Original Articles

Acute Pesticide Poisoning among Female and Male Cotton Growers in India

FRANCESCA MANCINI, MS, ARIENA H. C. VAN BRUGGEN, PHD, JANICE L. S. JIGGINS, PHD, ARUN C. AMBATIPUDI, HELEN MURPHY, FNP, MHS

A season-long assessment of acute pesticide poisoning among farmers was conducted in three villages in India. Fifty female cotton growers reported the adverse effects experienced after exposures to pesticides by themselves and by their male relatives ($n = 47$). The study documented the serious consequences of pesticide use for the health of farmers, particularly women field helpers. Typically female tasks such as mixing concentrated chemicals and refilling spraying tanks were as hazardous as direct pesticide application. Of 323 reported events, 83.6% were associated with signs and symptoms of mild to severe poisoning, and 10% of the pesticide application sessions were associated with three or more neurotoxic/systemic signs and symptoms typical of poisoning by organophosphates, which were used in 47% of the applications. Although in 6% of the spray sessions the workers' neurotoxic effects were extremely serious, none sought medical care. Low-income marginal farmers were more often subjected to severe poisoning than were landlords. *Key words*: pesticide acute poisoning; cotton; India; integrated pest management; gender.

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Agriculture in South India is primarily a subsistence production system that involves 127 million cultivators and 107 million agricultural laborers. Crop productivity in the rain-fed area, which includes more than 70% of the cultivated land, is low and unpredictable.[1] The majority of the population (74.3%) is rural,[2] and 34.7% live below the international poverty level.[3]

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Address correspondence and reprint requests to Francesca Mancini, BFS, Marijkeweg 22, 6709 PG Wageningen, The Netherlands; e-mail: <Francesca.Mancini@wur.nl>.

During the Green Revolution, high-yielding varieties of various crops were introduced into the farming systems to increase productivity. These varieties were significantly more susceptible to plant pests and diseases and, subsequently, the use of pesticides became more intense, increasing from 2,330 kton during 1950–51 to 54,773 kton in 1990–91 (Directorate of Plant Protection, 2002, personal communication). Pesticides are largely applied to protect commercial crops. Cotton cultivation alone uses more than 60% of the national consumption.

The consequences of such indiscriminate use of pesticides have recently become a matter of public concern in India, following the publication of alarming information about the levels of pesticide residues in drinking water and soft drinks.[4] Beside the consumers' risks stands the documented hazard to producers, who are directly exposed to chemical substances.[5–8] Agricultural laborers and farmers work in a highly unsafe occupational environment. The pesticides used largely belong to WHO categories I and II (Highly Hazardous and Moderately Hazardous).

Chemical products such as Aldicarb, Dieldrin, and Paraquat that are banned in developed countries are still registered in India. Protective measures and equipment for safe handling and spraying of the pesticides are far from being adopted. Instead, people work barefoot and barehanded, wearing only short-sleeved cotton tee shirts and traditional sarongs (lungi). During an average spraying session, a farmer is directly exposed to pesticides for three to four hours at a time through leaking spray equipment, dripping plants and wind drift. Concentrated chemical products are mixed with water with bare hands. Farmers' risky behavior is not necessarily explained by a lack of awareness. On the contrary, farmers' level of knowledge on the health hazards of pesticides—even though partial and inexact—is in many cases higher than expected.[9–12] Training does little to change hazardous use of pesticides. For example, a program conducted by Novartis to train farmers in the safe handling and use of pesticides in the Coimbatore District of Tamil Nadu, India, in 1992

Refilling the tanks with pesticide.

failed to achieve substantial and sustainable changes in the farmers' practices.[13] Not only is protective equipment expensive, unavailable, and cumbersome to use, but in extreme hot weather conditions of the tropics protective gear is rarely used.[5] Therefore, educating farmers about the safe use of pesticides alone does not seem to be a viable way to eliminate occupational risks.

To date, studies have focused on the adverse health effects occurring among people applying chemical products. However, the focus should also extend to those who play supportive roles in the pesticide applications: women and children. In India, the production of cotton is female-labor-intensive. Extremely time-consuming operations such as weeding are often performed by women and children during the peak of the spraying season, when there are high residue levels in the fields. Other key female tasks are mixing pesticides with water and refilling the sprayers' tanks.

Pesticides are largely applied by low-income people, marginal farmers and landless workers. Associated malnutrition and infectious diseases in these populations make them more vulnerable to poisoning.[14,15] The need to generate information about the social and gender implications of pesticide application has been well documented and recommended in a review of the health impacts of pesticides compiled by Kishi.[16]

This study was engendered by the need to document the serious human health consequences of the indiscriminate use of pesticides on cotton in India. The intent was to focus on less visible, but much exposed, subjects: women and marginal farmers. Women perform secondary activities that have often been neglected in studies dealing with direct exposure. Marginal farmers are often engaged in professional spraying and therefore prone to continuous exposure.

METHODS

Study Objectives

In 2003, the European Union–Food and Agriculture Organization, Integrated Pest Management (EU-FAO IPM) Program for Cotton in Asia designed a participatory project that aimed to assess the frequency and severity of acute pesticide poisoning among cotton growers in Andhra Pradesh, India. For the last three years the program has been operative in the state, educating farmers in sustainable alternatives to pesticide use in farmer field schools (FFSs). As part of the regular FFS curriculum, farmers were taught the adverse effects of pesticides on human health and the environment. The assessment was conceived as a season-long special activity to be undertaken in three villages that had IPM* farmer field schools.† The initiative aimed to measure the health effects of pesticide exposures in real time through direct documentation by farmers. Because previous studies focused on male farmers who applied chemical products, this study concentrated on women as respondents (for themselves and for their male relatives). This surveillance activity assisted farmers in generating information about:

- The frequencies and severities of acute pesticide poisoning occurring among male and female cotton farmers
- The exposure of women performing supportive roles during spray operations
- The vulnerability of low-income groups involved in pesticide application

A second part of the assessment, undertaken in 2004, measured actual changes in the health of the respondents as a result of their participation in the cotton IPM FFS. Monitoring continued for several months, using the same reporting method as the study reported here. The data were analyzed against the baseline survey data collected in 2003.

This paper represents the first part of the assessment, conducted to estimate the effects on cotton growers' health of a chemical-based plant-protection system.

Study Area

The study was conducted in three cotton-growing villages, selected immediately after the commencement of the FFS on the basis of high female participation (over 50%) and marginal (< 1 ha) farmer participation (55%) predetermined by the FFS farmer selection

*Integrated pest management (IPM) is based on preserving natural enemies and growing healthy crops to control pests.

†Farmer field school (FFS) is an adult educational approach to empower farmers, developed in Indonesia in the early nineties.

process and the community's interest in the monitoring activity. The EU-FAO IPM Program adopted the strategy of conducting one FFS in each village, regardless of the village's size. Therefore, there were 25 trained farmers per village, of which some were women. All the women who had participated in the FFSs in the three villages joined the self-monitoring project. Two of the villages (Sairedapalli and Srinagar) were located in Warangal District and one (Darpalli) in Mahabubnagar District, Andhra Pradesh.

Andhra Pradesh is one of the nine major cotton-producing states of India. The rural population is 73% of the total. Cotton is grown on 1.02 million hectares. The industrial production of cottonseed is also concentrated in the state. According to the 2001 census, Mahabubnagar and Warangal districts had total populations of 3,077,050 and 2,818,832, respectively. Cotton is grown as the main crop during the rainy season (*Karif*) on 121,260 ha in Warangal and 22,697 ha in Mahabubnagar.

Darpalli is a small village populated by marginal native farmers (721 inhabitants). The area under cotton was 45 ha. The level of education among the people was found to be very low (in 1997, 70% of the rural people in the state were not literate). In contrast, communities of migrants, who moved from the state coastal area in search of fertile lands to cultivate, mainly inhabited Srinigar and Sairedapalli villages. These villages had, respectively, 3,108 and 1,038 inhabitants; the areas under cotton were 500 and 122 ha. Those villages could be considered better off, in that the people had more education and wealth.

Training of Enumerators and Farmers

The study involved three FFS facilitators trained by the EU-FAO IPM Program for Cotton in Asia in season-long (six months) residential Training of Facilitators (ToF) on IPM. In addition to technical knowledge, the ToF provides a solid background in adult non-formal education and enables facilitators to conduct participatory action research with farmers. In order to coach self-health monitoring, three FFS facilitators were also taught how to identify the signs and symptoms of acute pesticide poisoning. Emphasis was given to the need for establishing clear correlations between illness and exposures to pesticides. Minor adaptations to the specific study's requirements were made to the reporting format and method developed by Murphy.[6,17]

During the initial FFS sessions, three facilitators trained the farmers who had volunteered to participate in the monitoring. The forms to be used were field-tested with 20 respondents to correct for any potential misunderstandings of the reporting procedures as well as misconceptions about signs and symptoms. During the four months of the assessment, the project staff provided constant coaching to the farmers and the facilitators. A mid-season review meeting was also held

Application of pesticide.

two months after project initiation. A simple analysis of the forms was done together with the farmers at the end of the season in a final workshop.

REPORTING METHOD

Period and Procedure

The actual reporting started in the second month of the cotton-growing season, when pesticides are first applied to the young plants in August 2003, and lasted until December 2003. Women farmers ($n = 50$) attending the FFSs organized in their respective villages filled in health-monitoring forms after potential exposures to a variety of pesticides. In addition to self-reporting their own signs and symptoms of acute poisoning, the women each interviewed one male family member ($n = 47$) who had applied pesticides. Respondents were asked to fill in a form after every potential pesticide exposure regardless of whether or not they had experienced an adverse effect. Forms were filled in as a result of any of the following circumstances:

- Spraying pesticides in the field
- Mixing chemical solution and refilling spray tanks
- Working in field sprayed within the same day

Only the signs and symptoms that occurred during the working session or within 24 hours after exposure were recorded. At each FFS meeting the forms were reviewed.

Format

The reporting format was pictorial, to facilitate participation among those who were not literate (Figure 1).

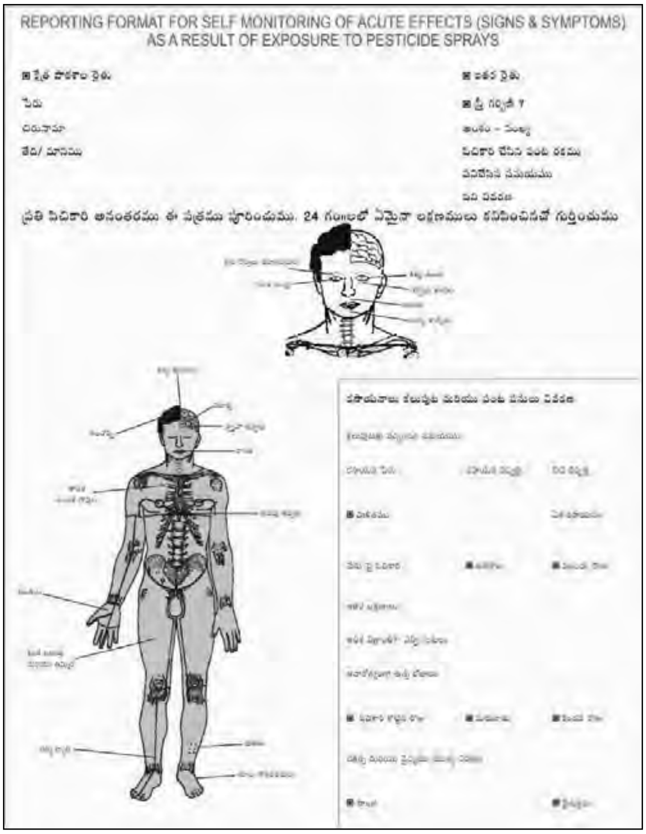


Figure 1—Reporting format in the local language, Telegu.

Facilitators provided the necessary assistance to review the forms throughout the monitoring.

The form allows for the reporting of the following:

- A list of 18 signs and symptoms of acute pesticide poisoning‡
- Type of chemical products used
- Quantity of chemical products used (mL formulated product/L water)
- Hours spent in performing the operation
- Hours extra–respite taken due to illness
- Number of sick days not worked as a consequence of the illness
- Use of medical treatments and home-made remedies
- Operation performed

The following socioeconomic parameters were collected in separate interviews from each respondent: age, gender, formal education, land holding, profession, and income level.

A total of 97 farmers, 50 women and 47 men, participated in the self-health monitoring (Table 1). All women participating in the FFSs, in the three villages were involved in the self-monitoring. As a result of the purposive selection of the villages, the sample included 70% of small farmers (< 2 ha).

‡Developed by Keifer[18] and adopted by Murphy.[17] The list is given in Table 2.

TABLE 1 Distribution of Respondents among the Villages

	Women (Respondents)	Men (Indirect Reporting)	Total
Darpalli	25	23	48
Sairedapalli	14	14	28
Srinagar	11	10	21
Total	50	47	97

Scoring System

The forms were assigned to four categories according to the signs and symptoms reported following Murphy's method.[17] Local effects were considered consequences of mild poisoning and rated in category 1. In the same category were some systemic or neurotoxic effects that are ill-defined (headache, dizziness, difficulty breathing) and effects that could be related to or confused with environmental factors such as heat exposure (excessive sweating, excessive salivation). Other neurotoxic effects such as nausea and vomiting, which might reflect cholinesterase depression, were classified in category 2, or moderate poisoning. Category 3 included loss of consciousness and seizure as effects of severe poisoning. Each form was assigned a final value (*severity class)* equivalent to the highest category marked. Forms with no signs and symptoms marked were assigned severity class 0 and classified as asymptomatic. A form containing only category 1 effects was classified as mild acute poisoning (Class 1). If at least one effect belonging to category 2 was included, the form was classified as moderate poisoning (Class 2). Finally, if one of the effects of category 3 was marked, the form was considered an example of severe acute poisoning (Class 3).

In addition to the severity class, the total sum of signs and symptoms reported in each form was also considered as an indicator of poisoning. For each form two values were therefore entered in the database as severity indicators: 1) *severity class* and 2) *total number of signs and symptoms reported (#S&S).*

Data Analysis

Linear trend analysis (frequencies analysis and chi-square test) was performed to describe pairs of variables (men versus women and small versus large). The severity class and the #S&S were analyzed in relation to the exposure variables. Multivariate analysis (multiple linear regression) was used to assess the contribution of each independent variable (age, gender, formal education, exposure time, pesticide toxicity, volume, operation, land-holding income, profession) to the severity

TABLE 2 Signs and Symptoms of Acute Pesticide Poisoning

	Type	Category
Burning eyes	Localized	1
Burning nose/tearing	Localized	1
Difficulty breathing	Systemic/neurotoxic	1
Dizziness	Systemic/neurotoxic	1
Excess sweating	Systemic/neurotoxic	1
Excessive salivation	Systemic/neurotoxic	1
Headache	Systemic/neurotoxic	1
Runny nose	Localized	1
Skin rashes	Localized	1
Blurred vision	Systemic/neurotoxic	2
Muscle cramps	Systemic/neurotoxic	2
Nausea	Systemic/neurotoxic	2
Staggering	Systemic/neurotoxic	2
Tremors	Systemic/neurotoxic	2
Twitching of eyelids	Systemic/neurotoxic	2
Vomiting	Systemic/neurotoxic	2
Loss of consciousness	Systemic/neurotoxic	3
Seizure	Systemic/neurotoxic	3

values. (Further analysis of the combination of signs and symptoms per spraying event was performed on the complete data set at the end of the second season's collection.)

RESULTS

Characteristics of the Respondents

The average ages of the reporting women and interviewed men were, respectively, 36.5 and 37 years. The distribution by age categories is given in Table 3. Almost half of the respondents fell into the class "marginal" (< 1 ha) (Table 3). Forty-one percent of the farmers lived below the national poverty level (10 rupees a day or 1$ per four or five days).

Spraying Operations

Individual spraying sessions recorded in four months of monitoring totaled 392. On average, farmers filled out one form per month. However, 69 forms had to be discarded due to incomplete information about the pesticides used. The distribution of the discarded forms could not be analyzed, and therefore biases introduced by the selection cannot be excluded. The women self-reported 165 events and reported on 158 spraying sessions that had been performed by their male relatives. The total number of forms per farmer did not reflect the individual field's spraying frequency, which was separately recorded. In Darpalli village the average number of sprays during the cotton-growing season was 5.9 (range 2–15); in Sairedapalli, 6.4 (range 1–11), and in Srinagar, 11 (range 5–14).

In the case of the women, the health forms were filled in after mixing concentrated chemicals with water and filling spray tanks (47%), mixing and subsequently working in the field (24%), working in a recently sprayed field (17%), applying pesticides (9%), and others (3%). Application of pesticides referred to the spreading of phorate granules (organophosphate, WHO 1A hazard class) on maize and chili plants.

TABLE 3 Distribution of Respondents by Age and by Land Class

	Women (n = 50)	Men (n = 47)
Age (years)		
< 30	18	10
30–39	15	15
40–50	17	13
> 50	—	9
Land (hectares)		
Marginal (< 1)	22	19
Small (1–2)	11	13
Semi-medium (2–4)	12	7
Medium/large (> 4)	8	8

Men's forms were filled in after spraying pesticides (75%), spraying and subsequently working in the field (22 %), and mixing concentrated chemicals with water and filling spray tanks (4%). The average working sessions lasted 4 h 36 m for men and 4 h 24 m for women. Average volumes of, respectively, 238 and 242 L, containing 212 and 190 mg of active ingredient, were applied per session. During the study, participatory observations were conducted to better elucidate the gender roles of the pesticide-application task. An example is given in the specific session described at the end of the article.

Twenty-six types of chemicals (Table 4) were used. Products belonging to the organophosphate family were used in 47% of the spraying events. Endosulfan (organochlorine) alone was used in 135.

Consolidation of results.

TABLE 4 Pesticides Used by the Reporting Farmers*

Pesticide	WHO Hazard Class	Chemical Family	Cholinesterase Inhibitor	% of All Pesticides
Parathion	1A	Organophosphate	+	0.3
Monocrotophos 36% SL	1B	Organophosphate	+	12
Phorate 10% G	1B	Organophosphate	+	3.7
Triazophos 40% EC	1B	Organophosphate	+	0.6
Chlorpyriphos 20% EC	2	Organophosphate	+	10
Cypermethrin 25% EC	2	Pyrethroid		8
Dimethoate 30% EC	2	Organophosphate	+	0.6
Endosulfan 35 EC	2	Organochlorine		13
Fipronil	2			0.6
Lambda cyhalothrin 5% EC	2	Pyrethroid		0.6
Phosalone 35 EC	2	Organophosphate	+	1.3
Profenophos 50% EC	2	Organophosphate	+	4
Quinalphos 25% EC	2	Organophosphate	+	13.7
Acephate 75% SP	3	Organophosphate	+	4.3
Acetamiprid 70% WP	3	Chloro-nycotil		4.6
Copper oxychloride 50% WP	3	Inorganic		1.3
Dicofol 18.5%	3	Organochlorine		0.6
Fenvalerate 20% EC	3	Pyrethroid		0.3
Imidachloprid 17.8% SL	3			4.7
Malathion 50% EC	3	Organophosphate	+	0.3
Carbendazin	U	Azole		0.6
Indoxacarb 14.5% SC	U	Chloro-nycotil		4.7
Mancozeb 75% WP	U	Carbamate	+	0.3
Spinosad 45% SC	U	Macrobial		2
Sulfur 80% WP	U	Inorganic		0.6
Wafarin 0.025%	U	Coumarin		0.6
Other (botanical, inorganic, unidentified ingredient)				7.0

*The WHO hazard classification refers to the formulated chemical products. The classification of the formulations was based on toxicity data obtained on that formulation by the manufacturer: In the cases in which this was not available, the values were calculated on the basis of the LD50 oral or dermal toxicity using WHO conversion tables.[19]

1A = extremely hazardous, 1B = highly hazardous, 2 = moderately hazardous, 3 = slightly hazardous, u = unlikely to present acute serious hazard in normal use.

HEALTH EFFECTS

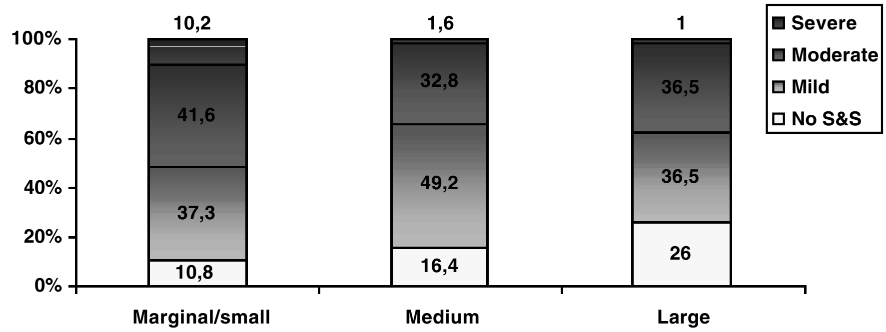
Reported Signs and Symptoms

Of the 323 reported events, 16.4% were asymptomatic, 39% led to mild poisoning, 38 % to moderate poisoning, and 6% to severe poisoning.

Participatory evaluation is sometimes subject to strategic bias introduced by the respondents themselves, who are centrally involved in the risk behaviors. In the case of this study, such bias would have led to an overreporting of the health effects. In order to assess the validity of the respondents' reporting, three symptoms (excessive tearing, excessive salivation, and tremor) specific to organophosphate exposure were used as dummy symptoms. Tremor was associated with organophosphate exposure in 83% of the cases, excessive tearing in 62%, and excessive salivation in 60%. According to the respondents, endosulfan (organochlorine) was responsible for 28% of the excessive tearing, 12% of excessive salivation, and 8% of tremor (one case). The remaining cases were explained by exposures to chloro-nicotinyl, a relatively new chemical class of systemic insecticides that acts on the central nervous system. Organochlorines do not stimulate glands and therefore are not expected to cause the above-mentioned symptoms. However, the relatively high associations of the symptoms with the use of endosulfan, imidachloprid, and acetamiprid but not with the use of any other pesticide is striking. No association between the three symptoms and the use of pyrethroids or botanical or inorganic components was reported.

The frequencies of spray-session illness events are significantly different depending on land-holding status (chi square significant at $p < 0.0001$). The incidence of severe poisoning was ten times higher among marginal farmers than among larger land-holding farmers (Figure 2). Of the marginal and small-land-holding farmers, 10.2% suffered major effects. The distribution in Figure 3 shows that marginal and small farmers experienced more signs and symptoms than did those who owned medium-sized and large farms. Average exposure times and pesticide toxicities were calculated for the subsamples marginal, medium, and large farmers, but the values did not explain this result. The level of formal education can partially explain the finding. Illiterate

Figure 2—Distribution of severity classes of signs and symptoms by economic class.



farmers experienced on average 4.8 #S&S and a *severity class* of 2.9 against respectively 2.4 and 2.2 for farmers educated to the secondary-school level. The values for farmers educated beyond secondary school were remarkably lower (0.6 #S&S and 1.3 *severity class*); however, the sample of educated farmers was too small (4) to be considered representative. The greater vulnerability of small and poor farmers could also be related to their general health conditions and to a cumulative effect of prolonged occupational exposures over the years. An important factor that could have played a role in diversifying exposures among groups is the differences among application methods, not considered in this study. Wealthier farmers are often in the position to afford safer equipment to apply pesticides. It worth noticing that 70% of the asymptomatic events occurred indeed among farmers who owned large and medium-sized farms. The higher incidence clearly reported calls for confirmation through an appropriate research design.

The village-wide analysis also showed a higher illness incidence among farmers in Darpalli than in the other two villages. Loss of consciousness and seizure were recorded only among the poor community of this village. In the case of the two villages in Mahabubnagar, the effects of pesticides on the health of the reporting farmers were mild. The results of a separate ongoing analysis of the labor organization within the same households may provide additional information that will make it possible to cross-check individual exposure times and explain some of the difference. A village effect might have been introduced in the reporting by the fact that each facilitator was operative in only one village.

The gender-segregated analysis showed no significant difference in the distributions of signs and symptoms between men and women. Also, severity class was not significantly correlated with the gender of the respondents. The health effects experienced by the women were comparable to those experienced by men. No significant correlation was found between severity class and age. However, the reader is reminded that children were not included in the surveillance.

These results confirm the hypothesis that women cotton workers in India are seriously exposed to pesticide contamination.

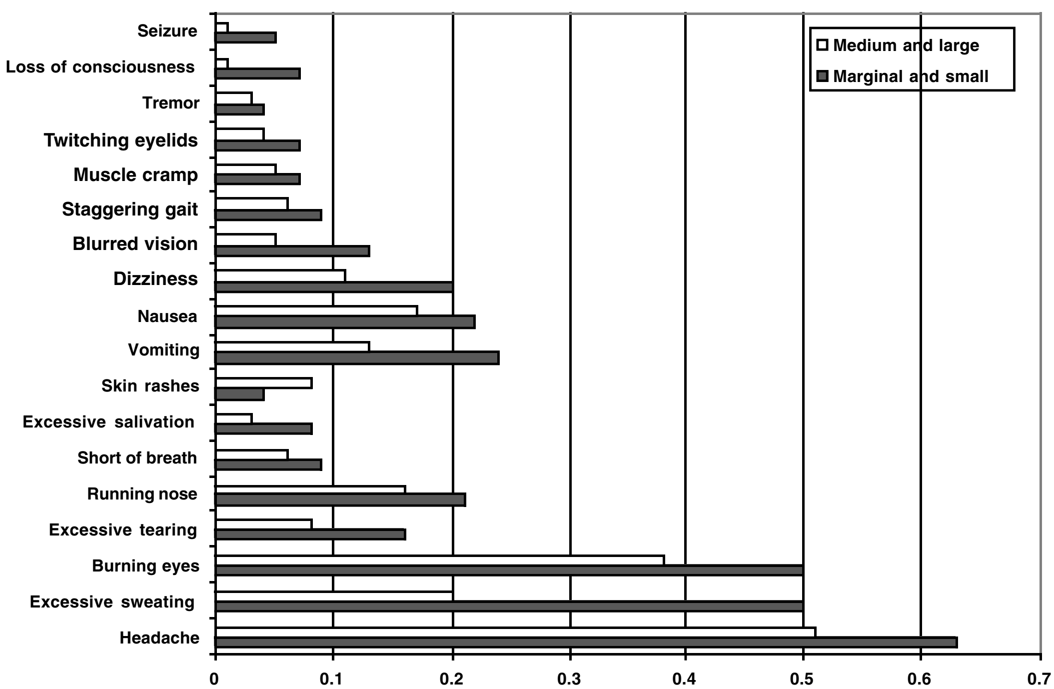


Figure 3—Distribution of signs and symptoms by land-holding class.

TABLE 5 Associations between Total Number of Signs and Symptoms (#S&S) and Severity Class, Pesticide Toxicity, and Exposure

	#S&S (Mean/Median)
Severity class	
No S&S	0/0
Mild	1.9/2
Moderate	4.0/4
Severe	8.4/8
Toxicity (WHO class)	
U	0.6/0
3	1.4/1
2	2.7/2
1b	3.0/2
1a	2.9/3
Exposure time (hours)	
1–2	1.8/2
3–4	2.0/2
5–6	2.4/2
7–8	4.8/5
9–12	8.4/9

Severity Class and #S&S versus Exposure Variables

Each exposure was described by five variables:

Pesticide toxicity: toxicity of the formulated chemical product classified according to the WHO hazard classes. Pesticides belonging to WHO class 1a ("extremely hazardous") scored 1 point, class 1b ("highly hazardous") 2 points, class II ("moderately hazardous") 3 points, and class III ("slightly hazardous") 4 points. Pesticides unlikely to present acute hazard in normal use (class U) were assigned a score of 5 points.

Weekly meeting to revise the reporting forms.

Exposure time: the duration in hours of the working session.

Volume: the final volume of the spraying solution expressed in liters.

Operation: the activity performed during the working session.

Profession: The variable referred to whether the respondents were hired to apply pesticides in others' fields, in addition to their own.

The mean and median values of the *#S&S* associated with the different categories of pesticide toxicity, severity class, and exposure time are shown in Table 5.

The distribution of severity class by gender across operation performed (Table 6) showed that spraying and mixing were key exposure activities associated with very similar incidences of severe poisoning. During the mixing operation, the respondents prepared chemical solutions in rapid succession at close time intervals. Between mixing sessions, the respondents were present in the field. The associations of mixing with field work afterwards led to a slight shift of the distribution towards greater severity. The mixing and spraying tasks had average durations of 3.5 and 3.8 hours, respectively. The same operations combined with field work lasted 6.7 hours (mixing and field work) and 7 hours (spraying and field work). Prolonged exposure led eventually to the development of more severe illness. Field work alone did not cause any severe or moderate poisoning. This may be explained by the absence of direct contact with the concentrated chemical.

To determine the contributions of individual factors, severity class and *#S&S* were regressed (Table 7) on the five exposure variables, the three social variables (gender, age, formal education), and three economic variables (land holding, income, profession). The highest R^2 was found for the model that incorporated education, land holding, profession, exposure time, and toxicity.

Participant Observation of a Pesticide-spraying Session

In order to corroborate the finding for women's exposures to pesticides, the first author observed some spraying sessions in Darpalli village. Table 8 refers to a typical hour of work during which wife and husband were continuously present in the field. The pesticide mixture was prepared by the woman, without any sort of protective equipment. The concentrated product was mixed barehanded, and every 7–9 minutes the tank was refilled, for a total of six refillings an hour. The session lasted three hours. Throughout the session the woman followed the man, who was spraying the mixture. Repeated exposures of the two operators were evident. The average reporting session of the female respondents for "mixing of pesticides" was likely to include 26–28 brief exposures

TABLE 6 Distribution of Signs and Symptoms by Severity Class among Operations by Gender, as Percentages and Total Numbers of Events

	% (Total No. of Events)					
	Mixing	Mixing + Field Work	Field Work	Spraying	Spraying + Field Work	Total
No S&S						
Men	2 (2)	0 (0)	0 (0)	1 (1)	3 (1)	1 (4)
Women	8 (7)	0 (0)	57(16)	19 (26)	0 (0)	15 (49)
Mild						
Men	4 (3)	0 (0)	0 (0)	41 (55)	0 (0)	18 (58)
Women	49(42)	10 (4)	43 (12)	3 (4)	19 (7)	21 (69)
Moderate						
Men	1 (1)	0 (0)	0 (0)	24 (32)	50 (21)	17 (54)
Women	31 (27)	80 (31)	0 (0)	8 (10)	5 (2)	22 (70)
Severe						
Men	0 (0)	0 (0)	0 (0)	4 (6)	11 (4)	3 (10)
Women	5 (4)	10 (4)	0 (0)	0 (0)	3 (1)	3 (9)
TOTAL	100 (86)	100 (39)	100 (28)	100 (134)	100 (36)	100 (323)

to the concentrated products and a prolonged air exposure to the freshly applied mixture.

Medical Assistance

Regardless of the seriousness of the illness, farmers sought medical advice only in 8% of cases. Home-made treatments were taken in 70% of the cases; no action was taken in the remaining cases. In rare cases, short periods of extra rest (1.41 hours for women and 1.38 hours for men) were necessary before resuming the work. In 7% of the cases, a full day of rest was recorded—a total of 23 sick days for the all participants during the four-month reporting period. This percentage is similar to the total percentage of severe cases reported (5.9%), suggesting that the use of sick days as an indicator might lead to an underestimation of the extent of pesticide poisoning.

Farmers' Workshop

Farmers consolidated and discussed the results of the project in a final workshop. A color-based code, suitable for a non literate population, was used to score the forms, following the scoring procedure described above. Participants attributed a final severity class to each form and analyzed its frequency. The findings led to the farmers' realization of the serious health consequences associated with the irrational use of pesticides. The monitoring was conducted as part of the FAO Cotton IPM Program to support the adoption of viable and socially acceptable alternatives to the use of pesticides.

TABLE 7 Multiple Regression of Severity Class on Socioeconomic and Exposure Variables

Variable	β Coefficient	Standard Error	Beta		Significance (t)
Severity index					
Pesticide toxicity	0.295	0.035	0.439	8.495	0.000
Exposure time	0.104	0.021	0.262	4.897	0.000
Formal education	–0.129	0.063	–0.128	–2.051	0.041
Land holding	–1.11	0.007	–0.091	–1.499	0.135
Profession	–0.162	0.120	–0.076	–1.356	0.176
Adjusted R square = 0.292, F-value (df5, 275) = 24.1, *p* = 0.0001					
#S&S					
Pesticide toxicity	0.654	0.106	0.318	6.152	0.000
Exposure time	0.447	0.065	0.367	6.884	0.000
Profession	–1.12	0.367	–0.171	–3.079	0.002
Formal education	–0.549	0.193	–0.177	–2.850	0.005
Land holding	–3.87	0.023	–0.104	–1.705	0.089
Adjusted R square = 0.294, F-value (df5, 275) = 24.3, *p* = 0.0001					

TABLE 8 Time Schedule of One-hour Spraying Session (Participant Observation)

Time	Operator*	Operation	Comments
8.00–8.10	W	Preparation of spray solution	Bare hand
8.10–8.20	M W	Spraying Preparation of refilling solution	Bare hand and foot Legs and back wet
8.20–8.21	W	Refilling	Mixing with bare hand
8.22–8.29	M W	Spraying Preparation of refilling solution	Strong smell of chemical spreads in the air
8.30	W	Refilling	
8.30–8.40	M W	Spraying Preparation of refilling solution	Both have to walk across the sprayed area to reach unsprayed areas. Contact with solution dripping from the plants
8.41	W	Refilling	Rinsing of the chemical measuring container with bare hand
8.41–8 50	M W	Spraying Preparation of refilling solution	Woman works in the field
8.51	W	Refilling and moving to another field	
8.55–9.00	M W	Spraying Preparation of refilling solution	

*W = woman, M = man.

DISCUSSION

The study documented the serious consequences of the indiscriminate use of pesticides for the health of farmers' health in India, and specifically women field helpers. Kishi[16] pointed out that the existing world data on poisoning refer mainly to young male subjects applying pesticides. There have also been investigations of the exposures of women performing the same operations.[6,20,21] However, women in developing countries are prone to other ways of exposure because through their supportive roles, they are often involved in the chemical-application process.[22] Few studies have mentioned this aspect, and none has ever estimated the ill effects.[13,22,23] The current survey addressed this information gap by focusing on the adverse effects in two target groups, women and marginal farmers, after they performed operations at risk of contamination.

Women scoring the health-monitoring forms at the final workshop.

The current self-monitoring has shown no difference between the degrees of illness experienced by women and by men. Whether this is related to the fact that these women were reporting on both themselves and their husbands is not entirely clear. Nevertheless, the women reported significant health effects. Typically female tasks, such as mixing concentrated chemical products and refilling spraying tanks, are key exposure activities, which have been proved to be as hazardous as direct pesticide application itself.

Ten percent of the spray sessions were associated to three or more neurotoxic/systemic signs and symptoms, which is the functional definition of acute poisoning used in Indonesia by Kishi et al.[5] The adverse effects on the central and the peripheral nervous systems were typical of poisoning caused by organophosphates,[24] these products were used in 47% of the applications. Damage caused by cholinesterase inhibitors with organophosphates can become permanent.[25–29] Although 6% of the workers' spray sessions were associated with serious neurotoxic effects, none sought medical care or were hospitalized. On the contrary, these farmers rarely stopped working for more than a day. This finding confirms the serious underestimation of statistics based on official medical records.[18,30]

Low-income marginal farmers were more often subjected to severe poisoning than landlords. Smallholders and landless people often apply pesticides throughout

At the final workshop, farmers consolidated the results with the assistance of facilitators.

the season as waged workers. Repeated exposures, in addition to malnutrition and other diseases, might explain the greater vulnerability of these groups.[15,31] Indeed, pesticide toxicity and exposure time were positively correlated with the extent to which symptoms were experienced in this survey, while formal education and land holding were negatively correlated with this measure of ill health. Yet, only 29% of the variation in symptom severity could be explained by these factors.

However, more research is needed on factors contributing to the effects on health of people exposed to pesticides, in particular high-risk groups that are rarely included in surveillance of pesticides' health effects.[32,33]

The survey aimed primarily to raise farmers' awareness of the seriousness of the pesticide poisoning occurring in the villages. It also aimed to quantify the problem by direct reporting by farmers. The method has some limitations. Murphy et al.[17] provide a detailed strength-and-weakness analysis of the method. We report here only those aspects that are relevant to our survey. Since signs and symptoms of acute poisoning are nonspecific, the health data generated can be taken only as estimates. Whether the women over- or under-reported the true extent of the problem cannot be determined without biomarkers. A gender bias related to the difference in reporting methods between women and men could also have been introduced. Self-monitoring data would need to be backed up by clinical data and blood sample analyses, such as cholinesterase depressions. Another issue is that respondents belonging to the same village had close interactions. This may have introduced a systematic bias yielding homogeneity of reporting. Finally, the method cannot appreciate the chronic consequences of prolonged exposures to pesticides. Relevant in the case of women are the long-term effects on the reproductive system that can lead to abortions, stillbirths, neonatal deaths, and congenital defects.[34–37] A study conducted in India has shown that female cotton workers experience the same long-term consequences of exposure to pesticides.[38]

Our research concerned only adult respondents (18 years old or older), and no age factor related to the severity of the poisoning was found. However, the Pan American Health Organization has estimated that 10–20% of all pesticide poisoning cases involve children. The cottonseed industry in India employs thousands of girls 7 to 14 years old to manually cross-pollinate the plants. There is need to investigate the impact on children exposed to pesticides.

The survey covered one cotton season and therefore the number of records is limited. A second data collection was done in 2004 with the same respondents to estimate changes in farmers' health induced by the cotton IPM FFSs.

The extent of pesticide poisoning among farmers and workers in developing countries is worrying.[16] In the extreme hot weather of the tropics, protective gear does not seem to be a viable solution to eliminate occupational risks. Educating farmers about the pesticide hazard alone has not achieved significant results.[13] The solution seems to be in the replacement of pesticides with non- or less toxic alternatives. One example of such alternatives can be found in the integrated pest management approach.

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References

1. Department of Agriculture and Cooperation. Agriculture Statistics at a Glance. Government of India, 2002.
2. Census 2001, <http://www.censusindia.net/rural.html>.
3. World Bank, Measuring poverty, <http://www.worldbank.org/data/wdi2003/pdfs/table%202-6.pdf>.
4. CSE (Centre for Science and Environment). Pesticide residues in bottled water. CSE Report, New Delhi, India, 2003.
5. Kishi M, Irschhorn N, Djajadisastra M, Satterlee LN, Strowman S, Dilts R. Relationship of pesticide spraying to signs and symptoms in Indonesian farmers. Scand J Work, Environ Health. 1995; 21:124-33.
6. Murphy H, Sanusi A, Dilts R, Djajadisastra M, Hirchhorn N, Yuliantiningsih S. Health effects of pesticide use among women Indonesian farmers: Part I: Exposure and acute effects. J Agromedicine. 1999; 6 (3):61-85.
7. Wesseling C, Aragon A, Castillo Leta l. Hazardous pesticides in Central America. Int J Occup Environ Health. 2001; 7:287-94.
8. Kunstadter P, Prapamontol T, Siririjn BO, Sontirat A, Tansuhaj A, Khamboonruang C. Pesticide exposure among Hmong farmers in Thailand. Int J Occup Environ Health. 2001; 7: 313-25.
9. Aragon A, Aragon C, Thorn A. Pests, peasants, and pesticides on the northern Nicaraguan Pacific Plain. Int J Occup Environ Health. 2001; 7: 295-302
10. Clarke EE, Levy LS, Surgeon A, Calvert IA. The problems associated with the pesticide use by irrigation workers in Ghana. Occup Med (Lond). 1997; 47 (July) (5): 301-8.
11. Eisemon TO, Nyamete A. School literacy and agricultural modernization in Kenya. Comparative Education Review. 1990; 34: 161-76.
12. Kishi M. Indonesian farmers' perception of pesticides and resultant health problems from exposure. Int J Occup Environ Health. 2002; 8: 175-81.
13. Atkin J. In: Lesinger KM (ed). Safe and Effective Use of Crop Protection Products in Developing Countries. Wallingford, UK: CABI Publishing, 2002.
14. London L, Rother A. People, pesticides and the environment: who bears the brunt of background policy in South Africa? New Solutions. 2000; 10:339-50.
15. WHO. The Public Health Impact of Pesticides Use in Agriculture. Geneva, Switzerland: World Health Organization. 1990.
16. Kishi M. The health impacts of pesticides: what do we know, what can be done? In: Pretty J(ed). The Pesticide Detox. 1st ed. London, U.K., Sterling, VA: Earthscan, 2005: 23-38.
17. Murphy H, Hoan N P, Matteson P, Morales Abubakar AL. Farmers' self-surveillance of pesticide poisoning: a 12-month pilot in Northen Vietnam. Int J Occup Environ Health. 2002; 8:201-11.
18. Keifer M. Estimating underreported poisonings in Nicaragua. Am J Ind Med. 1996; 30: 195-201.
19. IPCS. International Programme on Chemical Safety. The WHO recommended classification of pesticides by hazard. 2000-2002.
20. Kimani VN, Mwanthi MA. Agrochemicals exposure and health implications in Githunguri location, Kenya. East Afr Med J. 1995; 72: 531-5.
21. Trivelato MD, Wesseling. Use of pesticides in non-traditional crops in Costa Rica: environmental and labor health aspects. In: Kopke U, Schulz DG. Proceedings 9th International Scientific conference IFOAM. November 16–21, 1992, Sao Paolò, Brazil.
22. London L, de Grosbois S, Wesseling C, Kisting S, Rother HA, Mergler D. Pesticide usage and health consequences for women in developing countries: out of sight, out of mind? Int J Occup Environ Health. 2002; 8: 46-59.
23. Rother HA. Influences of pesticide risk perception on the health of rural South African women and children. African Newsletter on Occupational Health and Safety. 2000; 10:42-6.
24. Keifer M. Human health effects of pesticides. Occup Med. 1997; 12 (2).
25. McConnell R, Magnotti R. Screening for insecticide overexposure under field conditions: a revaluation of the tintometric cholinesterase kit. Am J Public Health. 1994; 84:479-81.
26. McConnell R, Delgado-Tellez E, Cuandra R, et al. Organophosphate neurophathy due to methamidophos: biochemical and neurophysiological markers. Arch Toxicol. 1999; 73: 296-300.
27. Miranda J, Lundeberg I, McConnell R. Onset of grip- and pinch-strength impairment after acute poisonings with organophosphate insecticides. Int J Occup Environ Health. 2002; 8:19-26.
28. Rosenstock L, Keifer M, Daniell W, et al. Chronic central nervous system effects of acute organophosphate pesticide intoxication. Lancet. 1991; 338:223-7.
29. Wesseling C, Keifer M, Ahlbom A, et al. Long-term neurobehavioral effects of mild poisonings with organophosphate and n-methyl carbamate pesticides among banana workers. Int J Occup Environ Health. 2002; 8: 27-34.
30. Murray DL. Cultivation crisis: the human cost of pesticides in Latin America. Austin, TX: University of Texas Press. 1994.
31. Repetto R, Baliga S. Pesticides and immunosuppression: the risks to public health. Health Policy Plan. 1997; 12:97-106.
32. Moses M, et al. Environmental equity and pesticide exposure. Toxicol Ind Health. 1993; 9: 913-59.
33. Zham S H, Blair A. Cancer among migrant and seasonal farmworkers: an epidemiologic review and research agenda. Am J Ind Med. 1993; 24: 753-66.
34 Restrepo M, et al. Prevalence of adverse reproductive outcomes in a population occupationally exposed to pesticides in Colombia. Scand J Work Environ Health. 1990; 16:232-8.
35. Taha TE, Gray RH. Agricultural pesticide exposure and prenatal mortality in central Sudan. Bull WHO. 1993; 71 (3-4): 371-21.
36. Zhang J, Cai WW, Lee DJ. Occupational hazard and pregnancy outcomes. Am J Ind Med. 1992; 21:397-408.
37. Rojas A, Ojeda ME, Barrazza X. Congenital malformations and pesticide exposure. Rev Med Child. 2002; 128: 399-404.
38. Rupa DS, Reddy PP, Reddi OS. Reproductive performance in population exposed to pesticides in cotton field in India. Environ Res. 1991; 55: 123-8.