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EXPOSURE OF COMMERCIAL PESTICIDE APPLICATORS TO THE HERBICIDE ALACHLOR

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Presented in this paper are the results of a pilot study to estimate the alachlor inhalation (2-chloro-2′,6′-diethyl-N-[methoxymethyl] acetanilide) and skin exposures of commercial pesticide applicators, who apply a variety of herbicides and insecticides to crop land. Twenty applicators and seven hauler-mixers participated in the study. Inhalation exposures ranged from 0.32 to 6.4 μg/m³, with a geometric mean of 1.6 μg/m³. Alachlor deposition on clothing patches was highly variable, ranging from <0.01 to 32.0 μg/cm². The thigh patches generally received more deposition than patches in other areas. Surface-wipe and hand- and glove-wash samples also indicated that the hands frequently were exposed; alachlor concentrations in postshift handwash samples ranged from 3 to 324 μg/sample. The results of the study indicate that commercial pesticide applicators encounter substantial exposures to alachlor and that proper precautions for reducing exposures are not always followed. Practical steps, in particular the use of good work practices, may be taken to reduce exposures in this population.

Alachlor (2-chloro-2′,6′-diethyl-*N*-[methoxymethyl] acetanilide) is the active ingredient in some of the most commonly used herbicides for pre-emergence control of weeds in corn and soybean crops.[1] Alachlor, in either emulsifiable concentrate or microencapsulated formulations, is typically mixed with water or sprayable fluid fertilizer and applied by ground boom equipment at rates ranging from 1.5 to 4 lbs/acre.[2,3] Data from 1991 indicated the annual usage of alachlor in the United States was in the range of 50 to 55 million pounds.[4]

Because alachlor was found to cause an increased incidence of tumors in animals, the Environmental Protection Agency (EPA) announced its decision in 1987 to classify alachlor for restricted use by only certified applicators or persons under their direct supervision.[5–7] No epidemiological studies of the carcinogenic potential of alachlor in humans have been conducted; however, two exposure assessment studies have been published by the manufacturer of alachlor.[8,9]

In these exposure assessment studies the participants mixed and applied relatively small amounts of alachlor while uniformly following the label requirements. No air- or hand-exposure measurements were collected. In calculating total alachlor exposure, the authors assumed that no alachlor passed through the workers' clothing and that only the face, back of the neck, and front of the neck were subject to alachlor exposure.

Presented in this paper are the results of a pilot study conducted by the National Institute for Occupational Safety and Health (NIOSH) to evaluate alachlor sampling and analytical techniques and to assess the exposure of commercial pesticide applicators and hauler-mixers to alachlor. Commercial applicators were studied because they use herbicides for several successive weeks over a large number of acres and are therefore likely to have greater exposure to alachlor than other work groups. Samples were collected concurrently to evaluate inhalation and skin exposures and to measure concentrations of alachlor metabolites in the urine. The results of the urine monitoring are presented in a separate report.[10]

BACKGROUND

Commercial applicators are hired by farmers to apply pre-emergent herbicides to crops shortly before or shortly after seeds are planted. The commercial applicators typically apply herbicide mixtures in a broadband or broadcast method using wide-wheeled flotation vehicles mounted with long-spray booms. A single job may require a few minutes to several hours to complete, depending on the terrain and size of the field. However, once the applicators leave the base station, they often do not return for several hours while applying herbicides to numerous fields. During the peak application season, it is not uncommon for the applicator's workday to last from 12 to 15 hr.

Hauler-mixers drive trucks mounted with large tanks, transporting herbicides, water, and liquid fertilizer from the base station to the field location of the applicators. Water or liquid fertilizer is transferred from the truck tank to the application vehicle tank through large hoses. The herbicides may be added to the

Mention of company names or products in this report does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH).

water or liquid fertilizer at the base station or at the spray site by using one of two systems: (1) a closed system, in which herbicide is drawn directly from a bulk tank into the flow of water or liquid fertilizer as it is pumped into the application tank; or (2) an open-pour system, in which herbicide is poured from small batch containers into the top of the application tank or an induction box on the side of the vehicle.

Applicators and hauler-mixers also spend a considerable portion of their time involved in maintenance operations. These operations are often conducted in the field where the workers have limited access to washing facilities, and no opportunity to decontaminate the equipment or themselves.

METHODS AND MATERIALS

Selection of Study Participants

Every registered pesticide application company specializing in the agricultural use of pesticides in three counties in east central Illinois and three counties in southwestern Ohio was contacted by telephone to determine their use of alachlor, types of application equipment used, and number of full-time applicators employed. These counties were selected because they were noted for high corn and soybean production.

A total of 75 base stations were located in these 6 counties, and 31 stations used alachlor as one of their main pre-emergent herbicides. Applicators and hauler-mixers from 12 of these 31 stations were monitored for 1 day when they were scheduled to use substantial amounts of alachlor. Five of the stations were located in Illinois and seven in Ohio. Some of the companies represented large, multistation companies, while others represented small, single-station companies, but none of the 12 stations employed more than 5 full-time applicators. The primary types of equipment used commercially to apply herbicides were represented at the selected stations.

During the study applicators used a variety of alachlor-containing formulations, but Lasso Micro-Tech® was used most frequently. The alachlor-containing herbicides often were mixed with other herbicides to broaden the weed control spectrum, and from job to job workers switched from alachlor-containing mixes to mixes not containing alachlor, such that during a portion of the workday they were not using alachlor. The amount (in pounds) of all types of herbicides handled by each study participant and the length of time that each applicator spent applying alachlor on the survey day were recorded. Bulk samples of all the herbicides applied during the workday were used in sample analysis to delineate alachlor from the presence of structural analogs in other herbicides. A list of all the pesticides used by the applicators in the study is presented in Table I.

TABLE I. Herbicides Applied by Applicators During the Study

Trade Name	*Active Ingredients*
Aatrex	atrazine
Banvel	dicamba
Bicep	atrazine + metolachlor
Bladex	cyanazine
Bullet	alachlor + atrazine
Butyrac	2,4-D
Cannon	alachlor + trifluralin
Canopy	metribuzin + chlorimuron ethyl
Command	clomazone
Commence	trifluralin + clomazone
Dual	metolachlor
Eradicane	EPTC
Extrazine	cyanazine + atrazine
Gramoxone	paraquat
Judge	alachlor
Lariat	alachlor + atrazine
Lasso EC	alachlor
Lasso Micro-Tech	alachlor
Lorox	linuron
Preview	metribuzin + chlorimuron ethyl
Scepter	imazaquin
Sencor	metribuzin
Sonalan	ethalfluralin
Squadron	pendimethalin + imazaquin
Tandem	tridiphane
Treflan	trifluralin
Turbo	metolachlor
Weedone	2,4-D

Air Sampling and Analysis

Inhalation exposure to alachlor was measured using a personal air sampler attached to the lapel of study participants. The air sampler consisted of a glass fiber prefilter in a 37-mm two piece cassette, connected to an Orbo-42® adsorption tube. Air was drawn through the filter and tube at a rate of 1 L/min for the duration of the workday.

Hexane extracts from the filters and tubes were analyzed using a modification of NIOSH Analytical Method 5503.[11] A gas chromatograph equipped with an electron capture detector and a fused silica capillary column was held at a temperature of 75°C for 2 minutes, then ramped at 40°C /min to 150°C, ramped again at 5°C/min to a final temperature of 235°C. Helium was used as the carrier gas. With the use of this method, the lower limit of detection (LOD) and the lower limit of quantitation (LOQ) ranged from 0.002 to 0.1 µg/sample and 0.007 to 0.4 µg/sample, respectively.

The total air concentration was estimated by summing the micrograms of alachlor on the filter and adsorption tube, and dividing by the volume of air sampled. Air concentrations were expressed in micrograms of alachlor per cubic meter of air sampled (µg/m^3). To estimate the total number of micrograms of alachlor inhaled during the work shift, the air concentration was multiplied by an inhalation rate of 29 L/min and the time period in minutes over which the sample was collected. An average inhalation rate of 29 L/min has been estimated for workers doing light work.[12]

Patch Sampling and Analysis

Alachlor skin deposition was estimated by attaching up to nine 8-ply 5.0 × 7.25 cm hexane prewashed gauze patches to

the outside of the participants' clothing. The patches were attached with safety pins to the cap (if worn), right and left sleeve just above the elbow, right and left chest, center of the back near the base of the neck, right and left front thigh, and front-center of the undershirt or inside of the shirt if no undershirt was worn.[12] The patches were worn for the entire duration of the workday. Hand deposition was assessed using a washing technique that is described later.

Hexane extracts from the patches also were analyzed using gas chromatography with electron capture.[11] The LOD and LOQ for alachlor on the gauze patches ranged from 0.04 to 0.2 µg/sample and 0.1 to 0.5 µg/sample, respectively. The concentration of alachlor deposited on the patches was expressed as the number of micrograms per square centimeter (µg/cm^2).

The concentration of alachlor on these patches was multiplied by the surface area of the corresponding body region represented by the patch and summed to estimate the total number of micrograms of alachlor deposited on the body. This total body deposition estimates the amount of alachlor deposited on the clothing and skin areas unprotected by clothing but excludes the hands and feet. EPA-recommended surface areas were used for the body regions (Table II).[12,13] The extrapolated deposition on all the respective body regions was summed to estimate the total deposition of alachlor on the body. The concentration of alachlor on the undershirt patch was compared with the average concentration on the chest patches to estimate penetration of alachlor through the clothes.

TABLE II. Surface Areas for Regions of the Adult Body and Locations of Exposure Pads Representing the Regions

Region of the Body	*Surface Area (cm^2)*	*Location of Patch Representing Region*
Head	1300	cap
Front of neck and torso	3700	chest
Back of neck and torso	3660	back
Arms	4120	sleeve
Legs	6200	thigh

Hand and Glove Washes

Evaluation of hand exposures was not planned initially in this pilot study, but when it was discovered that workers often did not wear protective gloves, the following technique was added for monitoring hand exposures. At the end of the workday, each participant's hands were washed in a solution of 10% ethanol and distilled water. Each hand was placed in a plastic bag containing 75 mL of the solution and shaken vigorously for 30 seconds. If the applicators and mixers wore protective gloves, the insides of the gloves were washed by pouring 75 mL of the 10% ethanol solution into the gloves and shaking vigorously for 30 seconds. The gloves then were inverted, and a wash sample of the outside of the gloves was collected in the same manner.

Methylene chloride extracts of the washes were dried, concentrated in a hot water bath, and solvent exchanged to hexane. The hexane extracts then were analyzed by a gas chromatograph equipped with an electron capture detector. The LOD and LOQ for alachlor in the hand- and glove-wash samples ranged from 0.02 to 0.1 µg/sample and 0.06 to 0.4 µg/sample, respectively. The concentration of alachlor in micrograms per milliliter of wash solution (µg/mL) were multiplied by 75 mL to estimate the total number of micrograms washed from the hands and gloves.[12]

Surface-Wipes

Inside some application vehicles, the surfaces of steering wheels, gear shift knobs, control levers, and arm rests were wiped with prewashed gauze wipes saturated with hexane. These samples were collected only to detect the presence of alachlor inside the vehicles, and no attempt was made to cover a common surface area. Analysis of hexane extracts from the wipes was performed using gas chromatography with electron capture. The LOD and LOQ for the surface wipes ranged from 0.04 to 0.2 µg/sample and 0.1 to 0.7 µg/sample, respectively. The concentration of alachlor on the wipes was expressed in micrograms per sample. Because the wipes were not collected over a uniform surface area, the actual concentration of alachlor on the wipes has limited meaning. However, the samples do indicate the presence and, in a gross way, the degree of alachlor surface contamination inside the vehicles.

Quality Control and Statistical Analysis

For quality control of sampling and analytical procedures, field blanks and sampling media spiked with known amounts of alachlor were submitted along with the exposure samples. The analytical recoveries of the spiked samples averaged 90% for the Orbo-42 adsorption tubes, 35% for the prefilters attached to the adsorption tubes, 81% for the gauze patches and hexane-wipes, but less than 5% for the hand and glove washes. These quality control samples indicate that the analytical techniques may underestimate the inhalation and body exposures, but the technique for the washes was inadequate for monitoring hand exposures. Therefore, the results of the hand- and glove-wash samples may only be viewed as semiquantitative. Alachlor was not detected on the field-blank samples.

The geometric mean (GM) and geometric standard deviation (GSD) of the exposure measurements were calculated as summary statistics. In calculating the summary statistics, a sample below the analytical limit of detection was given a nonzero value of the limit of detection divided by the square root of two.[14] T-tests were used to compare differences in the logarithms of the total inhalation and skin exposure estimates by job, equipment, size of the application company, presence of air conditioning in the vehicles, and use of protective gloves. Correlations between the total inhalation and skin exposure estimates and alachlor usage (pounds of alachlor applied, number of acres sprayed, and length of application period) were evaluated using polynomial regression.

RESULTS

Twenty applicators and seven hauler-mixers participated in the exposure assessment study. All participants were male, as is typical for this occupation. The average age and length of employment of the participants are presented in Table III. Over one-half of the participants had been employed by commercial application companies for ≥5 yrs, and only five had been employed for ≤1 yr.

Fifteen of the applicators drove three- or four-wheeled flotation tractors, while five drove wide-wheeled trucks. The cabs of all the vehicles were enclosed. The spray booms and tanks were located in the rear of all the vehicles, except for one, a Hagie Hi-Boy®, which had the spray boom located directly in front of the driver and the tanks mounted on the sides. The exposure measurements collected from the driver of the Hagie Hi-Boy are presented separately from the other applicators' exposure measurements.

The average amount of alachlor handled and applied by the applicators and hauler-mixers on the day they were monitored, the number of acres sprayed, duration of alachlor application, and duration of the workday are presented in Table IV. As reflected by the general nature of commercial pesticide application, wherein the amounts and types of pesticides used and duration of the workday depends on customer needs and the weather, the duration of the workday and amount of alachlor used by each individual ranged widely. Only 1 applicator exclusively used alachlor on the day of the survey, while 14 applicators (70%) used 3 or more herbicides in addition to alachlor.

The geometric mean, geometric standard deviation, and range of alachlor exposure measurements from the air, clothing patch, and hand-wash samples are presented in Table V by job classification. Measurements for some subjects are missing: 10 applicators and 1 mixer did not wear a cap, and hand-wash samples from 12 subjects and an undershirt sample from 1 applicator were damaged during shipment and discarded.

The amount of alachlor on the air filters was generally four to five times higher than the amount on the adsorption tubes; median weight for the filters and tubes was 0.9 μg and 0.2 μg, respectively. In only 3 of 27 air samples did the amount of alachlor detected on the adsorption tubes exceed the amount on the filters.

The results of the glove-wash samples are presented in Table VI. Washings from gloves that had a cotton lining are presented separately from gloves with no lining. Rubber gloves with a cotton lining are frequently worn by the applicators when working with anhydrous ammonia, but the workers also may use them

TABLE III. Age and Length of Employment of Study Participants

	# Subjects	Age (yrs) Mean	Age (yrs) Range	Length of Employment (yrs) Mean	Length of Employment (yrs) Range
Applicators	20	32.0	19–50	5.7	0.2–14.2
Hauler-mixers	7	39.4	22–55	7.1	0.1–25.0

TABLE IV. Handling of Alachlor and Duration of the Workday

	Applicators (n = 19) Mean	Applicators (n = 19) Range	Hauler-Mixers (n = 7) Mean	Hauler-Mixers (n = 7) Range
Duration of workday (hrs)	11.7	3.5–15.4	11.8	6.8–14.1
Alachlor handled (lbs)	436	65–897	454	140–897
# Acres sprayed with alachlor	168	26–336	—	—
Duration of alachlor application (hrs)	2.9	0.5–6.5	—	—

when handling pesticides. Although the amount of alachlor washed from the outside of the gloves was always greater than the amount washed from the inside, alachlor was detected in all of the inside glove-wash samples. The inside and outside concentrations were linearly and directly correlated ($r = 0.74$, $p = 0.001$). The ratio between the average outside concentration and the average inside concentration was 12 for the unlined gloves and 5 for the cotton-lined gloves. Although the comparison did not achieve statistical significance, the average alachlor concentration washed from the inside of the lined gloves was over twice as high as the average concentration washed from the inside of the unlined gloves ($p = 0.37$).

The results of the surface-wipe samples are presented in Table VII. Alachlor was detected in all but two of the surface-wipe samples collected inside the vehicles. The actual concentrations on the wipes have limited meaning because nonuniform surface areas were covered, but five of the steering wheel wipe samples contained over 100 μg of alachlor.

The results of the hand-wash measurements are presented in Table VIII by whether the workers wore no gloves, cotton-lined gloves, or unlined gloves. Although the comparison did not achieve statistical significance ($p = 0.56$), the hand-wash measurements are consistent with the supposition that workers who wear no gloves have the greatest hand exposures, workers who wear cotton-lined gloves have the next greatest hand exposures, and workers who wear unlined gloves have the lowest hand exposures.

The geometric means and standard deviations of the estimated total alachlor inhaled, deposited on the skin and clothing, and contaminating the hands are presented in Table IX. Since hand-wash samples were available for only 15 of the participants, hand exposures could be estimated for these individuals only.

The total inhalation and body exposure estimates of the applicators were not significantly correlated with the number of pounds of alachlor applied, number of acres sprayed with alachlor, or length of time spent applying alachlor during the workday ($p > 0.05$). Hand exposures were not included in these correlations. Also, no statistically significant differences (t-test, $p > 0.05$) were observed between the mean exposure measurements by job (applicator versus hauler-mixer), type of application equipment driven (flotation tractor versus

TABLE V. Results of Air, Clothing Patch, and Hand-Wash Measurements by Job Classification

	Air ($\mu g/m^3$)	Clothing Patches ($\mu g/cm^2$)						Hand Wash[A] (μg)
		Cap	Chest	Arms	Back	Thighs	Under shirt	
Applicator who drove vehicle with spray boom in front								
Sample concentration	6.35	—	1.24	2.84	1.36	29.87	0.13	120
Applicators who drove vehicle with spray boom in rear								
# Samples	19	10	19	19	19	19	18	11
# Samples > LOQ	19	9	19	19	19	18	18	11
GM[B]	1.66	0.11	0.20	0.42	0.13	0.85	0.09	21
(GSD)	(2.15)	(6.85)	(4.01)	(3.26)	(3.53)	(7.42)	(4.22)	(5.5)
Range	0.32–4.39	<0.01–1.37	0.01–2.20	0.08–2.49	0.01–2.93	<0.01–9.42	0.01–1.33	2–320
Hauler-mixers								
# Samples	7	6	7	7	7	7	7	3
# Samples > LOQ	7	6	7	7	7	7	7	3
GM[B]	1.21	0.17	0.25	0.12	0.06	1.69	0.10	16
(GSD)	(1.81)	(4.53)	(9.05)	(2.12)	(1.38)	(2.34)	(3.35)	(5.6)
Range	0.47–3.39	0.05–2.40	0.07–31.76	0.07–0.63	0.05–0.13	0.40–4.67	0.02–0.53	3–84

[A] The hand wash samples should only be viewed as semiquantitative estimates of exposure.

[B] In calculating a geometric mean and geometric standard deviation, a sample below the analytical limit of detection was given a value of the limit of detection divided by the square root of two.[14]

truck), or size of the company (large multistation company versus small single-station company). However, the applicator who drove a Hagie Hi-Boy with the spray booms in the front of the vehicle had an air exposure estimate 1.7 times higher and a skin exposure estimate over three times higher than any other applicator. No statistically significant differences were noted in the air and body exposures between workers with air conditioning in their vehicles and those without air conditioning.

DISCUSSION AND CONCLUSIONS

Commercial pesticide applicators who spray crop land may have the most intensive exposure to a wide range of herbicides of any work group in the United States. The measurements collected in this study represent only their exposure to the herbicide alachlor.

Air measurements indicated that inhalation exposures occurred primarily in the form of aerosol. The vapor pressure of alachlor is low (2.2×10^{-5} mm Hg at 25°C); therefore, inhalation exposure would be expected to occur primarily in the form of aerosol rather than vapor. Although the air samplers did not distinguish particle size, the orientation of the air sampling devices and the use of the filters closed-face would prevent the collection of very large particles by the samplers.

The clothing patch measurements indicate that alachlor deposition on the clothing was quite variable. This variability probably reflects differences in work practices while using alachlor during the workday. The thighs received the greatest amount of alachlor deposition. Thigh exposure most likely occurred during the mixing and loading operations, when both applicators and hauler-mixers leaned against contaminated equipment or were splashed with the application mixture, and when workers wiped contaminated hands on their pants legs.

Clothing provided some protection, but alachlor penetrated the clothes, as indicated by patches placed under the shirts. On average the alachlor concentrations detected on patches beneath the shirts were approximately 60% lower than chest-patch concentrations on the outer shirt surface. A wide variety of clothing materials and styles was worn by the workers, and the type of clothing and fabric

TABLE VI. Results of Glove-Wash Measurements

Location	Glove Wash Samples[A] # Samples	GM (GSD) μg/sample		Range μg/sample
Unlined gloves				
Outside gloves	10	72 (4.6)	12	5–700
Inside gloves	10	6 (7.5)		<1–130
Cotton lined gloves				
Outside gloves	7	68 (3.4)	5	11–360
Inside gloves	7	14 (3.4)		2–50

[A] Samples should be viewed as semiquantitative measurements.

TABLE VII. Results of Surface Wipe Measurements[A]

Location	# Samples	# Samples > LOQ	Median µg/sample	Range µg/sample
Steering wheel	17	16 (94%)	38	<1–1200
Arm rest/door handle	9	8 (89%)	16	<1–38
Gear shift/control switches	5	5 (100%)	12	3–87

[A] Samples should be viewed as semiquantitative measurements.

[B] In calculating the geometric mean and geometric standard deviation, a sample below the analytical limit of detection was given a value of the limit of detection divided by the square root of two.[14]

construction likely influenced the degree of alachlor penetration to the skin. Unfortunately, placing only one patch on the chest inside the shirt is not adequate to represent the large variability in penetration through the various types of clothing worn in the study.

The weight of woven fabrics most influences their penetration resistance—as weight decreases, penetration increases. Nonwoven fabrics and woven fabrics of heavy cut twill have been shown to provide the best protection.[15] Because herbicide application occurred primarily during the warmer months, workers commonly wore lightweight clothing and shirts with short sleeves. Although the product label recommends wearing long-sleeved shirts or jackets of tightly woven material, only six (24%) of the participants in this study were observed to wear shirts with long sleeves.

Although hand-wash samples were analyzed for only 15 of the study participants, the data indicate that hand exposures were highly variable, and that protective gloves were sometimes not effectively used to prevent alachlor exposure. It must be emphasized, however, that these wash samples suffered from some major limitations. A single hand-wash sample collected at the end of the work shift probably did not reflect the true hand exposure, since the workers cleaned and re-exposed their hands several times throughout the work shift. And washings did not collect any alachlor that had absorbed through the skin already during the workday. Also, recovery of alachlor from spiked wash samples was <5%, demonstrating that the wash sample analysis greatly underestimated the true alachlor concentrations. Hand exposure has frequently been noted to be the most significant contributor to the total dermal exposure of pesticide workers.[16–18]

The wipe samples demonstrated that, although the cabs of all the vehicles were enclosed, alachlor did contaminate surfaces inside the vehicles, particularly surfaces in frequent contact with the hands, such as steering wheels and gear shifts. The applicators and hauler-mixers were never observed to wear gloves while driving their vehicles.

Because of small sample size and poor recovery of alachlor from the wash solutions, it is difficult to draw firm conclusions from the glove- and hand-wash samples. However, the glove- and hand-wash samples indicated that the insides of gloves were routinely contaminated with alachlor but do afford some protection to the hands against exposure.

The evidence of alachlor inside the gloves highlights several problems with the use of protective gloves noted during the surveys. Applicators and hauler-mixers were observed wearing their gloves only during mixing, loading, and maintenance operations; immediately after completing these tasks, the gloves were removed. Most of the applicators and hauler-mixers used the same pair of gloves for several successive days without cleaning or replacement, putting them on and removing them many times during the workday. Workers continued to wear gloves that had obvious cracks and holes. Obviously, as the amount of alachlor deposited on the outside of the gloves increased, so would the amount of alachlor on the inside. Workers often removed their gloves during some maintenance maneuvers that were difficult to perform while wearing protective gloves. After completing the maneuvers, they would then put their gloves back on without washing their hands. These practices served to constantly contaminate the inside of the gloves.

Although 24 out of 27 applicators and hauler-mixers wore protective gloves when handling herbicides, 9 of these participants wore rubber, cotton-lined gloves designed for use with anhydrous ammonia. The cotton lining may absorb pesticides and make these gloves difficult to decontaminate; thereby, workers' hands would be chronically exposed with continued use of these gloves.

In addition to improper use of protective gloves, other problems were observed during the study. The product label of herbicides containing alachlor requires that mixers and applicators wear goggles or face shield; rubber gloves; long trousers; long-sleeved shirt or jacket of tightly woven material; along with boots high enough to cover the ankles when transferring and mixing, and when adjusting, repairing or cleaning equipment. Only two workers were observed wearing goggles or face shields during loading operations, and the applicators did not wear caps, long-sleeved shirts, or rubber boots routinely. Workers often were observed to lean against contaminated equipment during maintenance and loading operations, resulting in exposure to the waist, hips, and upper legs. A few workers were observed to smoke cigarettes and eat with contaminated hands. On two occasions applicators were drenched with herbicides (other than alachlor) when the spray tank overflowed during loading. These workers continued to work several hours, wearing clothing soaked with herbicide.

The lack of correlation between the total air and skin exposure estimates and alachlor usage, and the lack of significant differences between exposure estimates by type of application

TABLE VIII. Comparison of Hand-Wash Measurements by Type of Gloves Worn

Type of Gloves Worn	# Samples	GM (GSD) (µg)	Range (µg)
No gloves worn	2	47 (1.4)	38–58
Cotton lined gloves	6	31 (6.9)	2–324
Unlined gloves	7	13 (5.2)	2–123

TABLE IX. Summary Statistics by Job for Estimated Number μg Alachlor Inhaled, Deposited on Clothing and Skin, and Contaminating the Hands

Exposure Measurement	*Number of Measurements*	*GM (GSD) (μg)*	*Range (μg)*
Applicator who drove vehicle with spray boom in front			
Air	1	151	
Clothing and skin	1	208 000	
Hand[A]	1	123	
Applicators who drove vehicle with spray boom in rear			
Air	19	31 (2.3)	6–90
Clothing and skin	19	12 500 (3.2)	1430–62 700
Hand[A]	11	20 (5.5)	2–320
Hauler-mixers			
Air	7	24 (1.8)	11–68
Clothing and skin	7	16 800 (3.2)	3490–139 000
Hand[A]	3	16 (5.6)	3–84

[A] Hand measurements should be viewed as semiquantitative estimates of exposure.

equipment driven or the presence of air conditioning in the vehicles, may indicate that individual work practices are more important contributors to exposure. However, this was a small cross-sectional study with few observations in each comparison group. Therefore, the power of the study to detect differences between the mean exposures of each group and the ability to compare worker exposures within multiple groups is limited.

Since workers in this small study were observed over a brief period of time, the results may not be generalizable to all commercial pesticide applicators who apply herbicides to crop land, and evaluation of all potential risk factors for exposure may not be adequately addressed. However, the results of this study indicate that commercial pesticide applicators encounter substantial exposures to alachlor. Proper precautions for reducing exposures were not always followed, either because of attitude or the demands of the job. Practical steps may be taken to reduce exposures in this population, but the training that pesticide workers receive and the design of the equipment used to load and apply pesticides may need further evaluation.

RECOMMENDATIONS

As is the case with most herbicides, no government agency or safety and health association has established standards for safe levels of occupational exposure to alachlor. Because it has been shown to cause cancer in animals, and its potential to cause cancer in humans is unknown, it is prudent to reduce exposure through good work practices. For the proper handling of alachlor, EPA has established requirements, which are printed on the product label. Commercial pesticide applicators also are required to comply with the EPA Worker Protection Standard 40 *CFR* 170.[19] The following recommendations may serve to reduce exposures when handling herbicides in general.

(1) Station managers and supervisors should evaluate work practices continually and require adherence to training and label requirements for the safe handling of pesticides.

(2) Protective gloves should be worn during mixing, loading, and maintenance operations, or whenever the hands are likely to come in contact with pesticides. Gloves resistant to permeation by pesticides should be used; cotton-lined gloves should not be used. Care should be taken to avoid contamination of the insides of gloves. If gloves must be removed to perform maintenance operations, hands should be washed before redonning the gloves. If gloves become damaged, they should be replaced.

(3) Washing with soap and water has been shown to remove alachlor from the skin effectively.[20] Therefore, workers should wash their hands frequently, especially after mixing, loading, and maintenance operations. Workers should carry soap and water with them to wash and rinse their hands when in the field away from washing facilities. They should never smoke cigarettes or eat with contaminated hands.

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