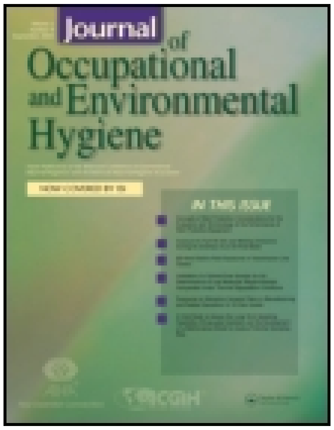

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The Validation of a Pesticide Exposure Algorithm Using Biological Monitoring Results

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A pesticide exposure algorithm was developed to calculate pesticide exposure intensity scores based on responses to questions about pesticide handling procedures and application methods in a self-administered questionnaire. The validity of the algorithm was evaluated through comparison of the algorithm scores with biological monitoring data from a study of 126 pesticide applicators who applied the herbicides MCPA or 2,4-D. The variability in the algorithm scores calculated for these applicators was due primarily to differences in their use of personal protective equipment (PPE). Rubber gloves were worn by 75% of applicators when mixing and 22% when applying pesticides, rubber boots were worn by 33% when mixing and 23% when applying, and goggles were worn by 33% and 17% of applicators when mixing and when applying, respectively. Only 2% of applicators wore all three types of PPE when both mixing and applying, and 15% wore none of these three types of PPE when either mixing or applying. Substantial variability was also observed in the concentrations of pesticides detected in the post application urine samples. The concentration of MCPA detected in urine samples collected on the second day after the application ranged from less than <1.0 to 610 μg/L among 84 of the applicators who applied MCPA. The concentrations of 2,4-D detected in the urine samples ranged from less than <1.0 to 514 μg/L among 41 of the applicators who applied 2,4-D. When categorized into three groups based on the algorithm scores, the geometric mean in the highest exposure group was 20 μg/L compared with 5 μg/L in the lowest exposure group for the MCPA applicators, and 29 μg/L in highest exposure group compared with 2 μg/L in the low exposure group for the 2,4-D applicators. A regression analysis detected statistically significant trends in the geometric mean of the urine concentrations across the exposure categories for both the 2,4-D and the MCPA applicators. The algorithm scores, based primarily on the use of PPE, appear to provide a reasonably valid measure of exposure intensity for these applicators, however, further studies are needed to generalize these results to other types of pesticides and application methods.

Keywords exposure, pesticides, ppe, questionnaires

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The development and validation of methods to assess exposure to pesticides are vital to improve our understanding of the potential hazards to human health. The methods used to assess exposure to pesticides in epidemiology studies vary from indirect surrogates, such as an occupation of farmer, to the direct measurement of pesticides or their metabolites in biological samples.[1,2] Environmental and biological measurements are generally considered reliable indicators of recent exposure; however, the assessment of exposures based on individual measurements for all subjects in large epidemiology studies is not feasible.[3] However, quantitative measurement data from smaller scale exposure studies, along with detailed descriptions of factors that may affect exposure levels, can be used to identify exposure determinants.[4] Once identified, questionnaires can be designed to collect information directly from study subjects about important exposure determinants, such as application method or use of personal protective equipment. The responses to these questions can then be analyzed to determine not only whether exposure to a specific pesticide has occurred, but also to estimate the relative intensity of exposure compared to other subjects.[5] In this study, the validity of exposure intensity estimates developed based on questionnaires was evaluated by comparison with exposure measurements.

The Agricultural Health Study (AHS) is a large prospective cohort study with over 55,000 pesticide applicators.[6] The pesticide applicators enrolled in the AHS completed self-administered questionnaires to identify specific pesticides they applied, along with the frequency of application in days per year and total duration of use in years. Questions on mixing procedures, application methods, the repair of pesticide application equipment, and the use of personal protective equipment were also included in the questionnaire. An algorithm was developed to provide a systematic and reproducible method to combine the responses to these questions into a single quantitative exposure intensity score. The exposure intensity score is then combined with information on the frequency and duration of use to calculate a cumulative exposure metric for the epidemiologic analyses of the AHS cohort.

The AHS exposure algorithm was developed based on the premise that self-administered questionnaires can be used to identify pesticide applicators with higher intensity exposures. To evaluate this assumption, the data from a previously published study of herbicide applicators conducted in Canada known as the Pesticide Exposure Assessment Study (PEAS) was used.[7] During the PEAS, detailed questionnaires were completed by 126 herbicide applicators following the application of either MCPA (4-chloro-2-methylphenoxyacetic acid) or 2,4-D (2,4-dichlorophenoxyacetic acid). Urine samples were collected prior to the application and for 2 days following the application. The concentration of MCPA and 2,4-D was measured in these urine samples.

The questionnaire used in the PEAS contained questions that were similar to the questions used in the AHS enrollment questionnaire, thus, the data collected by these investigators provided an opportunity to evaluate the exposure algorithm developed for the AHS. The pesticide exposure intensity scores for the applicators in the PEAS were calculated using the algorithm and then compared with the post application urine concentrations to evaluate the strength of the relationship between the algorithm exposure intensity scores and the urine concentrations.

METHODS

The pesticide exposure algorithm was developed to provide quantitative estimates of exposure intensity based on categorical responses to questions on mixing and application methods, repair activities, and the use of personal protective equipment.[2] The algorithm assigns weighting factors to each of the possible responses to these various questions, which are then combined to calculate a pesticide exposure intensity score. The algorithm variables and their weighting factors were selected based on a literature review of studies in which quantitative exposure measurements were collected during various pesticide application scenarios. The variables and weighting factors used in the general algorithm developed for the AHS are summarized in the Appendix. A more detailed algorithm with additional exposure variables was also developed for the AHS, but this algorithm was not assessed because not all the variables required for the detailed algorithm were included in the PEAS questionnaire.

The general algorithm contains four basic factors: (1) mixing status (MIX), (2) application method (APPLY), (3) equipment repair status (REPAIR) and (4) personal protective equipment (PPE):

$$\text{Exposure Intensity Score} = (\text{MIX} + \text{APPLY} + \text{REPAIR}) \times \text{PPE}$$

The MIX factor is included to represent exposures that occur when handling concentrated solutions and transferring or loading the solutions into the application equipment. The MIX factor takes a value of 0, 3, or 9 depending on how often the applicator mixes pesticides prior to applying. The APPLY factor is intended to represent exposures that occur during the actual application of the pesticide. A larger weighting factor is assigned to application methods with the potential for higher exposure levels. For example, the use of a backpack sprayer has a weighting factor of 9 compared with a weighting factor of 3 for a tractor boom application method based on the assumption that higher exposures occur when applying with a backpack sprayer than when applying with a tractor boom. The REPAIR factor takes on a value of 2 for applicators who reported performing maintenance and repairs, other than clean-up, on pesticide application equipment. The MIX, APPLY and REPAIR factors are summed, and then multiplied by a reduction factor to account for the use of personal protective equipment.

The use of PPE is generally assumed to reduce the potential for exposure when handling pesticides and, therefore, a reduction factor for PPE is included in the algorithm. To account for all the possible combinations of PPE used by these applicators, the different types of PPE listed in the AHS questionnaire are grouped into three categories, PPE-1, PPE-2 and PPE-3, with reduction factors of 0.8, 0.7 and 0.6, respectively, for the use of PPE from each of these categories (see the Appendix). To account for the use of a combination of PPE, a cumulative reduction factor is calculated by combining the reduction factors from each of the categories. For example, the use of a face shield (PPE-1) results in 20% reduction (a factor of 0.8), and the use of disposable coveralls (PPE-2) results in a 30% reduction (a factor of 0.7). The use of both a face shield and disposable coveralls results in a 50% reduction (a factor of 0.5). The addition of protective rubber gloves (PPE-3) to the ensemble provides a further 40% reduction resulting in a reduction factor of 0.1 for use of PPE from all three groups.

In the PEAS study, information on PPE use was collected during four stages of the application process (i.e., mixing, loading, applying and cleanup), whereas, the AHS questionnaire asked only about general use when personally handling pesticides, regardless of the stage of application. In the PEAS study, PPE use varied by stage of the application process, therefore, a separate PPE reduction factor was calculated for each stage and then averaged across the four stages to calculate a single PPE score for each applicator. The PEAS questionnaire also included questions on whether any maintenance and repair activities had been conducted on the day of the application.

The details of the procedures used for the collection and laboratory analysis of the urine samples in the PEAS study have been described by Arbuckle et al. in a previous publication.[7] Preapplication spot samples, along with two composite urine samples were collected for two consecutive 24-hour periods following the application process. The application day is refered to as Day 0. The Day 1 sample was collected on the first day after the day of application, and the Day 2 sample was collected on the second day after the day of application. A total of 126 applicators in PEAS completed questionnaires. Of these, 89 reported applying MCPA and 43 reported applying 2,4-D, including 11 applicators who reported applying both. There were 5 applicators who did not apply either of these herbicides, and were excluded from this analysis. In addition, 5 of the MCPA applicators and 2 of the 2,4-D applicators applied these herbicides on the day before the baseline sample was collected and were also excluded, leaving 84 of the MCPA applicators and 41 of the 2,4-D applicators for further analysis. Among the 84 applicators who reported applying MCPA, 50 of the applicators applied on one day only and 34 applied on two consecutive days. Among the 41 applicators who applied 2,4-D, 26 applied on one day only and 15 applied on two consecutive days. The questionnaires were administered after the first day of application only, so for applicators who applied on two days, algorithm scores were not calculated for the second day.

The Day 1 urine samples correspond to exposures that occurred during the first day of application. For the subset of applicators who applied on two consecutive days, the Day 2 urine samples are affected by exposures that occurred on two consectutive application days. Therefore, the relationship between the algorithm scores and urine concentrations were analyzed separately for both the Day 1 and the Day 2 urine samples. The analysis of the Day 1 urine samples avoids possible confounding for those applicators who also applied on two days. However, the timing of the Day 2 samples corresponds more closely with the half-life of 2,4-D in urine, which is reported to be between 12 to 72 hours.[8] Also, the Day 2 urine concentrations were consistently higher with fewer samples below the limit of detection, even for applicators who applied on one day only. The limit of detection for both herbicides was 1.0 μg/L and a value of 0.5 was substituted for the non-detect values to allow logarithmic transformation of the results and reduce bias introduced by using a value of 0 when calculating mean values.

Spearman rank correlation coefficients were calculated to compare the algorithm exposure scores with both the Day 1 and the Day 2 urinary concentrations for applicators who applied on Day 0 only and for applicators who applied on both Day 0 and Day 1. In addition, scatter plots were generated to visually display the relationship between the algorithm score versus the log of the concentration of MCPA and 2,4-D in the Day 2 urine samples.

The responses to questionnaires are often used as categorical variables for epidemiologic analyses. Thus, the algorithm scores were also used to categorize the applicators into low, medium and high exposure groups using cut points of <5 for the low, 5–10 for the medium and >10 for the high exposure group. The percent of samples below the limit of detection, the arithmetic and geometric mean concentrations, and the geometric standard deviation of the urine concentrations for these three categories were calculated for both Day 1 and Day 2 urine samples. The trend in the geometric means across the three exposure categories was evaluated by linear regression analysis of log-transformed urinary concentrations on the mean algorithm scores for the low, medium and high exposure groups. The total duration of the application process in hours was determined based on the start times and finish times reported on the day of application questionnaire. To adjust for differences in the duration, the application hours and number of application days were included in the regression analysis. All statistical analyses were performed using the STATA software (STATA Corp, College Station, Texas).

RESULTS

The pesticide exposure intensity scores ranged from a 1.2 to 14. The cumulative distribution of the algorithm scores for all 126 applicators who completed a questionnaire in PEAS study is plotted in Figure 1. The algorithm scores were uniformly distributed between these two values.

Almost all the applicators in the PEAS applied using a tractor with a spray boom, thus, the influence of the application method on exposure levels could not be evaluated with this data set. In addition, all but two of the applicators in the PEAS reported mixing herbicides prior to application, and therefore, the MIX variable contributed very little to the variability in algorithm scores. However, 76% of the applicators did report performing maintenance and repairs on the application equipment, so the REPAIR variable did contribute to some of the variability in the algorithm scores.

The variability in the algorithm exposure intensity scores among these applicators was due primarily to the differences

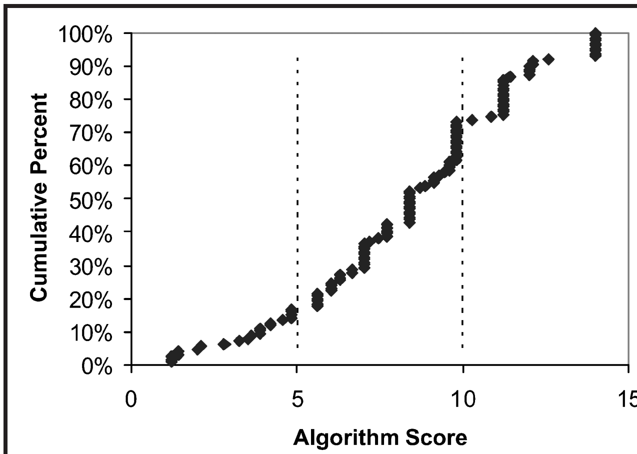

FIGURE 1. Cumulative distribution of pesticide exposure algorithm scores (N = 126)

TABLE I. Percentage of Applicators Who Reported Use of Personal Protective Equipment (PPE) by Type of PPE and Stage of Application Process (N = 126)

Group	Type	Mix	Load	Apply	Clean
PPE-0	No Use or PPE	12	15	42	28
PPE-1	Face shield	1	1	1	1
	Goggles	33	33	17	22
	Fabric/leather gloves	1	1	2	1
	Rubber boots	33	33	23	29
	Apron	8	7	2	4
	Rain pants	1	1	1	1
PPE-2	Respirator	10	9	8	4
	Disposable coveralls	11	11	9	7
PPE-3	Rubber gloves	75	75	22	52

reported in their use of personal protective equipment (PPE). The percentage of applicators who reported use of each particular type of PPE by stage of the application process is presented in Table I. In general, applicators wore PPE when mixing and loading more often than when applying. The three types of PPE used most frequently were rubber gloves, rubber boots, and goggles. Rubber gloves were worn by 75% of applicators when mixing and loading and by 22% of applicators when applying pesticides. Rubber boots were worn by 33% when mixing and loading and 23% when applying. Goggles were worn by 33% of applicators when mixing and loading and 17% of applicators when applying.

The percentage of applicators who reported using various combinations of the three PPE groups is displayed in Table II. The corresponding reduction factor for each combination of the three PPE groups is also displayed. A reduction factor of 1.0 was assigned to applicators who did not use any PPE during any stage of the application process. A reduction factor of 0.1 was assigned to applicators who reported the use of rubber gloves and at least one other type of PPE from each of the other two categories during all four stages of the application process.

TABLE II. Percentage of Applicators by Combination of PPE Used and Stage of Application Process (N = 126)

PPE Group			PPE				
PPE-1	PPE-2	PPE-3	Factor	Mix	Load	Apply	Clean
Yes	Yes	Yes	0.1	12	12	6	7
No	Yes	Yes	0.3	4	4	2	4
Yes	No	Yes	0.4	32	33	11	25
Yes	Yes	No	0.5	0	0	3	0
No	No	Yes	0.6	28	26	3	21
No	Yes	No	0.7	2	1	4	1
Yes	No	No	0.8	10	10	29	14
No	No	No	1.0	12	15	42	28

There was a wide range in the urinary concentrations detected in both the Day 1 and Day 2 samples. The range presumably reflects variability in the exposure received during the application of herbicides among these applicators, as well as variability in the metabolism and excretion rates. The Day 2 urine concentrations of MCPA ranged from less than 1.0 μg/L to 610 μg/L with a geometric mean 14.2 μg/L and a geometric standard deviation of 6.0 among the 84 applicators who reported applying MCPA. The Day 2 urine concentrations of 2,4-D ranged from less than 1.0 μg/L to 520 μg/L with a geometric mean value of 9.7 μg/L with a geometric standard deviation of 6.2 among the 41 applicators who reported applying 2,4-D.

The Spearman rank correlation coefficients between the algorithm scores and the concentration in the Day 2 urine samples were 0.17 for the 84 MCPA applicators and 0.45 for the 41 2,4-D applicators (Table III). Higher correlations were observed for 2,4-D compared with MCPA. In Figures 2 and 3, scatter plots display the variability of the algorithm score when plotted against the log transformed Day 2 urine concentration.

Descriptive statistics for the MCPA and 2,4-D applicators grouped by algorithm score into low (<5), medium (5–10), and high (>10) ranges are presented in Table IV. The number of applicators and the average algorithm score is displayed for each of the three exposure groups, along with the number and percentage of samples with concentrations less than the limit of detection, the arithmetic mean, the maximum value, the geometric mean, and geometric standard deviation of the urine concentrations for both the Day 1 and the Day 2 urine samples. For applicators in the low exposure group, 40% of the urine samples had concentrations below the limit of detection for both MCPA and 2,4-D, while in the highest exposure group, only 8% of the MCPA applicators and none of the 2,4-D applicators had concentrations below the limit of detection. The geometric mean concentration detected in the Day 2 urine samples was four times higher in the highest algorithm exposure group compared with the lowest exposure group for MCPA applicators, and 14 times higher for the 2,4-D applicators. In addition, a statistically significant increase in the geometric mean concentration was detected across the exposure groups for both herbicides. There was, however, a wide range of urine concentrations detected within each of the three groups as shown in the box plots of the Day 1 and Day 2 urine samples displayed in Figure 4 for the MCPA applicators and Figure 5 for the 2,4-D applicators. The box plots display the interquartile range of the logtransformed urine concentrations, and the horizontal bar inside the box shows the median values. The whiskers on the boxes extend to the minimum and maximum adjacent values that fall within 1.5 times the interquartile range, and the individual points show any values that lie outside the range of the adjacent values.

DISCUSSION

Questionnaires are often used in epidemiologic studies to collect information directly from individual subjects,

TABLE III. Correlation of Pesticide Algorithm Exposure Scores With Concentrations of Pesticides in Post Application Urine Samples

		Day 1 Sample		Day 2 Sample	
	N	Spearman Correlation Coefficient	(p-value)	Spearman Correlation Coefficient	(p-value)
Applied MCPA					
Day 0 only	50	0.27	(0.05)	0.21	(0.15)
Day 0 and Day 1	34	0.13	(0.45)	0.16	(0.37)
All	84	0.18	(0.09)	0.17	(0.11)
Applied 2,4-D					
Day 0 only	26	0.18	(0.38)	0.39	(0.05)
Day 0 and Day 1	15	0.51	(0.05)	0.49	(0.07)
All	41	0.34	(0.03)	0.45	(0.003)

Day 0 = day of application.
Day 1 = one day after first application day.
Day 2 = two days after first application day.

particularly for situations in which exposures cannot be measured. In a study of pesticide applicators, questionnaires were used to collect information on the previous use of specific pesticides, including information on the frequency and duration of use, along with application methods and the use of personal protective equipment. An algorithm was developed to convert the categorical responses from questionnaires into quantitative exposure intensity scores that could be used to calculate cumulative exposure metrics based on both the duration and intensity of exposure.

Questionnaires provide an efficient method to collect information on the use of pesticides for determining duration of exposure, but the validity of using questionnaires for estimation of exposure intensity has not been as well established.[9,10] The results of environmental and biological monitoring studies have generally indicated potentially large variability in exposure levels when handling pesticides due to a variety of factors that include but are not limited to the application method, personal hygiene, and the use of personal protective equipment.[11,12] While biological monitoring has several advantages for assessing exposure to pesticides, the use of biological monitoring in a large-scale epidemiology study such as the AHS is not currently feasible due to factors such as cost and logistical constraints. Also, biological monitoring is not useful for assessment of past exposures to pesticides with short half-lives. Therefore, questionnaires will remain important tools for the collection of exposure information for the foreseeable future.

The PEAS study was designed to identify factors that influence exposure to pesticides under actual field conditions, and the questionnaires used collected information on

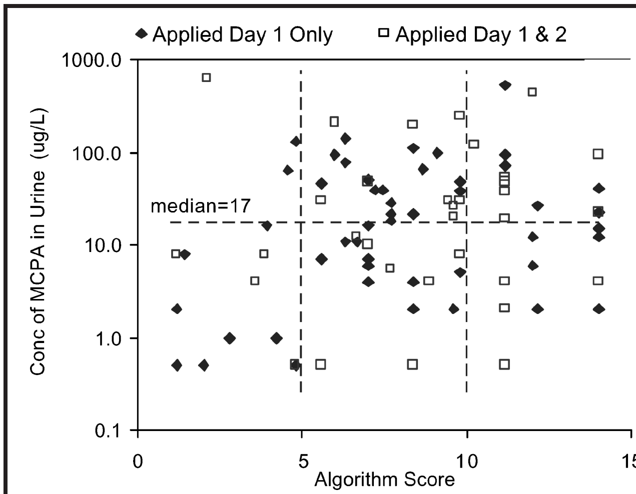

FIGURE 2. Pesticide exposure algorithm score vs. MCPA concentration in Day 2 urine sample

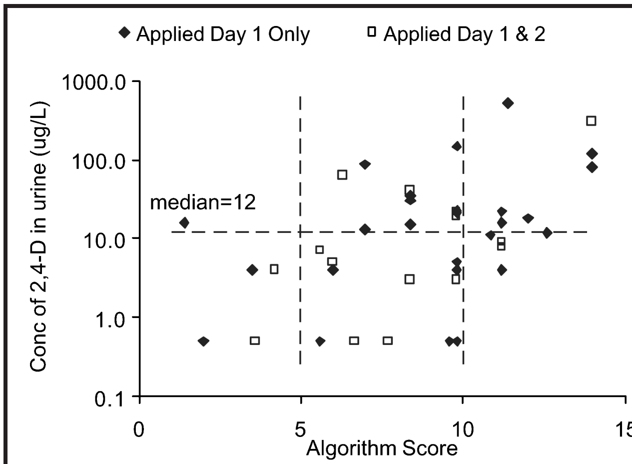

FIGURE 3. Pesticide exposure algorithm score vs. 2,4-D concentration in Day 2 urine sample

TABLE IV. Pesticide Concentrations Measured in Urine Samples (in ug/L) For Applicators Grouped by Algorithm Exposure Score

Algorithm Exposure Score			Day 1 Sample					Day 2 Sample				
	N	Mean	N < LOD (%)	AM	MAX	GM	GSD	N < LOD (%)	AM	MAX	GM	GSD
Applied MCPA												
1–<5	15	3.1	6 (40)	35	280	3	9.1	4 (27)	57	610	5	9.3
5–10	45	7.8	4 (9)	35	330	11	5.7	3 (7)	42	250	17	4.7
>10–15	24	12.3	2 (8)	44	520	12	5.4	1 (4)	69	520	20	5.6
Total	84	8.7	12 (14)	38	520	9.1	6.4	8 (10)	52	610	14.2	6.0
p-value for trend						0.05					0.03	
Applied 2,4-D												
1–<5	5	2.9	2 (40)	6	20	2	4.8	2 (40)	5	16	2	4.5
5–10	24	8.2	7 (29)	18	200	4	6.1	5 (21)	23	150	8	5.8
>10–15	12	12.1	0 (0)	60	410	16	4.5	0 (0)	93	514	29	4.7
Total	41	8.2	9 (22)	29	410	5.4	6.1	7 (17)	41	514	9.7	6.2
p-value for trend						0.03					0.007	

N = Number of applicators.
MEAN = Arithmetic mean of algorithm score.
N < LOD = Number with urine concentration below limit of detection (LOD = 1.0 ug/L).
AN = Arithmetic mean (ug/L).
MAX = Maximum value (ug/L).
GM = Geometric mean (ug/L).
GSD = Geometric standard deviation.
p-value for trend based on linear regression adjusted for application hours and application days.

approximately 130 variables thought to have a possible influence on exposure levels. In the published results from the PEAS, a multivariate regression analysis was used to determine which of these variables had a significant influence on urinary concentrations.[7] The factors found to be significant predictors of urinary herbicide levels included pesticide formulation, the use of protective clothing/gear, type of application equipment, handling and personal hygiene practices. However, the specific factors differed for the two herbicides thereby limiting the extent to which the results could be generalized for prediction of exposures to other pesticides and for other application scenarios.

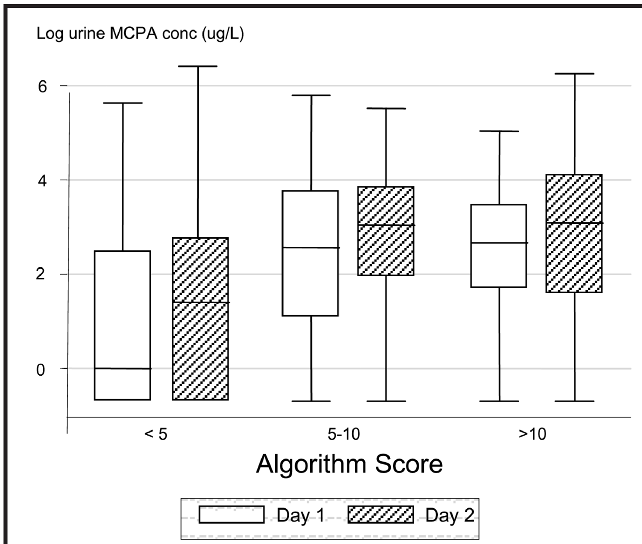

FIGURE 4. Box plot of Day 1 and Day 2 urine concentration of MCPA for applicators grouped by pesticide exposure algorithm score (N = 84)

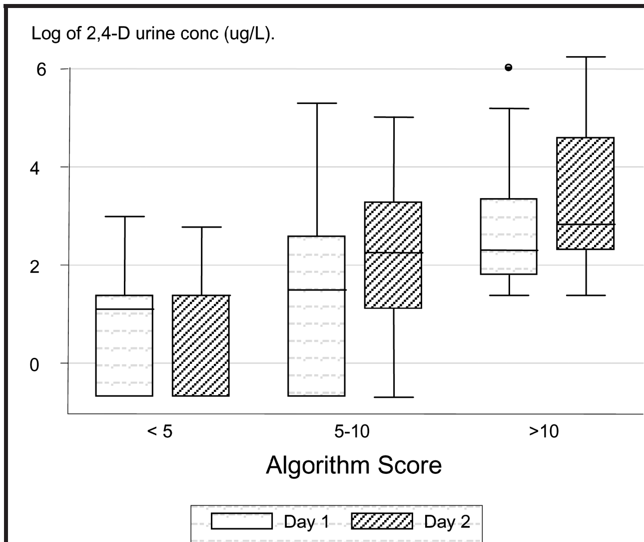

FIGURE 5. Box plot of Day 1 and Day 2 urine concentration of 2,4-D for applicators grouped by pesticide exposure algorithm score (N = 41)

In an ideal validation study, applicators would be assigned randomly to specific exposure groups in which the amount of pesticide applied, the timing and duration of the application, and the use of PPE use would be carefully monitored and controlled. However, the PEAS was conducted to identify factors that affect exposure to pesticides under actual field conditions, and thus represents a natural experiment in which no attempt was made to modify or control application methods or exposures. The start times ranged from 5:00 a.m. to 10:00 p.m. with a median of 11:00 a.m., while the total durations ranged from 1.0 to 13.5 hours with a median of 4 hours. The differences in the start time and duration, as well as total amount applied and acres treated, could account for some of the variability in urine concentrations seen among applicators with similar algorithm scores.

A number of assumptions inherent in the algorithm scores could not readily be tested in this analysis. Since almost all applicators used the same mixing and application methods, the effect of these variables on the urine concentrations could not be evaluated. Also, the REPAIR factor was a dichotomous variable that increased the exposure score if the applicator reported performing one or more maintenance or repair activities on the day of application. While repair activities may increase the potential for exposure, they may not always result in higher exposure than the application itself.

Another factor that could influence exposure to pesticides among these applicators was the use of a tractor with a cab. Approximately 37% of the applicators reported the use of an enclosed cab, and 9% reported the use of a cab with an air filter. The presence of a tractor cab could affect exposure levels as well as the use of PPE and thereby confound the relationship between the algorithm scores and the urinary concentrations. However, information on the use of a tractor cab was not available from the AHS questionnaire and therefore was not incorporated into the general algorithm.

For this validation study, a biological marker was used as the reference value for comparison with the algorithm intensity scores based on the assumption that higher exposure intensities will result in higher absorbed doses, leading to higher body burdens and ultimately higher urinary concentrations. However, post application urine concentrations depend on factors other than exposure intensity, for example, physiological differences between individuals in the rates of absorption, metabolism, distribution and excretion.[14] In addition, breathing rates, physical exertion, surface area and location of exposed skin, and damage to the skin will also affect the total absorbed dose. For example, the excretion rates of 2,4-D following a single dermal exposure varied by the site of application.[12] Factors such as temperature and humidity, the formulation of the pesticide product, and the presence of other chemicals on the skin or in the pesticide product may also impact on the degree of absorption of the herbicide.[14] In that the algorithm scores are intended to represent the exposure intensity rather than absorbed dose, environmental measures of external exposure, such as air and dermal samples, would provide useful reference values for further validation of the algorithm intensity scores. Despite these limitations, the algorithm was robust enough to detect statistically significant trends in the urinary concentrations for applicators categorized by algorithm intensity score.

CONCLUSIONS

The increasing trend in the geometric mean urine concentrations observed across the three categorical exposure groups for both MCPA and 2,4-D indicates that the algorithm scores, based mostly on PPE use, provide a reasonably valid estimate of exposure intensity for these applicators. However, the large variability in the urine concentrations among applicators with similar algorithm scores suggests that opportunities may exist to identify additional exposure determinants to improve the performance of the algorithm. The statistically significant correlation observed between the algorithm scores and the urine concentrations for 2,4-D, but not for MCPA, indicates the algorithm worked less well for MCPA compared with 2,4-D. Thus, additional field studies during which air and dermal samples in addition to urine samples are collected to measure pesticide exposure levels are needed to provide the necessary data to more further evaluate the algorithm for other pesticides, application methods and exposure scenarios.

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APPENDIX

AHS Pesticide Exposure Algorithm

Exposure Intensity Score = (MIX + APPLY + REPAIR) * PPE

MIX Factor:
- if [MIX] = Never then score = 0
- if [MIX] = <50% of time mixed, then score = 3
- if [MIX] = 50% + of time mixed, then score = 9

APPLY Factor:
- if [APPLY] = does not apply, then score = 0
- If [APPLY] = aerial aircraft, then score = 1
- if [APPLY] = distribute tablets, then score = 1
- if [APPLY] = in furrow/banded, then score = 2
- if [APPLY] = boom or tractor, then score = 3
- if [APPLY] = backpack, then score = 8
- if [APPLY] = hand spray, then score = 9

REPAIR Factor:
- if [REPAIR] = does not repair, then score = 0
- if [REPAIR] = repair, then score = 2

PE FACTOR:
- if [PPE] = never used then PPE-0 = Yes
- if [PPE] = face shields or goggles, then PPE-1 = Yes
- if [PPE] = fabric or leather gloves, then PPE-1 = Yes
- if [PPE] = other protective clothing such as boots, then PPE-1 = Yes
- if [PPE] = cartridge respirator or gas mask, then PPE-2 = Yes
- if [PPE] = disposable outer clothing, then PPE-2 = Yes
- if [PPE] = chemically resistant rubber gloves, then PPE-3 = Yes

PPE-0 None	PPE-1 Face Shield; Goggles; Other	PPE-2: Respirator; Disposable Other Clothing	PPE-3: Chemical Resistant Gloves	Reduction Factor
Yes	No	No	No	1.0
No	Yes	No	No	0.8
No	No	Yes	No	0.7
No	No	No	Yes	0.6
No	Yes	Yes	No	0.5
No	Yes	No	Yes	0.4
No	No	Yes	Yes	0.3
No	Yes	Yes	Yes	0.1