# Reducing the Incidence of Acute Pesticide Poisoning by Educating Farmers on Integrated Pest Management in South India

**FRANCESCA MANCINI, PHD, JANICE L. S. JIGGINS, PHD, MICHAEL O'MALLEY, MD, MPH**

Sixty-five farmers reported on pesticide use and the signs and symptoms of acute pesticide poisoning when using two different plant protection strategies: in 2003 using chemical controls and in 2004 using an approach to Integrated Pest Management (IPM) based on an ecological analysis of the field conditions. Exposure to organophosphates was confirmed as a serious risk factor for occupational poisoning. The adoption of IPM reduced the use of pesticides and halved the incidence of acute pesticide poisoning. Overall, the pesticide use spectrum shifted towards lower WHO Hazard Classes. A reduction of adverse health effects was attained through a reduction in exposure to toxic pesticides and behavioural changes. Given that other strategies to reduce the rate of acute poisoning have proven ineffective, interventions aiming to minimize pesticide poisoning in India and in other developing countries with similar rural conditions should focus on restricting the use of highly toxic compounds and educating farmers on IPM. *Key words*: Pesticide poisoning; organophosphates; Farmer Field School; Integrated Pest Management; cotton

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Synthetic pesticides are widely used in agriculture to control crop losses caused by insects and other pests. In 2007, the global market value for conventional crop protection products reached US$33.4 billion, 9.7% up from the previous year, according to Croplife International.[1] The trends in the use of pesticides in more recent years are unclear, as official statistics on global consumption of active ingredients are not yet available. In OECD countries, the use and handling of pesticides is strictly regulated, while in many developing countries the necessary legislation is still incomplete or not properly enforced.

In 2006, the World Health Organization (WHO) estimated global pesticide poisoning at 3 million cases. However, clinical surveillance has provided compelling evidence that these estimates do not represent the real extent of illness and death by pesticide poisoning, failing either to reflect the actual hospital records or to account for misdiagnosed or nonhospitalized cases.[2–4]

Reportedly, national authorities fail to keep complete records on non-fatal occupational exposure in developing countries.[5] Pesticide poisoning studies based on questionnaires have shown much higher figures than hospital registries, and directly observed poisoning rates have been recorded at levels even higher than recalled information provided by farmers in questionnaires.[6]

Farmers and agricultural workers perceive the signs and symptoms of acute poisoning as an unavoidable part of their occupation. As signs and symptoms often disappear by themselves, those affected tend to avoid visits to health centers or hospitals, which are often too far away or too expensive to access. In 140 cases of moderate to severe acute pesticide poisoning recorded in a sample of 97 Indian cotton growers during one spraying season of 4 months, poisoned individuals never sought the advice of a doctor.[7] Less predictable forms of contamination, like take-home exposure to pesticides among farm families or entering fields recently sprayed before the no-entry recommended period, have been overlooked in epidemiological assessments, even though the few studies conducted have shown that farm children of pesticide applicators are more highly exposed to pesticides[8–10] and have higher levels of pesticide metabolites in their urine samples, compared to other farm children and non-farm children.[11–12] Socioeconomic factors such as poverty, malnutrition and illiteracy[13–14] amplify the adverse consequences of pesticide exposure of poor people.

The implementation of appropriate preventive measures in occupational exposures remains limited by insufficient information among users.[15] Some studies evaluating the effectiveness of Personal Protective Equipment (PPE) in reducing exposure to pesticides have estimated that effective PPE reduces exposure up to 50% in developing countries; others have shown its inadequacy to protect farmers. Hruska and Corriols[16] monitored the cholinesterase levels of farmers who used PPE over two years and found no reduction of exposure to organophosphate insecticides as compared with farmers who did not use the equipment. Atkin[17] has shown the inadequacy of risk reduction programs promoting the use of PPE and training on safe use as a means to contain exposure in the socio-eco-

Received from: Biological Farming Systems, Wageningen University (FM), Communication and Innovation Studies Group, Wageningen University (JLSJ), and Occupational Health Services, University of California Davis (MO). Send correspondence to: Francesca Mancini, Corso Martinetti 34a/7, 16149 Genova, Sampierdarena, Italy; email: <francescab.mancini@libero.it>.

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*Manual application of fertilizer.*

nomic context of rural India. PPE includes impermeable gear that is usually not affordable or available, nor acceptable to workers in hot climates.[18,19] The local cotton garments commonly used by Indian farmers do not offer any protection against skin exposure. McConnell,[20] who studied the epidemic of pesticide poisoning in Nicaragua, listed among the main causes of poisoning the use of acutely toxic pesticides under primitive working conditions which did not allow for safe handling.

The Food and Agriculture Organisation (FAO) of the United Nations (UN) has developed the International Code of Conduct on the Distribution and Use of Pesticides[21] (the Code), which serve as globally accepted voluntary standards of conduct for all public and private entities engaged in, or associated with, the distribution and use of pesticides. The Code recommends that pesticides whose handling and application require the use of PPE that is uncomfortable, expensive, or not readily available should be avoided, especially in the case of small-scale users in tropical climates. Preference should be given to pesticides that require inexpensive personal protective and application equipment and to procedures appropriate to the conditions under which the pesticides are to be handled and used (Article 3.5). According to the Code, the 'prohibition of the importation, sale and purchase of highly toxic and hazardous products, such as those included in WHO Hazard Classes Ia [extremely hazardous] and Ib [highly hazardous], may be desirable if other control measures or good marketing practices are insufficient to ensure that the products can be handled with acceptable risk to the user' (Article 7.5).

Due to shortcomings in the implementation of the code, the incidence of pesticide poisoning remains often high in developing countries and among casual or migrant workers in industrial countries. Phasing out the most toxic pesticides (WHO Hazard Class I), and in particular organophospate products, has been called for as the only effective intervention to protect farming communities wherever proper use can not be guaranteed, as is the case in most developing countries.[22–24] In 2006, the FAO Council (COAG/ 2007/Inf.14) agreed that the activities of FAO on risk reduction shall support the progressive ban on highly hazardous pesticides, and the promotion of good agricultural practices. However, implementation of such a policy requires a strong political will and effort to provide farmers with plant protection alternatives.

In India, large quantities of pesticides are used on cash crops, primarily on cotton, chilies and vegetables. Significant efforts have been made by the government to promote Integrated Pest Management (IPM) in the country to improve the profitably of farming and the health of the farming population. IPM is an approach to plant protection based on the principle that healthy field ecosystems with a balanced pest and predator population ratio offer resilience to economically damaging insect attack. Farmers are trained on IPM throughout an entire cropping season in intensive group trainings on field-based ecological management, namely Farmer Field Schools (FFSs). In FFSs, 20–25 farmers meet weekly to monitor pest and predator populations in the training field under the facilitation of two IPM experts. The facilitators are generally development agents of the Department of Agriculture who have undergone a season-long Training of Facilitators (ToF) on technical and facilitation skills. ToF and FFS programmes have been organized in the country since the 1990s. The deeper ecological understanding achieved as a result of attending FFSs has reportedly led to a significant reduction in the use of pesticides.[25]

The current study offers a comparative analysis of the use of pesticides, exposure level, and incidence of acute poisoning during (2003) and after (2004) farmers' participation in FFSs, in order to establish whether participation led to measurable improvements in the health of field workers. It was conducted as a follow up to the health assessment by Mancini et al., which documented an alarming level of acute pesticide poisoning occurring among cotton growers.[7]

As part of a larger impact assessment of FFSs, the farmers who participated in this study were also interviewed in 2003 and 2004 on their management practices in separate sessions. The results of the survey showed that FFS-trained farmers used one-sixth of the pesticides used by the control group to obtain the same yield. Farmers with strong ecological knowledge and an analytical approach to decisions pertaining to control measures, including chemicals as well as botanicals, attained the largest decrements.[26]

## METHODS

### *Data Collection*

The study was conducted in three cotton-growing villages in the state of Andhra Pradesh: Sairedapalli and

Srinagar (Warangal District) and Darpalli (Mahabubnagar District). The use of pesticides in the two districts is among the highest in the country. 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. In each village, one FFS was conducted in 2003 to train 25 farmers.

FFSs were conducted during the cotton cropping season of 2003. The curriculum included weekly training exercises that aimed to increase farmers' awareness of the hazards of pesticide use. A series of practical exercises were carried out to train farmers on the ways pesticides enter the human body and potential exposure based of liters of products applied, as well as farmers' behavior in the field with respect to handling, application, storage and disposal practices.

As part of the FFS curriculum, fifty female farmers monitored their signs and symptoms of acute pesticide poisoning and those of 47 male relatives from August to December 2003. Prior to the start of the monitoring, respondents were trained on the identification of signs and symptoms in four hourly sessions. Discussions were held on the mode of action of different chemical families (organophosphate, carbamate, organochlorine and pyrethroid) and their health effects on the central nervous system. Many of these effects are unspecific and can be caused by other conditions such as extreme fatigue and sun exposure; therefore farmers were trained to examine themselves before and after spraying to establish a link between exposure and the manifestation of illness. Farmers were given guidelines to recognize signs and symptoms during the exercises and throughout the monitoring.

As significant decrements in pesticide application practices have been usually observed a year after the FFSs are concluded in the case of India, in the current study the 2003 assessment was considered a baseline of the pesticide handling practices of the respondents. During the FFS, participants implement and evaluate IPM practices in the experimental plot during the training session, while practices in their own fields are not monitored. However, it cannot be excluded that some of the trained farmers adopt more ecological practices in their respective fields during the training, in which case the impact measured in the current study would result in an underestimation of the actual change. In the subsequent cotton season, a second monitoring was carried out by a subgroup of the female farmers (34) and their male family members (31) from July to December 2004.

The second monitoring activity started a month earlier than the baseline had in the previous year, due to weather-related differences in the cropping season. A detailed description of the reporting methodology used is given in Mancini.[7] In brief, women farmers

*Farmer mixes a pesticide with water for application.*

filled in a form containing a diagnostic pool of 18 signs and symptoms of acute pesticide poisoning[27,28] after every field exposure to pesticides (spraying in the field, mixing spray solution, refilling spray tanks, and working in field sprayed the same day). Women reported on their own health experience and on those of one male family member working in the field. Additional information on the type and quantity of chemical products used (mL formulated product/L water), operation performed, and hours spent in performing the operation were collected on the form. Forms were reviewed and corrected every week by experienced facilitators.

On the basis of the signs and symptoms reported, forms were assigned to four severity classes: mild poisoning (severity class 1), moderate poisoning (severity class 2), severe poisoning (severity class 3), and forms with no signs and symptoms marked were assigned severity class 0 and classified as asymptomatic. The total number of signs and symptoms (#S&S) reported on each form was also considered as an indicator of poisoning and analysed as a continuous variable in correlation analysis.

The comparison proposed in this study does not have the benefit of a control group, which was initially included in the first monitoring activity but subsequently dropped because of the low response of the farmers not enrolled in the FFSs; therefore it is not possible to control for external factors which may have influenced the health of the population under investigation, such as exposure to a different source of pollution. Individual predisposing factors to specific symptom or sign, such as headache, were controlled for using 2003 as a reference year and calculating individual variation in reporting.

### *Data Analysis*

We analysed individual risk factors for symptoms (severity class > 1, classified as probable cases of poisoning) associated with 311 applications in 2003 and 179 applications in 2004, using $2 \times 2$ tables and odds ratios (OR)

**TABLE 1 Distribution of Respondents by Age and Land Class, 2004**

| | 2004 | |
|---|---|---|
| | Women (n = 34) | Men (n = 31) |
| Age (years) | | |
| < 30 | 12 | 9 |
| 30–39 | 10 | 8 |
| 40–50 | 12 | 9 |
| > 50 | — | 5 |
| Land (acres) | | |
| Marginal (up to 2) | 7 | 6 |
| Small (>2 and <5) | 11 | 13 |
| Semi-medium (5-10) | 12 | 6 |
| Medium/large (>10) | 4 | 6 |

calculated with the public domain software EpiInfo. Specific risk factors included exposure to organophosphate, nicotinoid, pyrethroid, organochlorine, botanical insecticide, miscellaneous (fungicides, gaba receptor inhibiting insecticides and oxadiazine insecticides), and unclassified materials (pesticides reported only with local names, unidentified by study staff and not listed in several standard pesticide databases). Relative toxicity, as indicated by WHO Hazard Classes, was evaluated. Non-chemical factors evaluated included literacy level, gender, year of application (2003 vs. 2004, as a surrogate for the effect of the FFS training), mixing pesticides, spraying pesticides, and performing field work. Significant association between individual factors and probable cases of poisoning was calculated using a Yates-corrected chi-square statistic.

To evaluate possible confounding, factors that proved significant in the univariate analysis and were plausible biological risk factors or plausible protective factors were included in an unconditional logistic regression.[29]

For those participating in both monitoring years (65 respondents), we also analysed pesticide use, key exposure operations performed, mean number of signs and symptoms per informant, and incidence of poisoning. It was not possible to perform this analysis using EpiInfo so it was performed instead with the analysis pack in Microsoft Excel 2003.

## RESULTS

### *Characteristics of the Respondents*

Of the original reporting group (97) in 2003, a total of 65 reported in the 2004 survey. The 2004 group included 34 out of the original 50 female participants directly monitoring their health and 31 out of the original 47 male relatives reporting to the female farmers (Table 1). Of the 2003 respondents who did not report in the 2004 survey, the majority (25) had filled in only 1 or 2 forms in 2003; a likely reason for their attrition may be that they used virtually no pesticides in the year after the training. However, the remaining respondents (9) who reported in 2003 but not in 2004, reported a number of applications ranging from 3 to 8, with one exceptional case of 18. Hence it is possible that at least some of them had dropped out of the monitoring activities in 2004 for reasons unrelated to their continued use of pesticides. These assumptions were not independently verified and, in order to avoid biases in the findings, changes in the pesticide use, exposure level and incidence of health effects were analysed only for farmers who participated in both surveys.

The two monitoring exercises generated a total of 594 forms, including asymptomatic forms. The average age of the respondents was 37 years. Land holding size ranged from marginal (up to 0.8 ha) to small (1–2 ha) (Table 1).

### *Risk Factor Analysis of Acute Pesticide Poisoning*

The analyses of single variable risk factors are shown in Table 2. Factors that proved significantly associated with probable poisoning included exposure to organophosphates (OR=2.78, $p<0.01$), use of WHO Hazard Class II insecticides (OR=2.06, $p<0.01$), mixing pesticides (OR=1.49, $p=0.0476$), illiteracy (OR=2.35, $p<0.01$), and year of exposure ($OR_{2003\ vs\ 2004}=3.10$, $p<0.01$). Statistical significance of the health effects of exposure to WHO Hazard Class U products could not be determined due to the low number of exposure cases.

Significant protective factors included male gender ($OR_{male\ vs\ female}=0.595$, $p<0.01$), use of WHO Hazard Class U insecticides (OR=0.36, $p<0.01$), exposure to botanical/organic insecticides (OR=0.38, $p<0.01$) and performing field work without spraying or mixing (OR=0.28, $p<0.01$).

Variables included in the multivariate analysis were illiteracy, handling organophosphate insecticides, handling category IV pesticides, performing only field work, and exposure during 2003. Significant risk factors for probable poisoning in this analysis included illiteracy (OR=1.94, $p<0.01$), exposure during the year 2003

*Young farmer preparing pesticide to refill tank.*

**TABLE 2 Evaluation of Risk Factors and Demographic Variables Associated with Single Exposure to Pesticides (N=490)**

| | | Probable Poisoning | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Yes | No | Total | OR | Lower | Upper | Chi-square | p Value* |
| Organophosphates | | | | | 2.7774 | 1.9258 | 4.006 | 29.5643 | 0.00000 |
| | Yes | 152 | 98 | 250 | | | | | |
| | No | 86 | 154 | 240 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Neonicotinoid | | | | | 0.8532 | 0.5178 | 1.406 | 0.2468 | 0.61931 |
| | Yes | 33 | 40 | 73 | | | | | |
| | No | 205 | 212 | 417 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Pyrethroid | | | | | 0.7308 | 0.3821 | 1.397 | 0.6211 | 0.43064 |
| | Yes | 17 | 24 | 41 | | | | | |
| | No | 221 | 228 | 449 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Organochlorine | | | | | 1.5466 | 0.8765 | 2.729 | 1.8778 | 0.17058 |
| | Yes | 32 | 23 | 55 | | | | | |
| | No | 206 | 229 | 435 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Unclassified | | | | | 0.8063 | 0.3467 | 1.876 | 0.0823 | 0.7741 |
| | Yes | 10 | 13 | 23 | | | | | |
| | No | 228 | 239 | 467 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Other: fungicides—sulfur, copper sulphate, etc | | | | | 0.4334 | 0.2500 | 0.751 | 8.4403 | 0.00370 |
| | Yes | 21 | 46 | 67 | | | | | |
| | No | 217 | 206 | 423 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Hazard Class WHO 1 | | | | | 1.4895 | 0.9395 | 2.362 | 2.5090 | 0.11319 |
| | Yes | 51 | 39 | 90 | | | | | |
| | No | 187 | 213 | 400 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Hazard Class WHO 2 | | | | | 2.059 | 1.421 | 2.981 | 14.078 | 0.0002 |
| | Yes | 112 | 76 | 188 | | | | | |
| | No | 126 | 176 | 302 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Hazard Class WHO 3 | | | | | 1.406 | 0.985 | 2.007 | 3.2056 | 0.0734 |
| | Yes | 126 | 112 | 238 | | | | | |
| | No | 112 | 140 | 252 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Hazard Class U | | | | | 0.3553 | 0.2296 | 0.55 | 21.4991 | 0.0000 |
| | Yes | 37 | 86 | 123 | | | | | |
| | No | 201 | 166 | 367 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |

*p value obtained by univariate analysis

(*continued on next page*)

($OR_{2003\ vs\ 2004}$=2.67, p<0.01), and exposure to organophosphates (OR=1.70, p=0.02). Significant protective factors in the multivariate analysis included exposure to WHO Hazard Class U pesticides (OR=0.53, p=0.01, and performing only field work (OR=0.28, p<0.01).

### *Changes in the Use of Pesticides, Exposure, and Incidence of Acute Poisoning During and After the Farmer Field Schools*

*Changes in the use of pesticides.* The pesticides applied by the informants significantly changed over the two years. Organophosphates were the most applied in both years, but a reduction of 15% was registered in 2004. The applications of botanical products went up fifteen fold. Some of the moderately to highly toxic pesticides used in 2003, specifically Parathion and Phorate (WHO Hazard Class I), and Dimethoate and Phosalone (WHO Hazard Class II), were not reported in 2004. Exposure to Endosulfan was reduced from nearly 15% to 3% of the total cases of reported use. Applications of Monocrotophos (WHO Hazard Class I), Quinalphos, and Chlorpyriphos (WHO Hazard Class II) also decreased (Figure 1). Overall, the pesticide use spectrum shifted towards lower WHO Hazard Classes (Figure 2).

**TABLE 2 (*continued*). Demographic, Workplace Variables**

| | | Probable Poisoning | | | | 95% Confidence Interval | | Yates' Corrected | |
|---|---|---|---|---|---|---|---|---|---|
| | | Yes | No | Total | OR | Lower | Upper | Chi-square | p Value |
| Illiteracy | | | | | 2.3509 | 1.4960 | 3.694 | 14.1742 | 0.00016 |
| | Yes | 67 | 36 | 103 | | | | | |
| | No | 171 | 216 | 387 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Male | | | | | 0.5950 | 0.4156 | 0.852 | 7.5806 | 0.00598 |
| | Yes | 115 | 154 | 269 | | | | | |
| | No | 123 | 98 | 221 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Year 2003 | | | | | 3.0988 | 2.1018 | 4.569 | 32.6564 | 0.00000 |
| | Yes | 182 | 129 | 311 | | | | | |
| | No | 56 | 123 | 179 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Mixing pesticides | | | | | 1.487 | 1.022 | 2.165 | 3.9225 | 0.0476 |
| | Yes | 92 | 75 | 167 | | | | | |
| | No | 146 | 177 | 323 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Spray | | | | | 0.9398 | 0.6550 | 1.349 | 0.0599 | 0.80667 |
| | Yes | 140 | 152 | 292 | | | | | |
| | No | 98 | 100 | 198 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |
| Work in unsprayed field | | | | | 0.2704 | 0.1076 | 0.679 | 7.6441 | 0.0057 |
| | Yes | 6 | 22 | 28 | | | | | |
| | No | 232 | 230 | 462 | | | | | |
| | TOTAL | 238 | 252 | 490 | | | | | |

*Spraying operations.* In 2004, women played an enhanced role in the preparation and application of spray mixtures, primarily botanical preparations (43 out of 81 forms) such as nuclear polyhedrosis virus, neem oil, chili-garlic extracts and spinosad (Table 3). A redistribution of plant protection tasks among genders consequent to the adoption of IPM was also observed by Mancini et al. in their gender analysis of labor task allocations.[30] Behavioural changes, like informants tending to spend less time working in a recently sprayed field, were also observed.

The average duration of one exposure session in 2003 was 4.45 hours for men and 4.47 hours for women, and, respectively 3.04 hours and 3.06 hours in 2004; the average volumes applied during the session were respectively, 186 and 187 L in 2003, and 148 and 142 L in 2004. Spray parameters of application sessions in 2004 reflect the use of low-volume botanical products such as neem oil and powder.

*Respondent-Paired Analysis of Health Effects.* The following variables, in addition to the Severity Class variable, were used in the analysis of health effects:

- *Pesticide toxicity*: a score assigned to each reporting form according to the most toxic pesticide used during the reporting session. Pesticide toxicity is defined on the basis of the WHO hazard classification: Class Ia ("extremely hazardous") scored 1 point, Class Ib ("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
- *Individual severity class:* the highest class of poisoning reported in each form by the respondent in the year of reference
- *Individual mean #S&S:* the average number of S&S experienced per exposure session (form) by the respondent in the year of reference

In 2004, the reduction in the use of highly toxic compounds (–31%) was associated with a proportional reduction in the number of cases of Severity Class 3 poisonings reported (–28%). Severity Class was positively correlated to Pesticide Toxicity (Pearson correlation coefficient: 0.46). Moderate poisoning (Severity Class 2) was halved, whereas mild poisoning (Severity Class 1) slightly increased and asymptomatic cases (Severity Class 0) tripled (Figure 3).

The average level of poisoning experienced by the informants over the entire cropping season shifted from moderate (2003) to mild (2004). Correspondingly, the mean number of signs and symptoms experienced decreased. The association between mean #S&S and severity class already established in the first part of the monitoring[7] was reconfirmed (Table 4).

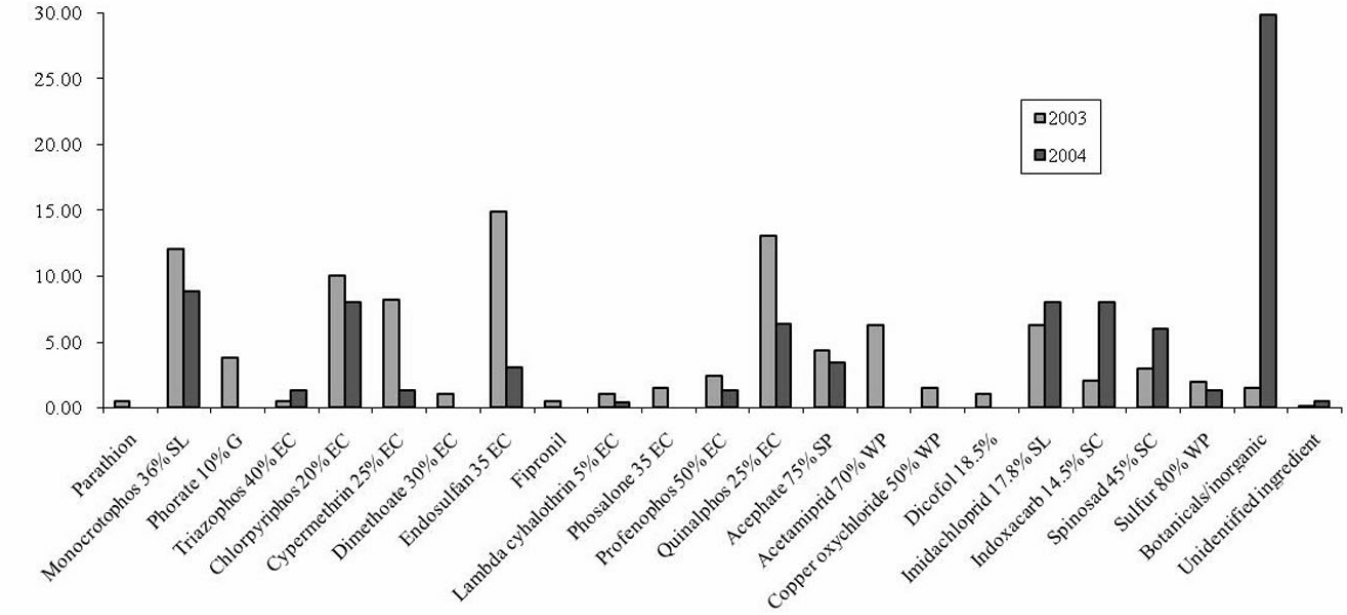


*Figure 1—Type of pesticides used, as in percentage of the total use, by year*

## DISCUSSION AND CONCLUSIONS

Organophosphates, used broadly in agriculture, were confirmed as a serious risk factor for occupational poisoning in this study. Illiteracy, a social proxy for poverty and malnutrition, aggravated the risk of being poisoned. Andhra Pradesh, and especially Warangal district where part of this assessment was carried out, have some of the largest reported use of organophosphates and the highest reported rates of pesticide poisoning in India.[2]

In the absence of a control group, it is hard to establish the exact extent of reduction in pesticide use attributable to the IPM training on the basis of the data collected in this study. Other factors, for instance pest pressure, weather conditions, and pesticide market prices might have differed in the two years of the study, leading to different levels of pesticide use. However, an additional questionnaire-based survey, using a double delta design, was carried out with the same group of farmers and a control group over two years.[30] According to the survey, the use of pesticides in the district in 2004 was overall lower than in 2003 because of a lower pest load as reported by the phytosanitary service. However, the reduction in the case of FFS trained farmers, in terms of total active ingredient used was almost 50% greater compared to the control group. FFS farmers' number of applications decreased from 7.8 to 1.7, whereas no significant variation of this indicator was registered for the control group. The most significant change introduced by FFSs in field management was the criteria applied to determine when and whether pesticides would be applied. FFS farmers

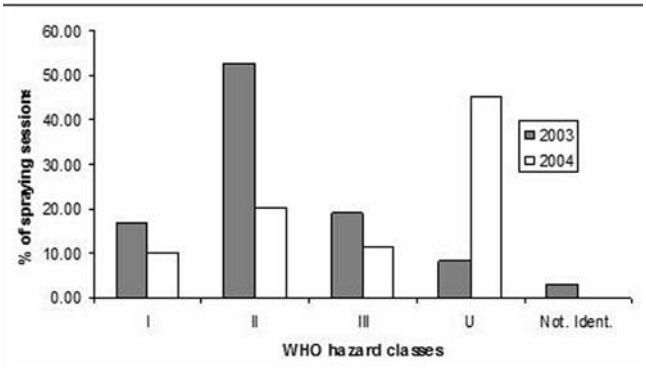


*Figure 2—Use of pesticides by WHO Hazard class*

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 (IPCS, 2002).
I = extremely and highly hazardous, II = moderately hazardous, III = slightly hazardous, U = unlikely to present acute serious hazard in normal use.

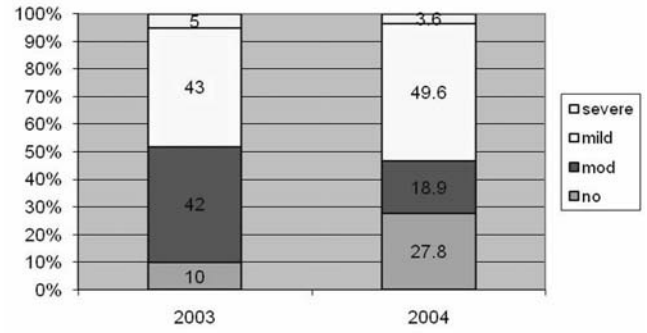


*Figure 3—Distribution of Severity Index by class and by year*

**TABLE 3 Pesticide-handling Operations Performed, by Year and Gender**

| | No. (%) Forms | | | |
|---|---|---|---|---|
| | 2003 | | 2004 | |
| Operations | Men | Women | Men | Women |
| Preparing spray mixture | 5 (5) | 54 (45) | 0 (0) | 81 (73) |
| Preparing spray mixture AND working in the field | 0 (0) | 31 (26) | 0 (0) | 0 (0) |
| Working in a recently sprayed field | 4 (4) | 21 (17) | 4 (3) | 3 (3) |
| Applying mixtures | 70 (65) | 12 (10) | 130 (94) | 27 (24) |
| Applying mixtures and working in the field | 28 (26) | 3 (2) | 3 (4) | 0 (0) |
| Total | 107 (100) | 121 (100) | 137 (100) | 111 (100) |

adopted the performance of a complete agro-ecosystem analysis (including the occurrence of natural enemies) of their own fields.[30] In particular, the application of highly toxic organophosphates like monocrotophos and the chlorinated insecticide endosulfan (WHO I and II Hazard Class) were significantly reduced. Consequently, the exposure and incidence of associated adverse health effects of pesticides were minimized. Trained farmers also avoided risky behaviors such as working in recently sprayed fields.

Increase in knowledge of risk associated with pesticide practices, changes in exposure behavior and reduced health risks for IPM-trained farmers are consistent FFS outcomes described also for Sri Lankan farmers cultivating maize[31] and Nicaraguan farmers.[18] In the case of Andean farming communities, the adoption of IPM through FFSs has resulted in a diminished skin exposure and improved neurobehavioural status of potato farmers.[4]

Limited access to health care, improper administration of antidotes and lack of trained doctors and nurses in hospitals make patient management a rather ineffective option in India[2] as in many other countries with emerging economies. A recent medical study has suggested that the inhibition of cholinesterase enzyme alone does not explain the wide range of disorders observed in association with exposure to organophosphorus products.[32] In addition to the well known cholinergic phase observed immediately after exposure, delayed neurotoxic effects can manifest themselves from 7 to 21 days after exposure.[33] Generally, the human toxicological effects of pesticides are still poorly understood and researched.[34]

The use of highly toxic products is currently under close evaluation in countries where their use is much more strictly regulated than in developing countries. As recently as January 2009, the European Parliament has approved a legislative resolution on the Council's common position for adopting a directive of the European Parliament and establishing a framework for Community action to achieve a sustainable use of pesticides.[35]

Given that insufficient medical information exists for implementing appropriate preventive measures and therapeutic interventions for occupational exposure,[15] interventions aiming to minimize pesticide poisoning in developing countries need to focus on restricting the use of highly toxic compounds, especially organophosphates.

Stronger regulatory measures might lead to the removal of a significant percentage of chemical products from the market. Concern has been expressed about possible risks to productivity that could be incurred in the absence of other plant protection measures, with negative consequences for food prices and hence for the well-being particularly of poor consumers. In the case presented in this study, ecological

**TABLE 4 Individual Average Level of Poisoning (Individual Severity Class ) and individual Average Number of Signs and Symptoms Reported Over the Reporting Period (Individual Mean #S&S), by Year**

| | Individual Severity Class* | | Individual mean #S&S | |
|---|---|---|---|---|
| | 2003 | 2004 | 2003 | 2004 |
| Mean | 1,923077 | 1,492308 | 3,409275 | 1,238543 |
| Variance | 0,697115 | 1,035096 | 4,145002 | 1,288168 |
| Observations | 65 | 65 | 65 | 65 |
| Pearson Correlation | 0,10046 | | –0,4074 | |
| Hypothesized Mean Difference | 0 | | 0 | |
| Df | 64 | | 64 | |
| t Stat | 2,779233 | | 6,470338 | |
| P(T<=t) one-tail | 0,003572 | | 7,83E-09 | |
| t Critical one-tail | 1,669014 | | 1,669014 | |
| P(T<=t) two-tail | 0,007145 | | 1,57E-08 | |
| t Critical two-tail | 1,997728 | | 1,997728 | |

*Severity class: mild poisoning (class 1), moderate poisoning (class 2), severe poisoning (class 3).

farming practices offered viable alternative plant protection options for cotton cultivation in India that did not affect production outcomes.

In order to restore the ecological viability of farming, in terms of impact on the environment and human health, it is necessary that significant investments are made to support the education of farmers on better management practices.

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