Determinants of Dermal Exposure among Nicaraguan Subsistence Farmers during Pesticide Applications with Backpack Sprayers

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Objectives: Identification of pesticide exposure determinants has become an issue in explaining exposure variability and improving control measures. Most studies have been conducted in industrialized countries. The aim of this study was to identify relevant dermal exposure determinants among Nicaraguan subsistence farmers.

Methods: Field data on possible determinants were collected during 32 pesticide applications through observation and supplementary videorecording. A multistep reduction strategy brought down the 110 potential exposure determinants to 27 variables, which were grouped as worksite, spray equipment, working practices, clothing or hygiene practices related. Dermal exposure was quantified with a modification of Fenske's visual scoring method. Multivariate linear regression modeling within groups and across groups was performed.

Results: In the within-group analyses, work practices, spray equipment and worksite related determinants explained 52, 33 and 25% of the exposure variability, respectively. Clothing and hygiene practices were weaker determinants and did not always reduce the exposure. The final model included determinants from all groups except hygiene practices and explained 69% of the exposure variability. A less restricted model increased the explained variability to 75%. Several novel determinants were identified, including spraying on a muddy terrain, dew on plants, sealing the tank lid with a cloth and wiping sweat from the face.

Conclusions: This study showed that a combination of observation and visual scoring techniques can provide valuable information on determinants of pesticide exposure and affected body parts under developing country conditions. The results could be used to develop job-specific questionnaires and to design training and preventive programs.

Keywords: dermal exposure; developing countries; exposure assessment; exposure determinants; fluorescent tracer; pesticide; subsistence farmers

INTRODUCTION

Many factors related to work environment, job content, organizational issues and individual characteristics can influence the level of exposure and the health of workers. Determinants of exposure have been identified and subsequently used to explain exposure variability, for example, among asphalt workers (Burstyn *et al.*, 2000), and to design and improve control measures in industry (Preller *et al.*, 1995; Burstyn *et al.*, 1997, 1998; Teschke *et al.*, 1999; Lumens and Spee, 2001). In recent years, the identification of the main exposure determinants has also become an issue in pesticide exposure assessment studies (Ohayo-Mitoko *et al.*, 1999; Cattani *et al.*, 2001; Hernández-Valero *et al.*, 2001; Hines and Deddens, 2001; Hines *et al.*, 2001). However, most

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of these studies have been performed in industrialized countries, where populations and settings are different from those in developing countries such as Nicaragua. Knowledge and understanding of exposure determinants during pesticide applications among subsistence farmers can be useful when defining priorities for preventive or regulatory programs, when designing training programs, and when developing observational strategies for exposure assessment.

Exposure to pesticides is one of the most important occupational risks among agricultural workers in developing countries (Wesseling *et al.*, 2001b). Some studies have shown deficiencies in basic work practices and pesticide handling. Kishi *et al.* (1995) found in Indonesia that wetting skin and clothes with the spray solution, the number of spray operations per week and the use of hazardous pesticides correlated with the number of health related signs and symptoms in Indonesian farmers. In Costa Rica, banana plantation pesticide users worked with leaking equipment and cleared blocked spray nozzles by blowing them out with their mouths. Furthermore, they showed inadequate hygiene practices such as eating, drinking or smoking during the application period and not showering immediately after work (van Wendel de Joode *et al.*, 1996). In a study conducted in Kenya (Ohayo-Mitoko *et al.*, 1999), including two areas with mainly subsistence farmers, participants washed or bathed immediately after spraying as a response to spillage accidents or other contamination. Overall, knowledge about the main determinants of pesticide exposure in developing country conditions remains scarce; in addition, exposure situations differ among countries.

Nicaragua has a long-term reputation as one of the countries with the highest number of pesticide poisoning incidents and mortality rates in the developing world (McConnell, 1988). Programs advocating the rational and safe use of pesticides have combined worker training with the use of personal protective equipment (PPE) to solve the problem in Nicaragua as well as in other countries (Weinger and Lyons, 1992). However, the poisoning statistics indicate persistent problems. Official surveillance statistics showed a poisoning rate of 30.1 per 100 000 inhabitants in 1998, with nearly 30% of these poisonings occurring in the northwestern region of the country. Organophosphates (primarily chlorpyrifos and methamidophos) caused 37% of the poisonings, and poisonings occur most frequently among subsistence farmers and part-time pesticide applicators (Berroterán, 2001). From a population-based survey in Nicaragua, it was recently estimated that almost 68 000 intoxications occurred during 2000, the majority being occupational poisonings (Corriols *et al.*, 2002).

The aim of this study was to identify the main determinants of pesticide exposure among Nicaraguan subsistence farmers by comparing direct observations and videotaped images of field applications with a visual dermal exposure score based on post-application fluorescent body images.

METHODS

This study is part of a larger project on 'Assessment of dermal pesticide exposure and pesticide-related skin lesions: implication for intervention' conducted by the Occupational and Environmental Health Program at Universidad Nacional Autónoma de Nicaragua (UNAN-León). The fieldwork for the study took place during June–October 1999.

Applicator recruitment

Community leaders in several villages close to the cities of León and Chinandega in the northwestern region of the country were contacted in order to identify subsistence farmers who planned to spray the organophosphate insecticide chlorpyrifos or methamidophos, the target pesticides of the umbrella project. The farmers identified were invited to participate in a meeting where the purpose of the study and the methods for exposure assessment were explained and questions raised by the farmers were answered. All farmers who attended the meeting were willing to participate and those who were eligible signed a written consent form. A total of 31 subsistence farmers were recruited, of whom six participated in the pilot phase of the study.

Observation and videotaping of the application

Based on previous field observations, two of the authors (L.B. and A.A.) listed the different activities and potential exposure events during pesticide application. Major operations such as transport, mixing, loading, spraying and waste management were broken down into smaller components. All activities were included, from the moment a farmer starts preparations for the application until the end of the work operation, when equipment and pesticide leftovers are stored. Data on clothing, personal protective equipment and climatic conditions were also considered. Thus, a list of factors entailing potential dermal exposure was used to design a preliminary form to guide the field observation. This form was tested during the pilot phase of the study and some exposure events that had not been anticipated were added to the observation guide.

In order to confirm and complement the data collected directly in the field with the use of the observation guide, the pesticide applications were also videorecorded. One person annotated observations on the form during the application, and another person videotaped the application. Although all applications were observed from start to finish, when the farmer planned to apply more than five loads, we

filmed intermittently for up to an hour and a half, taking care to include all relevant activities and potential exposure events. Relevant activities and exposure events identified for some farmers either during field observations or during videotape evaluations but not noticed for others were later rechecked on the videotapes of all participants. The exposure events were evaluated in terms of how contact with the pesticide occurred, for example, walking into the spray cloud or spilling, splashing or touching the pesticide solution. This follows the conceptual model for dermal exposure proposed by Schneider *et al.* (1999), which discusses processes of transferring contaminants from the source to the skin via emissions into the air and depositions on surfaces and clothing.

Total visual score

An adapted form of Fenske's visual scoring method was used to quantify the dermal exposure (Fenske, 1988; Aragón *et al.*, 2004). A small amount ($260 \, \mathrm{mg \, l^{-1}}$) of a whitening agent (Tinopal CBS-X®) was added as a fluorescent tracer to the pesticide dilution to be applied. Farmers applied pesticides as usual and were observed before and after application in a darkened room using a UV lamp (UVP® model UVSL-26P; 365 nm long wave). The pattern of fluorescent images on the skin of the farmer after application was videotaped using a camcorder (Hitachi® VMH-640A Hi8). All videotapes were evaluated by one of the authors (A.A.).

To facilitate the evaluation, the body was divided into the following body parts: face, neck, thorax, arms, forearms, hands, thighs, legs and feet. Each body part was subdivided into front and back sides, except for the face, which was divided into three sections—forehead and left and right sides—according to Fenske (1988). This resulted in 31 body parts scored for each subject. For ethical reasons the buttocks and genital area were covered and not scored. Each body area was evaluated using a matrix (Fenske, 1988) where the ordinate represented the exposed area and the abscissa exposure intensity. The exposed area was ranked from 1 to 5 (five ranges of 20%) and intensity from 0 to 5 (none to high). The product of these two ranks results in a score for the image ranging from 0 to 25. The total visual score is the sum of the scores of all body areas, and values may range from 0 to 775. The total visual score was used as the dependent variable in the multiple linear regression.

Data analysis

Statistical analysis was performed using SPSS software, release 11.0.0 (SPSS, Inc.). Descriptive statistics (counts for categorical data, and means, maxima and minima, and frequency distributions for continuous data) were calculated for all available variables (potential determinants). The distribution of the dependent variable (total visual score) was evaluated for normality ($P = 0.20$, Kolmogorov–Smirnov test with Lilliefors significance correction).

Multiple linear regression modeling was used to evaluate association between factors identified as determinants of exposure and total visual score. The model was built in several steps. Approximately 110 relevant activities and exposure events that could affect the visual score (as a dermal exposure measurement) were derived from the observations in the field, evaluation of the videotapes and field measurements of climatic conditions. The number of events/activities was reduced by combining events/activities that were described somewhat differently but essentially represented the same actions and contamination of the same body part, and by removing rare events/activities ($\leqslant 3$ observations), arriving at 47 variables. Subsequently, Pearson correlations were calculated, and among highly correlated pairs ($r > 0.7$; $P < 0.05$) only the ones more logically explained as associated with dermal exposure were retained for further analyses (Burstyn *et al.*, 1997). The remaining 27 variables were classified into five groups of related determinants (Stewart, 1999): worksite, spray equipment, clothing, working practices and hygiene practices (Table 1). Also, a factor analysis was carried out with all variables related to working practices (20 out of the 47) to corroborate the list derived from the analysis of the correlation matrix. The factor analysis (not shown) resulted in the same set of variables.

In the next step, multivariate analyses were conducted within grouped determinants with the total visual score as the dependent variable (Arbuckle *et al.*, 2002). Determinants with $P < 0.25$ are listed in Table 2 together with determinants that had been expected to be important predictors based on other studies. Finally, all determinants in Table 2 with a P-value <0.25 in the group-specific models (12 out of 16 in Table 2) were entered into a cross-group multivariate model. A backwards stepwise method was used to construct the exposure model with the best predictive fit, using as stepping criteria $P < 0.05$ for entry and $P > 0.10$ for removal.

RESULTS

One application during the pilot study was not videotaped and was therefore excluded, and in the case of two farmers two applications were observed. Thus, a total of 30 applicators and 32 applications were reported. The median age for applicators was 34 years (range 17–50). Applications lasted on average 71 min (21–163), with three loadings (1–12) per application as the median and the mode. A median of 0.5 l (0.1–4.5) of concentrated pesticide (30–40% of active ingredient) was diluted into a median of 50 l (10–120) of water, and applied on a median area of

Table 1. Results of univariate analyses of potential pesticide exposure determinants with the total visual score as the dependent variable among subsistence farmers, León, Nicaragua ($n = 32$)

Group	Factor	Mean (range)	Frequency	β (95% CI)	P
Worksite	Temperature (°C)	27 (21–32)		13.2 (0.1–26.2)	0.05
	Sprayed surface (Ha)	1.25 (0.35–4.20)		11.6 (−10.9–34.1)	0.30
	Height of the crop (cm)	57 (10–175)		−0.2 (−0.9–0.5)	0.57
	Dew on plants		22	14.8 (−55.2–84.9)	0.67
	Slightly sloping terrain		8	−11.7 (−86.8–63.4)	0.75
	Wet or slightly muddy terrain		10	66.5 (0.7–132.3)	0.05
Spraying equipment	Hand-pressurized backpack sprayer (versus a motor-pressurized sprayer)		13	102.8 (48.7–157.0)	0.00
	Leaking backpack		19	36.7 (−28.1–101.6)	0.26
Clothing	Wearing cap/headgear		27	40.7 (−47.7–129.2)	0.35
	Wearing long-sleeved shirt		15	−21.0 (−85.8–43.8)	0.51
	Wearing an old/overused shirt		19	22.8 (−42.9–88.6)	0.48
	Shirt partially covering chest or abdomen		27	29.9 (−12.5–72.2)	0.16
	Wearing long pants		24	−39.3 (−113.1–34.5)	0.28
	Wearing shoes		5	−25.3 (−114.6–63.9)	0.56
Working practices	Volume of sprayed dilution (l)	51 (10–120)		1.6 (0.5–2.6)	0.00
	Nozzle height (cm)	80 (40–160)		−0.5 (−1.7–0.6)	0.35
	Nozzle–applicator body distance (cm)	35 (20–180)		0.5 (−1.3–2.3)	0.57
	Spraying with nozzle directed in front		12	88.2 (29.5–146.9)	0.00
	Spraying against wind		20	42.8 (−22.5–108.2)	0.19
	Having a helper		16	−79.8 (−137.8 to −21.8)	0.00
	Splashing/spilling dilution over the pump		24	22.6 (−52.2–97.3)	0.54
	Splashing hands		23	21.2 (−50.8–93.2)	0.55
	Splashing on the feet		15	79.7 (21.6–137.8)	0.00
	Gross contamination of the hands by blocking a hose leakage, repairing nozzle or inserting hand into tank		15	75.5 (16.6–134.4)	0.01
Hygiene practices	Rinsing of hands		4	41.7 (−55.6–138.9)	0.38
	Wiping sweat off the face with a piece of cloth or shirt		5	69.5 (−16.4–155.4)	0.10
	Sealing tank lid with a piece of cloth		7	−47.1 (−123.9–29.7)	0.22

0.7 Ha (0.35–4.2). The pesticides applied were chlorpyrifos (12), methamidophos (12), a mixture of both pesticides (7) and cypermethrin (1). Although the latter application was not carried out with a target pesticide, it was not excluded for this report because the chemical nature of the pesticide influenced neither the observation nor the visual score.

The backpack used was either motor-pressurized (19) or hand-pressurized (13). In 19 applications the backpack had a leaking tank. None of the applicators wore any kind of PPE. Knee-high pants were used during eight applications, short-sleeved shirts in 17 and 27 were carried out barefoot.

The ambient air temperature during application varied between 21 and 32°C, with a relative humidity from 66 to 96% and a wind velocity between 0 and 2.7 m/s. Often the applications were carried out early in the morning after a rainy night. Thus, crops had dew on their foliage (22 applications) and the terrains were wet or slightly muddy (10). The maximum height of the crops was 175 cm with a median of 56 cm.

The average total visual score was 130 (SD = 88.8; range = 16–419). In general, the farmers presented the highest score on hands (palm and back), feet (instep), back and legs (front). A moderate score was observed on forearms (front and back), left leg (back) and thigh (front).

The results of the univariate linear regression analyses evaluating each of the 27 potential exposure determinants are presented in Table 1. Of these

Table 2. Results of within-group multivariate analyses of pesticide exposure determinants using the total visual score as the dependent variable among subsistence farmers, León, Nicaragua (*n* = 32)

Group	Factor	β (95% CI)	*P*	*R*^{2}	*P*
Worksite	Temperature (°C)	10.7 (−2.0–23.5)	0.10		
	Sprayed surface (Ha)	19.5 (−10.0–49.0)	0.19	0.25	0.04
	Wet or slightly muddy terrain	59.3 (−5.5–124.1)	0.07		
Spraying equipment	Hand-pressurized backpack sprayer	100.8 (43.2–158.4)	0.00		
	Leaking backpack	6.9 (−50.8–64.5)	0.80	0.33	0.00
Clothing	Wearing cap/headgear	66.8 (−28.3–162.0)	0.16		
	Wearing long-sleeved shirt	−23.0 (−90.1–44.0)	0.48		
	Shirt partially covering chest or abdomen	39.2 (−47.3–129.6)	0.34	0.14	0.36
	Wearing long pants	−55.7 (−130.7–30.0)	0.20		
Working practices	Volume of sprayed dilution (l)	0.8 (−0.2–1.8)	0.10		
	Spraying with nozzle directed in front	38.1 (−23.0–99.2)	0.21		
	Having a helper	−35.4 (−93.1–22.2)	0.22		
	Splashing on the feet	42.3 (−10.5–95.2)	0.11	0.52	0.00
	Gross contamination of the hands by blocking a hose leakage, repairing nozzle or inserting hand into tank	37.2 (−15.7–90.0)	0.16		
Hygiene practices	Wiping sweat off the face with a piece of cloth or shirt	60.4 (−28.2–149.0)	0.17		
	Sealing tank lid with a piece of cloth	−35.0 (−112.8–42.8)	0.36	0.11	0.19

Table 3. Results of across-group multivariate regression analyses of pesticide exposure determinants using the total visual score as the dependent variable among subsistence famers, León, Nicaragua (*n* = 32)

Factor	β (95% CI)	*P*	*R*^{2}	*P*
Constant	68.8 (13.4–124.2)	0.02		
Sprayed surface (Ha)	25.3 (2.6–48.0)	0.03		
Wet or slightly muddy terrain (No/Yes)	53.6 (10.2–97.0)	0.02		
Hand-pressurized backpack sprayer (No/Yes)	112.6 (68.1–157.2)	0.00	0.69	0.00
Wearing long pants (No/Yes)	−69.4 (−117.7 to −21.2)	0.00		
Gross contamination of the hands by blocking a hose leakage, repairing nozzle or inserting hand into tank (No/Yes)	42.3 (−3.4–88.0)	0.07		

determinants, 19 increased visual scores, six significantly (temperature, using a hand-pressurized backpack sprayer, volume of sprayed dilution, spraying with the nozzle directed in front, splashing on the feet and gross contamination of the hands). Eight determinants decreased the total visual score (height of the crop, applying on a slightly sloping terrain, wearing a long-sleeved shirt, wearing long pants, wearing shoes, nozzle height, sealing the tank lid with a piece of cloth as protection and having a helper), only having a helper being a significant finding. After grouping the variables by related factors, statistically significant models were derived for worksite, spray equipment and working practices (Table 2). The factors related to working practices influenced the visual score most strongly, explaining 52% of the total visual score variability. The model for factors related to worksite and equipment explained 25 and 33%, respectively, whereas grouped factors for clothing and hygiene practices were weaker predictors.

In the across-group multivariate regressions, sprayed surface, spraying on a wet or slightly muddy terrain, using a manual backpack sprayer and important skin contamination by touching the spray solution directly (blocking a leakage or putting a hand into the tank) emerged as the strongest determinants for increasing the total visual score, and wearing long pants emerged as the main preventive factor. The variability explained by the model was 69% (Table 3). An extended model including non-significant variables explained 75% of the variability in the visual score. The additional exposure

determinants of this latter model were spraying with the nozzle directed straight ahead, wiping sweat off the face with a piece of cloth or shirt, splashing the feet and having a helper, the latter decreasing the exposure (data not shown).

DISCUSSION

This study used a multistep approach to identify the most important determinants (as derived from field observations) of dermal pesticide exposure (as ascertained by a visual exposure score based on post-application fluorescent body images). Of the five groups of exposure determinants defined (worksite conditions, spray equipment, clothing, working practices and hygiene practices), working practices explained the highest proportion of variability of the dermal exposure. Across-group analyses yielded determinants from all five groups as components of the model that best explained the visual scores of dermal pesticide exposure. Some of the determinants, such as wet or muddy terrain, hand-pressurized versus motor-pressurized backpacks and dew on the crops, have rarely or never been considered in previous studies, including those carried out with small and subsistence farmers in Africa and Asia (e.g. Kishi *et al.*, 1995; Ohayo-Mitoko *et al.*, 1999).

Working practices explained >50% of the exposure variability. Such factors appear to be related mainly to the contamination of the hands, the front side of the legs and the instep of the feet. In fact, in this study, where none of the workers wore gloves, work practices such as blocking a leakage with bare hands, repairing the nozzles or inserting hands into the tank resulted in obvious contamination of the hands. Furthermore, with the workers not using boots, splashing the feet while diluting the concentrate and spraying with the nozzle directed straight ahead resulted in obvious contamination of the instep of the feet and the front of the legs.

Half of the applicators used a helper. The helper in most cases was a family member and only occasionally a paid worker. The helpers were mostly in charge of the mixing, assisting in placing the equipment on the applicator's back, and solving any unexpected troubles with the backpack. Thus, having a helper reduced especially contamination of the hands, feet and legs of the observed applicator. However, we observed contamination patterns among the helpers similar to those among the farmers who performed all activities themselves. Therefore, having a helper led to shared, but not overall decreased, exposure. Future studies should consider measuring the exposure of both types of workers.

Variables related to the spray equipment explained a third of the exposure variability. Spraying with a hand-pressurized backpack increased the visual score compared with the motor-pressurized backpack. Few studies have looked into the effect of pesticide spraying equipment on the level of exposure. Machado-Neto *et al.* (1992) reported that levels of exposure to fungicides in Brazilian applicators strongly depended on the type of gun on the application equipment. In our study, the type of backpack sprayer determined the skin exposure of the farmers partly by influencing working practices. For example, using a hand-pressurized backpack was related to the practice of spraying with the nozzle directed straight ahead and with a shorter nozzle–applicator body distance. In addition, farmers in this study tossed the lance on the ground while mixing. This practice led to clogging of the nozzles with soil and subsequent fumbling of the nozzle, primarily in the hand-pressurized backpacks, which have a smaller nozzle diameter. Surprisingly, leaking of the tank of the backpack, a recognized cause of poisonings (Wesseling *et al.*, 1993) and dermal injuries (Wesseling *et al.*, 2001a), did not emerge as a major exposure determinant. One possible explanation is that leaking backpacks often involve contamination of the back, the buttocks and genital area (van Wendel de Joode *et al.*, 1996) and, as discussed earlier, for ethical reasons the buttocks and genital area were not observed. In addition, in motor-pressurized backpacks leaking occurs mostly at the lid owing to pressure inside the tank, and half of these farmers reduced contamination by placing a cloth around the lid.

The group of variables related to the worksite explained a quarter of the variability of the total visual score. The most outstanding determinant in this group was wet or muddy terrain, which is a factor not previously discussed in the literature. Wet conditions occur in many tropical countries after rainy nights. In such circumstances, farmers have to make a bigger physical effort, resulting in more profuse sweating. With sweat dampening clothes from the inside and dew on plants dampening them from the outside, clothes become wet and the permeability probably increases for the water-soluble tracer and the water-soluble pesticides as well.

We expected that good hygiene practices would be primarily protective. Thus, sealing the tank lid with a piece of cloth prevented leakages and decreased exposure. However, rinsing the hands right after mixing increased the total visual score. This practice was observed only after significant contamination during mixing activities and probably reflects a response to gross contamination. Similar behavior was reported among Kenyan agricultural workers (Ohayo-Mitoko *et al.*, 1999). Wiping sweat off the face with a piece of cloth or the applicator's shirt appeared to be hazardous.

The within-group multivariate model for variables related to clothing explained relatively little of the variation and was not significant, but wearing a long-sleeved shirt, long pants or shoes was protective,

as expected. Wearing long pants, in particular, was identified as an important protective determinant in the final model. The fronts of the legs were among the most highly contaminated body parts, and are protected by wearing long pants. However, farmers tended to choose their oldest, most used clothing for application, resulting in limited protection, especially when dew and sweat soaked such clothes.

This study has several limitations. All participants were aware of the objective of the study, that is, evaluating their levels of exposure in association with their working practices. Thus, some of the practices observed might not represent regular practice. Another consideration is that the fluorescent images reflect patterns of contamination rather than the true pesticide exposure, since the concentration of the tracer in the solution is unrelated to the concentration of the pesticide and, also, its chemico-physical properties differ from those of the applied pesticide. Finally, owing to financial and infrastructure restrictions, the number of observed farmers was small. Nonetheless, the stepwise reduction strategy was a useful tool to reduce the number of variables in the analyses. Despite the limitations, this study showed that a combination of observation and total visual score techniques can provide valuable information on important determinants of exposure to pesticides and the most affected body parts in developing country conditions.

The strategy of reducing variables step by step allowed identification of the most important determinants, but did not completely eliminate the covariance between potential determinants in different groups. Although highly correlated variables with coefficients ≥0.7 were eliminated, variables in one group still could correlate up to a point with variables in other groups. For example, the volume of sprayed solution (working practice) correlated moderately with the sprayed surface area (work site) ($r = 0.43$; $P = 0.01$). Nevertheless, this strategy may be useful in developing job-specific questionnaires to identify homogeneous exposure groups based on the identified determinants (e.g. Tables 1 and 2).

It may also be useful in designing training and preventive programs. Before undertaking a training or monitoring program, it is necessary to identify both the variable(s) which lead to the highest exposure and the appropriate body part(s) (Garrido Frenich *et al*., 2002). Thus a training program for this group of farmers should emphasize maintenance of the equipment, the correct spraying technique when using manual backpacks, the type of clothes to wear during applications and in particular, considering the frequency of hand contact with the pesticide dilution, the use of gloves.

In conclusion, this study showed that a combination of observation and total visual score techniques can provide valuable information on important determinants of pesticide exposure in developing countries.

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