Exposure Received from Application of Animal Insecticides

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Part of an investigation of data collection methods in epidemiologic studies of farmers evaluated exposures received by farmers from the application of insecticides to animals. Twenty farmers were monitored during a normal application using a fluorescent dye surrogate for the active ingredient (AI). Two exposure measures were estimated, AI concentration and the time-weighted average for the application period (TWA_a). Four application methods were used: high- (n=5) and low-pressure (n=3) spraying, backpack (n=2) and pour-on (n=10). The two farmers using a backpack sprayer had nondetectable levels of dye. Only two of the farmers using the pour-on method had detectable dye levels, but these levels were high. All of the low- and high-pressure sprayers had detectable amounts of dye. Multiple layers of clothing, gloves, and boots (n=10) were associated with a low mean AI concentration for the exposed farmers (18 μg) and more than two-thirds of the farmers wearing this amount of clothing had nondetectable exposures. In contrast, clothing providing little or no protection was associated with a significantly higher ($p<0.01$) average AI concentration (4420 μg), and less than a third of the farmers with this degree of protection had nondetectable exposures. Poor work practices (leaking equipment, contact with wet animals or fences, and back splash) were associated with statistically higher exposure levels ($p<0.01$) than the absence of such practices. There was a moderate statistically significant association between AI concentration and TWA_a with total volume of the AI/dye/water mixture using the Spearman coefficient. Time was significantly inversely proportional to the two exposure measures. The association between the two exposure measures and AI volume was not significant.

Keywords: farm workers, livestock, insecticide application

Some pesticides are known to have carcinogenic, neurologic, reproductive and, other adverse health effects in humans,[1] and monitoring provides important information on the level of exposures for various pesticide-associated tasks. Although there have been numerous monitoring reports on pesticide exposure to applicators and harvesters from use of pesticides on crops, the authors know of no reports that have presented measurements taken during pesticide application to farm animals. Pesticide treatment of animals, however, may also be hazardous, as suggested by elevated risks of cancer and other adverse health effects[1,2] associated with the use of animal insecticides, including organophosphates and chlorinated hydrocarbons[3–8], and with raising hogs, chickens, cattle, and other animals.[7–9]

The use of dermal patches has been the traditional method for estimating dermal exposures from pesticides.[10] The patch, however, measures only those exposures that occur where the patch is located. Because it is impossible to predict where a pesticide may be deposited, the patch may not reflect the true exposure. Some investigators have attempted to compensate for this problem by extrapolating to body areas that were not measured. It has been shown, however, that deposition is not uniform,[11] and therefore extrapolation may either under- or overestimate the exposure. Video imaging techniques were developed to assess relative concentrations of total body exposure.[11]

This report describes the results of using a video imaging technique on farmers in Iowa applying insecticides to animals.[12] It is part of a series of reports[13,14] evaluating data collection techniques in epidemiologic studies of farmers. In these studies, because study subjects cannot report exposure levels, investigators often ask questions on exposure determinants to allow assessment of exposures of study subjects. This approach assumes that the determinants are reasonable surrogates for exposure level. It is important, therefore, to know what exposure determinants predict exposure measures. This study evaluated possible determinants in relation to the exposures received.

METHODS

Livestock farmers were identified from a database of over 200 Iowa farmers.[13] Twenty who indicated they would apply a liquid insecticide to livestock in 1991 agreed to be monitored. It was not necessary to restrict the type of pesticide applied, as concentrations received from deposition or impaction are believed to be a function of physical, not chemical, factors.[15] All tasks associated with insecticide application on a normal day, including mixing, application, clean-up and any incidental contact with the insecticide, were measured. Clothing was selected by the farmer.

Four application methods were monitored. In the high-pressure systems, either a mixed solution of concentrate and water was pumped with no mixing of additional water or the concentrate was mixed with water in line. The low-pressure sprays relied on the force of water from a regular hose to suction and mix the insecticide from a spray pot at a regulated rate. Farmers used a 32-fluid ounce pot, a screw-on spray cap with a suction line into the pot, a mixture ratio knob, and a nozzle. The backpack or handheld system used air pressure provided by a pump on the unit to force the insecticide mixture from the unit. Farmers using pour-on applications had a dipper that measured the desired amount of insecticide poured on the animal. All pour-on applications used undiluted concentrate.

A series of two still frame video images was taken of the front, left, and right side and back of the head, arms, legs, and torsos. The first set was taken before application; the second after application. Immediately before the mixing step in the application, fluorescein dye Uvitex OB [2,5-bis-(t-tert-butyl-2-benzoxazolyl)thiophene] was added to the insecticide. A rate of 0.3 g dye/gallon of the estimated amount of end product the farmer planned to use was mixed with acetone and added to the insecticide. This rate varied in one instance in which the total amount of liquid estimated was 16 fluid ounces, so that 0.15 gm of dye was added. The application process was monitored by the study staff with times, rates, method, and application conditions noted. If multiple layers of clothing were worn by the farmer due to the cold weather conditions, video images were taken only from the waist up (head, torso, and hands).

Video images of the exposures were made using a Javelin JE7442X high resolution two-thirds inch CCD black and white television camera mounted with an Icon TV zoom lens (1:1.2/12.5–75) and fitted with a Kodak Wratten 2E filter, DT2851 high resolution frame grabber (512 × 512 pixel resolution with 0 to 255 gray scale (8-bit), DT 2858 auxiliary frame processor, DT-IRIS driver (IDRV51, sys v. 1.02), and DT-IRIS subroutine library. Vitae software was used.[11] Eight F40 BLB ultraviolet (UV) bulbs behind long-wave selective UV-selective glass filters were positioned 90 cm from the 70-cm² subject plane. The camera was placed at 115 cm from the subject plane. The subject plane and the UV light panel were permanently positioned to minimize deviation from farmer to farmer, and the television camera was placed in a fixed position for each set of images. Images were downloaded to a Jumbo 250 MB tape backup system from Colorado Memory Systems for later analysis.

Because of the variability of skin or background gray levels, eight locations on the forearms of eight subjects (four on the right and left arms each) were used to develop the calibration curve. Each location was first video imaged three times without the presence of the dye. Two grams of fluorescein dye were then mixed with 1 L of acetone and diluted into eight concentrations of 0.39 to 50 mg dye. These solutions were then applied with a gas chromatograph syringe to approximately a 10-cm² area at each location, for a total of 64 measurements per person. After drying for 15 minutes, three replicate image series of the dyed area were taken. The values of the pre- and postexposure levels were each averaged and the slopes of the means and medians were plotted as a linear regression against the level of fluorescence. The same calibration regression numbers were used for each of the seven insecticides applied by the farmers. The limit of detection for the dye was 1.25 μg. When dye concentrations were below the limit of detection, this value was divided by the square root of two[16] for inclusion in statistical analyses.

The primary exposure measure used here is the concentration of the active ingredient (AI), estimated by multiplying the measured fluoresced dye concentration by the ratio of AI to dye in the liquid applied. A second measure is the estimated time-weighted average of the application period (TWA_a), calculated by dividing the AI concentration by the duration of the application.

Exposure determinants evaluated in this study were the application method, the level of protection from clothing, work practices (poor or not), the volume of the AI, the total volume of the AI/dye/water mixture, and application duration. The level of protection was rated as high if gloves, boots, and several layers of normal or Tyvek® clothing were worn and low if a single layer or less of normal clothing and no boots were worn. For the latter category, gloves may or may not have been worn.

The analysis used standard statistics to describe the results (mean, standard deviation [SD]) and to test differences between exposure groups (t-tests, Fisher's exact test).[17] The Spearman correlation coefficient (r_S) was used to evaluate associations between the exposure measures and exposure determinants.

RESULTS

Prolate (phosmet), Taktic (amitraz), HY-PY (piperonil butoxide), Warbex (famphur), Hard Hitter (permethrin), Ectiban EC (permethrin), Dursban (chlorpyrifos), and Tiguvon (fenthion) were used. These insecticides were applied to cattle and hogs using from 0.1 to 15.1 L of AI (mean=4.9 l, SD=5.4). That corresponded to a total volume (AI/dye/water) range of 0.9–201 L (mean=61.6 l, SD=78.3). Application duration ranged from 0.05 to 3.0 hours and averaged 1.4 hours. For 10 farmers no fluorescence was observed. The others had AI concentrations that ranged from 27 to 19,658 μg. The mean for all 20 farmers was 2219 μg (geometric mean [GM]=26.1 μg, geometric standard deviation [GSD]=45.7). These corresponded to TWA_as of 31 to 109,211 μg/hr (mean=7530 μg/hr; GM=29.0 μg/hr, GSD=99.4). Hands were the most frequently exposed part of the body, but eight farmers had other parts of the body exposed, including the head or face, forearms and legs. Two farmers appeared to receive some facial exposure from rubbing their skin with their contaminated gloves. Clothing ranged from pants, t-shirts opened to the chest and no gloves to gloves, boots, and several layers of clothing.

Two farmers used backpacks, and no fluorescence was found on either farmer (Table I). Among those farmers using high-pressure spray equipment, all five had measurable amounts of dye, but the average concentrations of AI and the TWA_a associated with

TABLE I. Amount of Fluorescence by Application Method, Level of Protection from Clothing, and Quality of Work Practices

Exposure Determinant	n	No. of <LOD[A]	Range: AI Concentration (μg)	Range: TWA_a (μg/hr)	Arithmetic Mean (SD): AI Concentration (μg)	Arithmetic Mean (SD): TWA_a (μg/hr)	Geometric Mean (SD): AI Concentration (μg)	Geometric Mean (SD): TWA_a (μg/hr)
Application method[B]								
Backpack	2	2	ND[E]	ND	ND	ND	ND	ND
High-pressure spray	5	0	27–790	31–1491	342 (305)	632 (589)	198.01 (4.0)	319.50 (4.9)
Low-pressure spray	3	0	55–19,658	550–109,211	7637 (10,528)	39,125 (60,799)	1512.15 (20.3)	7704.55 (14.1)
Pour-on	10	8	ND–15,036	ND–23,580	1976 (4822)	3004 (7509)	5.52 (48.1)	2.72 (85.7)
Level of protection[C]								
High	10	7	ND–88	ND–126	18 (31)	71 (173)	2.98 (7.2)	1.95 (19.6)
None to low	10	3	ND–19,658	ND–109,211	4421 (7075)	14,988 (33,895)	228.88 (57.9)	433.24 (83.4)
Poor work practices[D]								
No	13	9	ND–15,036	ND–6453	1164 (4168)	543 (1782)	3.34 (18.1)	2.40 (29.9)
Yes	7	0	ND–19,658	ND–109,211	4179 (7042)	20,505 (40,003)	1188.15 (6.2)	2983 (10.2)

[A]<LOD = below the limit of detection.
[B]The difference between the means of the log-transformed exposures for high- and low-pressure spray was not statistically significant, p > 0.05. Backpack and pour-on methods were not included in the model because of the less than detected values.
[C]The difference between the means of the log-transformed exposures for levels of protective clothing was statistically significant, p < 0.01.
[D]The difference between the means of the log-transformed exposures for quality of work practices was statistically significant, p < 0.01.
[E]ND = not detected.

this method of application were moderate (concentration mean=342 μg; TWA_a mean=632 μg/hr). This method was also associated with a relatively low variability (GSD=4.0–5.0). Contact with a wet surface or from back splash of the spray appeared to have been the source of the high exposure from this method.

Higher fluorescence was observed from low-pressure spraying (mean AI concentration=7637 μg; mean TWA_a=39,125 μg/hr). Leaking equipment and contact with wet animals or fences were the sources of the two high exposures. The exposure concentration received from using the pour-on method averaged 1976 μg AI and the TWA_a averaged 3004 μg AI/hr, but only two of the farmers using this method had measurable levels of the dye. These two exposures, however, were very high (AI concentrations=4716 and 15,036 μg), resulting in a very high level of variability (GSD for AI concentration=48.1).

There was no statistical difference between the A.I. concentrations received from low- and high-pressure spray methods. Exposures were not compared to the other methods because of the number of measurements below the limit of detection. The proportion of measurements below detectable levels was significantly greater in the pour-on group, however, than for the other methods ($p<0.01$).

The exposure measures differed by the degree of protection afforded by clothing. Farmers rated as having a high degree of protection (gloves and boots, multiple layers of clothing), had low concentrations and low TWA_as (mean=18 μg and 71 μg/hr, respectively). Seven of the 10 farmers rated as having a high degree of protection had no measurable levels of dye on their skin. In contrast, the 10 farmers who had low or no protection were observed to have high AI concentrations (mean=4421 μg) and high TWA_as (mean=14,988 μg/hr), and only 30% of these had no measurable levels of AI on their skin. The difference between means of the concentrations resulting from these two levels of protection was statistically significant ($p<0.01$).

The means of the AI concentrations were over three times as high when poor work practices were observed as when no poor work practices were observed (4179 and 1164 μg, respectively) and this difference was significant ($p<0.01$). The differences between the TWA_as were much greater (543 and 20,505 μg/hr). The poor work practices included physical contact with wet fences or animals, leaking equipment, or back splash from the spray.

There was a moderate statistically significant association between AI concentration and TWA_a with total volume using the Spearman coefficient ($r_S=0.61$ and 0.53, respectively) (not shown). Time was significantly inversely proportional to the two exposure measures ($r_S=-0.53$ for the AI concentration and $r_S=-0.68$ for the TWA_a). The association between the two exposure measures and AI volume was not significant. Total volume, volume of AI, and time differed significantly with the method of application ($p<0.01$), but not with the level of protection afforded by the clothing. Total volume was not correlated with AI volume or time ($r_S=-.25$, $p>0.05$ for both). AI volume and time were moderately associated with each other ($r_S=0.64$, $p<0.01$).

DISCUSSION

Farmers applying animal insecticides in this study had exposures of the same magnitude as that shown by video imaging studies of greenhouse workers,[18,19] timber mill workers,[20] and golf course workers.[21] There was a high number of nondetectable results, however, suggesting that there may be instances where inhalation could be an important route of exposure, in contrast to mixing or other types of applications when dermal exposure substantially overwhelms the inhalation route.[22]

In this study, exposure determinants were evaluated to determine which were likely to affect exposure levels. There was a statistically significant difference between the exposure means measured on farmers' skin with a high level of protective clothing compared with that with no or low protective clothing. Seven of the 10 farmers wearing clothing rated as providing a high degree of protection (several layers of clothing, gloves, and boots) had no measurable exposure. In contrast, only 30% of the farmers with little or no protection (bare skin, no boots or gloves) had no fluorescence detected.

The clothing worn by these farmers that was rated as providing good protection was more often multiple layers of clothing, rather than clothing specially designed for insecticide application. Two of the eight farmers (25%) monitored in warm weather were evaluated as having good protection, whereas about 40% of the farmers monitored under cold conditions had good protection. In addition, the level of protection afforded by clothing was not significantly associated with any of the exposure determinants. Thus, the farmers may have been selecting the level of protection based on weather conditions. If farmers wear less clothing in warmer months they could receive substantial insecticide exposures over a year. Selection of clothing should generally be made on the basis of the carrier solvent, rather than the insecticide, as the former appears to permeate cloth first.[23] Contaminated clothing should be removed and showering be done as soon as possible after insecticide use.

Work practices also appeared to be an important determinant. Some of the poor practices observed here, such as the leaking equipment, were easily correctable. Incidental contact from back splash or from wet animals or fences, because it is unanticipated, is more difficult to control. High-pressure spray was observed more often with these unanticipated incidents, but there were too few numbers to determine whether this application is more likely to result in these types of incidents or whether the association was due to chance. A barrier between the applicator and the animal and proper clothing may be the best protection against exposure occurring from these types of events.

The method of insecticide application was also important in the exposure levels. Eighty percent of the farmers using the pour-on method had no measurable exposure even though the insecticide was in the concentrate form. That no detectable exposure occurred was likely because there should be little aerosolization of the mixture with this method and therefore little drift or back splash. The two farmers who received measurable exposures had very high exposures, but neither wore what was rated as protective clothing. Thus, it appears the insecticide exposures received from pouring the insecticide onto the animal can be low or unmeasurable if proper protective clothing is worn. Most of the exposures from high-pressure spraying generally appeared to have come from back splashing or rubbing against the wet animals or fences and not from drift. The farmer receiving the lowest measurable exposure from this method was well protected. There were too few measurements on the other two application methods to make any conclusions on the likely exposures from using these methods.

The hands and head were the most frequently exposed areas. Of the eight farmers who had measurable exposure levels, five received the exposure on their hands. In this monitoring study 70% of the farmers wearing gloves had no measurable exposures, suggesting that gloves can provide considerable protection against exposure from application of animal insecticide.

There were surprises in the correlation statistics. The AI concentration and TWA_a were correlated directly with total volume and inversely with time, but there was no association with AI volume. Similarly, the volume of AI was not correlated with the total volume of the insecticide mixture, but AI volume was associated with time. In contrast, there was no correlation between total volume and time. Examination of the data suggests that the pour-on method (50% of the measurements) was associated with larger volumes of AI and lower total volumes (because the concentrate was not diluted) and longer application durations than the other methods. In contrast, the high-pressure spray had lower volumes of AI and higher total volumes because the concentrate was diluted and the application duration was shorter. Furthermore, the total volume, the volume of AI, and the duration of application differed significantly by method of application. Thus, the correlation statistics probably reflect the underlying association with the method of application.

The results presented here are based on only 20 measurements and therefore should be considered as preliminary. One must use caution when extrapolating these results to other situations because several of the cells were based on only two values. Nonetheless, this study provides guidance for future studies examining exposure from application of animal insecticides. It also suggests that the exposure determinants that may be predictors of exposure from application of animal insecticides are the method of application, the level of protective clothing, and quality of work practices. These are determinants that farmers are likely to be able to answer in a questionaire for an epidemiologic paper.[14]

CONCLUSIONS

Animal insecticide applicators can receive substantial amounts of insecticide, depending on the method of application. This study found that the pour-on method generally resulted in negligible exposure levels. High-pressure spraying also resulted in relatively low exposure levels. Poor work practices, such as leaky equipment and contact with wet animals or fences, can be the source of substantial exposures. Clothing can provide considerable protection, but it should be laundered regularly and should be selected based on the carrier solvent, rather than the AI.[23] Because rubbing of contaminated clothing against bare skin (such as the face) can occur, removal of clothing and showering as soon as possible is recommended.

ACKNOWLEDGMENTS

Our thanks to Dr. Richard Fenske of the University of Washington for his guidance in setting up the video imaging equipment.

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