	3	ND	8.6	ND	ND	39.8
Oxyfluorfen	SE37	3	ND	ND	ND	ND	34.4
Oxyfluorfen	SE37	10	ND	ND	ND	ND	34.4
Simazine	SE01	1	159.4	3042.0	30.9	212.0	3444.3
Simazine	SE01	2	ND	464.7	ND	105.0	583.7
Simazine	SE02	1	84.5	715.0	ND	183.0	992.5
Simazine	SE02	2	39.4	534.0	ND	157.0	740.4
Simazine	SE03	1	90.7	353.0	ND	172.0	625.7
Simazine	SE03	2	30.2	129.0	ND	56.3	225.5
Simazine	SE04	1	97.3	421.0	ND	105.6	633.9
Simazine	SE04	2	ND	34.7	ND	29.4	78.1
Simazine	SE15(1)	1	113.2	339.4	200.4	448.0	1101.0
Simazine	SE15(1)	2	95.2	288.6	118.7	1701.0	2203.5
Simazine	SE15(2)	4	135.2	328.5	24.5	824.2	1312.4
Simazine	SE21	3	43.0	246.0	ND	225.9	524.9
Simazine	SE21	10	ND	61.9	ND	ND	86.9
Simazine	SE22	3	9.4	47.8	ND	37.5	104.7
Simazine	SE22	10	ND	47.0	ND	ND	72.0
Simazine	SE27	1	173.9	1598.0	41.6	3814.0	5627.5
Simazine	SE38	13	50.0	819.0	ND	229.7	1108.7
Simazine	SE39	1	104.9	641.0	ND	441.5	1197.4

* - Dermal Exposure calculated with the following formula:

Face/neck Wipe (µg/sample) + Hand Wipe (µg/sample) + Long johns (µg/sample) + T-Shirt (µg/sample) = Dermal Exposure (ug/person)