INTRODUCTION

According to World Health Organization estimates, pesticides cause 30,00,000 cases of poisoning and 2,20,000 deaths annually across the globe, the majority of which are reported from developing countries. These numbers, even more alarmingly, show a rising trend (WHO, 1990; Down to Earth, 2001; Rosenstock, et al. 1991; Pimental, 1992; Kishi, et al., 1995; WRI, 1998). While indiscriminate use and unscientific handling of toxic chemicals are very common, the extent, severity and frequency of associated health problems are often unknown.

Pesticide-related health damages are difficult to identify, particularly in developing countries, because of the inherent problems of poverty, inadequate health care facilities, poor training support to health-care personnel, and unsatisfactory access to the health care system. Furthermore, the major victims are the most vulnerable sections of the population. The farm workers, small and marginal farmers and women, who are the most exposed owing to occupational factors, neglect the health hazards of pesticide exposure due to either lack of awareness and/or due to financial reasons. There have been attempts on a limited scale in some developing countries to evaluate the health damage due to pesticide exposure (Jeyaretnam, 1990; Ngowi, 2002; Wilson, 2002). But such studies are rarely seen reported from India where the use of pesticides in agriculture has been very common and unscientific. Often the economic impact of pesticide use in agriculture is projected as positive, as it does not consider the externalities associated with its use. This study tries to quantify the occupational health risks due to pesticides exposure among farm workers and assess the health costs associated. The estimation is based on the self reported morbidity effects and is expected to provide an estimate of negative externalities related to human health.
II

STUDY AREA AND METHODS

Kuttanad is a low-lying area near the coast of Kerala, India, with a total population of 1.4 million (Census, 2001). It is called the rice bowl of Kerala. Kuttanad area is stretched in three districts, Alappuzha, Kottayam and Pathanamthitta. Rice cultivation in Kuttanad is however of a special type, as the land is on an average three metres below the Mean Sea Level (MSL). The main rice crop of the area is known as the punja (summer crop). This study was conducted during the punja crop of 2004-05.

Rice fields in Kerala are usually demarcated as padasekharams that are contiguous stretch of wetlands bounded by waterways or other natural features which is a homogeneous physical entity. The main crop paddy in Kuttanad is grown in an area of 27,000 hectares, demarcated as 598 padasekharams which constitute 40,000 holdings. For the purpose of this study the pesticide-related information was collected from a sample of pesticide applicators and agricultural labourers. To select our sample, two Community Development Blocks were randomly selected from each of the three districts which form the Kuttanad area. From each block two panchayats were identified. From each selected panchayat, three padasekharams were chosen at random and these padasekharams formed the study area. All the pesticide applicators in the selected padasekharams were taken as samples.

The study focuses on the health risks impacts of pesticide application on farm workers who handle the pesticides. During the pilot survey it was found that many of the owners were depending on hired labourers for these operations. Mostly the pesticide applicators are local workers who are skilled in this work. During the off-season when spraying operations are limited, they engage in other types of agricultural and non-agricultural work. For the study, data were collected from 280 applicators. The agricultural labourers are those who engage in farm operations such as ploughing, fertiliser application, land preparation, etc., but do not undertake pesticide spraying. They also opt for non-agricultural work during the off-season. We surveyed a total of 101 agricultural labourers from the same selected padasekharams, on a random basis. They formed the control group.

Data collection was through a structured pre-tested questionnaire, by the personal interview method, and through a farm diary maintained by the respondents, which was closely monitored by the research team. The data included both qualitative and quantitative attributes. Direct observations were also made wherever possible. The data set for the study consisted of three components:

(i) Pesticide applicators during pesticide application work (n=280): Each applicator was contacted four times during the spraying season, which lasted for five weeks. During these visits data on the spraying details and the health status after spray operations (within a period of 24 hours) were gathered.
Hence, on an average, for each respondent four dose-response observations were available and the total data set include 1135 observations. However, some of the respondents were interviewed 5 times while others could be met only two times due to their work schedules.

(ii) Pesticide applicators when they undertake work other than pesticide application during the off-season (n=212): The applicators undertake wage labour in farms or other sectors when spraying operations are not available. The same applicator was contacted again during the off-season and data was gathered.

(iii) Agricultural labourers: This group comprised farm workers who do not undertake pesticide applications (n=101). The data on them includes responses related to agricultural and non-agricultural work.

Generally, the visits for the dose-response part of the data collection were undertaken during the morning hours before the workers left for work. During these interviews details were gathered on the previous day’s spraying operations and health response. Spraying operations were also directly observed on a random basis.

In order to estimate the economic impact of pesticides on human health, two types of information are required. First, the physical health impacts of the exposure need to be identified; second, the monetary health cost associated with this exposure need to be assessed (Freeman, 2003). In this study, we estimated a dose-response model for quantifying the physical impact and then we estimate the cost-of-illness.

III
DOSE-RESPONSE MODEL

A dose-response function presents a statistical relationship between exposure to pollutants and health risks. Dose-response functions frequently form the physical basis of economic models used to estimate the health costs of pollution. They involve the estimation of a relationship between illness and the ambient pollution levels while controlling other variables (socio-economic and behavioural) that affect the health status (Cropper and Freeman, 1991).

In this study, following studies by other scholars (Dasgupta, 2004; Huang et al., 2001; Jalan et al., 2003; Dasgupta et al., 2005), a dose-response function is estimated where the dependent variable is a binary variable. This function gives the probability of getting sick after an event of pesticide spray after controlling for other factors.

The use of probability models is conceptually preferable to conventional linear regression models when the dependent variable is dichotomous. Probability models provide parameter estimates, which are asymptotically consistent and efficient. In this study, a Probit model is used to assess the determinants of the probability of getting sick. The general model is a binary choice model involving estimation of the probability of falling sick (y) as a function of a vector of explanatory variables (x). It
is assumed that there is an underlying response variable $y^*_i$ defined by the regression relationship (Gujarati, 2004).

$$y^*_i = \beta' x_i + u_i \quad \ldots (1)$$

In practice, $y^*_i$ is unobservable and what is observed is a dummy variable $y$ defined by

$$y = 1 \text{ if } y^*_i > 0 \text{ (SICK = YES)}$$
$$= 0 \text{ otherwise (NOT SICK = NO)} \quad \ldots (2)$$

From the above relations, we get

$$\text{Prob (} y_i = \text{SICK}) = \text{Prob (} u_i > -\beta' x_i ) = 1 - F(-\beta' x_i ) \quad \ldots (3)$$

Where $F$ is the cumulative distribution function. Hence, we obtain the following likelihood function

$$L = \prod_{y=0} F(-\beta' x_i) \prod_{y=1} [1 - F(-\beta' x_i)] \quad \ldots (4)$$

Taking the logarithm of $L$ and maximising with respect to $\beta$ gives us the maximum likelihood estimator of the slope coefficients from which we can estimate the impact of different doses of pesticides on the probability of falling sick. The explanatory variables used in the Probit model and the expected signs are presented in Table 1. The dataset for estimating the dose-response variable includes 1448 observations from applicators (both during days when they were exposed to pesticides and when they did other work) as well as other agricultural labourers when they were doing field work.

$Y \ (1 = \text{sick or 0=not sick})$: The health effects of pesticide exposure are manifested as specific symptoms or a combination of a few symptoms. Building on scientific information as well as a preliminary pilot study, 17 types of symptoms were first identified. Based on whether or not pesticide-related symptoms were reported, a sickness dummy variable was created. This is the dependent variable in the dose-response function.

Body Mass Index: Body Mass Index (BMI) is a measure of the general health status of the individual. A BMI value between 18.5 and 25 is reported to be the desirable value and any value below or above is undesirable. The lower values represent risks due to malnutrition while the higher values reflect the danger of obesity. Malnutrition is a possibility with our sample and hence the expected sign of this variable is negative.
TABLE 1. THE DOSE RESPONSE FUNCTION AND DETERMINANTS OF HEALTH DAMAGE

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Variables</th>
<th>Expansion Description</th>
<th>Expected Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Y</td>
<td>Sick or Not Sick</td>
<td>0 = Not Sick, 1 = Sick</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Independent Variables**

1. DRed: DOSE of Red category chemical Quantity of the pesticide applied \( \times \) Concentration of the pesticide formulation
2. DYellow: DOSE of Yellow category chemical
3. DBlue: DOSE of Blue category chemical
4. DGreen: DOSE of Green category chemical
5. DUR: Duration of exposure Duration of work (mts) for all category
6. TEMP: Temperature (degree Celsius) Day temperature in the area
7. SMOKE: Smoking habits 0 = if non Smoker, 1 = Smoker
8. ALCO: Alcohol consumption (0,1) 0 = no consumption, 1 = if consumption
9. BMI: Body Mass Index Wt/Ht \( \times \) 100
10. EDU1: Education level Up to 7 years schooling
11. EDU2: Education level Up to 10 years schooling
12. AGE: Age Age in years
13. LAND: Holding size Land holding in hectares
14. AVBEH: Averting Behaviour 0 if they adopt personal protective gadgets, 1 if they do not.

**Pesticide Dose:** These variables capture the dilution of spray fluid and the toxicity of the chemical used. WHO prescribes a colour code for chemical pesticides according to toxicity. This is based on their LD\(_{50}\) value. The Lethal Dose (LD) is the quantity required to kill 50 per cent of the target population. The lower the value, the more toxic the chemical is. Extremely toxic chemicals are marked red (LD\(_{50}\) less than 50), highly toxic chemicals as yellow (LD\(_{50}\) value 50-500), the moderately toxic as blue (with LD\(_{50}\) 500-5000) and the slightly toxic as green (LD\(_{50}\) value greater than 5000). In this study, the dose variable captures the effect of the dilution of the spray fluid. It is a function of the quantity of the chemical used, the concentration of the formulation and the quantity of water used. Based on data on spray dilution, pesticide used and concentration, we created four variables that represent the pesticide dose: DRed (Dose of RED category), DYellow (Dose of YELLOW category), DBlue (Dose of BLUE category) and DGreen (Dose of GREEN category). We expected a positive sign for all the four variables. These variables took the value zero for workers who were agricultural labourers or for applicators on non-applying days.

**Duration of Exposure:** This variable represents the total time taken for preparing the spray fluid and actual application by the pesticide applicator. For non-application
days and for agricultural workers, this is the duration they engage in work. This variable is expected to have a positive sign.

*Temperature in Degree Celsius:* In tropical countries the temperature gradient during the spray has an influence both on the general health status of the worker as well as the decomposition of the chemical. We collected the maximum day temperature on the day of the spraying from the records maintained by the Rice Research Station, Alappuzha, which is the nearest station recording meteorological observation for the Kuttanad area. We expected a positive sign for this variable.

*Personal Habits:* The primary data showed smoking and alcohol consumption as the key personal habits that pose a health danger to farm workers. These two variables were included as two separate dummy variables and we expected a positive health risk to be associated with smoking and alcohol consumption.

*Education:* Education was expected to have a negative impact. The more educated people were expected to be at a lower risk owing to better awareness. The respondents were grouped into three based on the education level – up to the 4th standard, up to the 7th standard and up to the 10th standard. Two dummy variables were used to estimate the effect of education on the probability of sickness.

The identification of the variables were done through scientific advice, past studies and field experiences.

The dose response function allows us to estimate the predicted individual probabilities of sickness. The expected mean probability of sickness was then estimated for each group of pesticide applicators on applying days, pesticide applicators while doing other type of work, and agricultural labourers.

Undertaking sensitivity analyses, the probabilities of sickness under four policy contexts for the first group were also estimated: (a) the probability of sickness if there is a decline in dose of all chemicals by 10 per cent from the current level; (b) the probability of sickness if there is a decline in dose of all chemicals by 25 per cent from the current level; (c) the probability of sickness if there is a decline in dose of the most toxic chemical (Red) by 25 per cent from the current level; (d) the probability of sickness if the most toxic chemicals (Red) are fully replaced by safe chemicals (Green).

*The Cost of Illness*

The next step of the analysis was to identify the monetary costs associated with sickness that resulted from pesticide exposure. In general, the estimation of economic value of health damages is undertaken using three major approaches (Wilson, 1998): Avertive/defensive expenditure method, cost-of-illness method and contingent valuation method.

The cost-of-illness method (COI) is perhaps the most widely used approach and involves estimating the medical expenditure associated with illness, earnings due to lost work days or productivity losses, the value of leisure hours lost, travel costs and
special dietary expenses associated with medical treatment. Thus, the cost-of-illness estimates provide an account of the money spent in all direct and indirect aspects of illness, which includes the direct private costs (medical expenses) and indirect costs (loss of work days due to poor health, time spent on seeking medical help and losses due to poor efficiency). However, a wide variation can be observed in the literature in terms of what is considered under costs in COI studies. For example, Harrington and Portney (1987) take only medical costs and wage loss into account, whereas Hodgson and Meiners (1982) include transportation, special dietary costs, certain household expenses and certain property losses. In a more recent study, Maumbe and Swinton, (2003) exclude travel and leisure time value as well as the cost traditional and home remedies.

This study followed the method adopted by Wilson (1998). The cost-of-illness estimates thus include the doctor’s fee, cost of medicines, laboratory expenses, transportation expenses (for the applicator and companion), hospital fees, dietary expenses, and earnings from lost work days (wages multiplied by time lost on account of sickness and time taken to travel to seek medical help).

Cost-of-illness estimates are considered a lower bound of the actual costs incurred as the estimate does not include the social costs incurred (Drummond, 1992; Jefferson et al., 1996; Wilson, 2000). Apart from this, the estimate excludes the value of leisure time, disutility due to illness, losses due to poor work efficiency and productivity losses due to poor supervision or work in own farm.

Nevertheless, estimation of cost-of-illness in developing countries can pose several challenges. In poor countries, seeking medical help is rare among low-income groups, unless the symptoms are very severe. If the symptoms are not acute, they are often neglected or home remedies are adopted, for example, bathing in water boiled with neem or tulsi leaves. In this study, it was found easy to gather data when there was hospitalisation or when the respondents sought formal medical help. However, when the symptoms were not considered very serious, formal medical advice was not sought and the respondents depended on self-medication or ‘over-the-counter’ medicines that are available without formal medical prescription. They also adopted local practices (drinking tender coconut water), or consulted local ayurvedic practitioners (vaidyas). In such cases, the market value of the drugs/nutrition supplement and the opportunity cost of labour were imputed. In many cases, it was possible to obtain a clearer account of the expenses by talking to womenfolk in the house.

In this study, because of the high variability in the cost-of-illness, obtaining a simple average estimate of the cost-of-illness (as is often done in similar studies) is not justified. Hence, based on medical advice, health damages for each individual were categorised as mild, moderate and severe. The average cost of illness (C) for each category is estimated as:
where,

\( C_j \) is the average cost-of-illness in the j-th group, with \( j = 1, 2, 3 \) reflecting mild, moderate and severe symptoms

\( ME_{ij} \) is medical expenditure incurred by the i-th individual in the j-th group

\( W_{ij} \) is the wage rate of i-th individual in the j-th group

\( T_{ij} \) is the work-time lost by the i-th individual in the j-th group

\( N_i \) is total number of times the respondents reported sick in j-th group.

The overall cost of illness or welfare loss \( (W_j) \) due to sickness for individuals in each group is given by:

\[
W_j = C_j \left[ \frac{\sum_{i=1}^{N} \hat{P}(Y_{ij} = 1)}{N_j} \right] \quad \ldots (6)
\]

Where,

\( W_j \) is the welfare loss in j-th group

\( C_j \) is the average health cost in the j-th group

\( \hat{P} \) is the estimated probability of \( Y = 1 \) in j-th group

\( N_j \) is total number of times the respondents reported sick.

Finally, we estimated the welfare loss due to pesticide exposure as the difference between the welfare loss of pesticide applicators during application days and that of the applicators during non-application days. We found that the estimated health cost for the two groups, applicators on non-applying days and agricultural labour, to be the same.

Further the analysis is extended to assess the welfare gain through four management options as explained earlier.

**Health Risks**

Many potential health damages and acute symptoms of exposure to different chemical groups of pesticides are reported in the epidemiological literature.
Following these findings and on the basis of the major groups of pesticides used, 17 major symptoms were identified prior to undertaking our survey. Based on responses from the survey, in 71 per cent of spray events, the pesticide applicators reported some form of health impact relative to 45 per cent of the times when they engaged in other work. In the case of agricultural labourers, it was 32 per cent (Table 2).

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Type of sickness</th>
<th>Pesticide applicators during applying days</th>
<th>Pesticide applicators during non-applying days</th>
<th>Agricultural labourers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Eye irritation</td>
<td>12.95</td>
<td>0.94</td>
<td>2.97</td>
</tr>
<tr>
<td>2.</td>
<td>Nausea</td>
<td>5.81</td>
<td>0.47</td>
<td>14.85</td>
</tr>
<tr>
<td>3.</td>
<td>Giddiness</td>
<td>2.45</td>
<td>0.94</td>
<td>2.97</td>
</tr>
<tr>
<td>4.</td>
<td>Breathing problems</td>
<td>7.66</td>
<td>2.35</td>
<td>2.97</td>
</tr>
<tr>
<td>5.</td>
<td>Fever</td>
<td>1.5</td>
<td>4.24</td>
<td>1.98</td>
</tr>
<tr>
<td>6.</td>
<td>Dehydration</td>
<td>0.44</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7.</td>
<td>Vomiting</td>
<td>3.52</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8.</td>
<td>Cramps</td>
<td>2.55</td>
<td>1.41</td>
<td>0</td>
</tr>
<tr>
<td>9.</td>
<td>Itching</td>
<td>20</td>
<td>2.35</td>
<td>1.98</td>
</tr>
<tr>
<td>10.</td>
<td>Convulsions</td>
<td>2.11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11.</td>
<td>Burning sensation</td>
<td>4.49</td>
<td>0</td>
<td>0.99</td>
</tr>
<tr>
<td>13.</td>
<td>Diarrhoea</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14.</td>
<td>Excessive salivation</td>
<td>0.53</td>
<td>0</td>
<td>0.99</td>
</tr>
<tr>
<td>15.</td>
<td>Vision problems</td>
<td>0.53</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>16.</td>
<td>Tremor</td>
<td>0.97</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17.</td>
<td>Others</td>
<td>0.97</td>
<td>25.94</td>
<td>0</td>
</tr>
<tr>
<td>18.</td>
<td>No symptom</td>
<td>21.06</td>
<td>55.23</td>
<td>68.32</td>
</tr>
<tr>
<td>19.</td>
<td>Total sample</td>
<td>100 (1135)</td>
<td>100 (212)</td>
<td>100 (101)</td>
</tr>
</tbody>
</table>

Figures in parentheses are the total number of respondents.

Skin problems were reported as the most common symptom and itching was more frequent than hives. Eye-irritation and vision problems were also very common. However, these were regarded as minor ailments that were often managed by the workers themselves. Home remedies or traditional ayurvedic treatment were resorted to in these cases. Allopathic treatment was resorted to only in more serious cases. Though the frequency of symptoms like nausea, giddiness, breathing problems, dehydration, vomiting, cramps, convulsions, diarrhoea, etc., were comparatively less, they are more life-threatening and hence formal medical advice was sought more often in such instances.

The severe symptoms are breathing problems, dehydration, vomiting, cramps and diarrhoea which often manifest themselves soon after spraying and result in hospitalisation. In a majority of cases the person is taken directly from the farm to the hospital. In such cases people preferred to go to private hospitals owing to better care and facilities. This is also reflected in macro-level data where we find that the public health care system reports no cases of occupational health damage due to pesticide exposure.
In our study, we found 76 cases of hospitalisation among the 894 cases of sickness related to pesticide exposure. The expenditure on hospitals ranged from Rs. 450 to Rs. 3780 with a mean of Rs. 1,536. Where there is hospitalisation, the days spent in the hospital range from one day to one week. In the other two groups there were no cases of hospitalisation consequent to work hours.1

The majority of the respondents were aware of the potential health hazard due to exposure and the need for personal protective gadgets. Jeyaratnam et al. (1987) and Sivayoganathan et al., (1995) have also attested to this situation in the case of Sri Lanka.

However, none of the applicators used the suggested protective gadgets, which include a face-mask with replaceable filters, goggles, head-cover, rubber gloves, full-sleeved shirts and full pants, and boots. The cost factor, general lethargy, and the discomfort associated with the use of protective devices under hot and humid climatic conditions and in water-logged paddy areas were reported as the reasons for non-adoption. Moreover, there exists no mechanism to ensure their use.

Nonetheless, some form of protective covering of body parts was adopted by 71 per cent of the respondents while spraying. In 21 per cent of the cases, it was mainly full-sleeved shirts. However, many rolled up their sleeves while spraying/mixing. Thirty one per cent of applicators tied a piece of cloth around the nose. A mere 1 per cent used some form of eye protection (e.g., ordinary spectacles, which are in use even otherwise). These unscientific methods for avertive action often fail to achieve the desired objectives.

The summary statistics of the variables used in the dose-response function and the results of the analysis are furnished in Tables 3 and 4. The dose-response model, which was estimated to assess the influence of the independent variables on the probability of sickness, confirmed most of the assumptions and the signs of the

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Variables</th>
<th>Mean (1)</th>
<th>Minimum (2)</th>
<th>Maximum (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Y</td>
<td>.7048</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>DRED</td>
<td>61.05</td>
<td>0.00</td>
<td>1000.00</td>
</tr>
<tr>
<td>3</td>
<td>DYELLOW</td>
<td>131.73</td>
<td>0.00</td>
<td>1700.00</td>
</tr>
<tr>
<td>4</td>
<td>DBLUE</td>
<td>140.47</td>
<td>0.00</td>
<td>1950.00</td>
</tr>
<tr>
<td>5</td>
<td>DGREEN</td>
<td>1.18</td>
<td>0.00</td>
<td>125.00</td>
</tr>
<tr>
<td>6</td>
<td>DUR</td>
<td>284</td>
<td>30</td>
<td>540.00</td>
</tr>
<tr>
<td>7</td>
<td>TEMP</td>
<td>33.36</td>
<td>29.00</td>
<td>34.60</td>
</tr>
<tr>
<td>8</td>
<td>SMOKE</td>
<td>0.53</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>9</td>
<td>ALCOHOL</td>
<td>0.23</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>10</td>
<td>BMI</td>
<td>21.83</td>
<td>15.81</td>
<td>30.61</td>
</tr>
<tr>
<td>11</td>
<td>EDU1</td>
<td>0.32</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>12</td>
<td>EDU2</td>
<td>0.02</td>
<td>0.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>
TABLE 4. BINOMIAL PROBIT ESTIMATES OF THE DETERMINANTS OF HEALTH DAMAGE

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient (1)</th>
<th>Marginal Effect (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Const</td>
<td>-1.848698</td>
<td>-0.6225293</td>
</tr>
<tr>
<td>DR</td>
<td>0.001423894***</td>
<td>0.0004794809</td>
</tr>
<tr>
<td>DY</td>
<td>0.0004482059***</td>
<td>0.0001509286</td>
</tr>
<tr>
<td>DB</td>
<td>0.0005624209***</td>
<td>0.0001893892</td>
</tr>
<tr>
<td>DG</td>
<td>0.001473520</td>
<td>0.0004961922</td>
</tr>
<tr>
<td>DUR</td>
<td>-0.0005954632</td>
<td>0.0002005159</td>
</tr>
<tr>
<td>TEMP</td>
<td>0.04112364</td>
<td>0.01384795</td>
</tr>
<tr>
<td>SMOK</td>
<td>0.4181616***</td>
<td>0.1408114</td>
</tr>
<tr>
<td>ALCO</td>
<td>-0.06032019</td>
<td>-0.02031218</td>
</tr>
<tr>
<td>BMI</td>
<td>0.03076513*</td>
<td>0.01353983</td>
</tr>
<tr>
<td>EDU1</td>
<td>0.09592683</td>
<td>0.03230233</td>
</tr>
<tr>
<td>EDU2</td>
<td>-0.58344337***</td>
<td>-0.1964684</td>
</tr>
</tbody>
</table>

* and *** Significant at 10 and 1 per cent level, respectively.

significant coefficients were as expected. The dose of red, yellow and blue category chemicals, smoking, Body Mass Index and education levels recorded a significant influence on the dependent variable.

The dose of the toxic chemicals (red, yellow and blue), which capture the dilution of spray fluid and the concentration of formulation, exerts a strong positive effect on health risk. We observed that a majority of the sprayings (70 per cent) used red and yellow category of pesticides and these have a significant effect on the probability of sickness. The safer dose (green) has an insignificant effect.

Smokers are more likely to fall ill after spraying compared to non-smokers and smoking appears to be more harmful than alcohol consumption. Alcohol consumption, which was expected to have a positive effect on health damage, shows a negative sign. However this coefficient is not significant.

The more educated experience fewer chances of falling sick after spraying, apparently due to better care in handling the chemical. However, this is not reflected in the adoption of scientific protection gadgets. None of the respondents used the recommended protective gears.
Lower values of the Body Mass Index reflect the health risks due to malnutrition whereas higher values reflect obesity problems. In our sample, the chances of the former are more likely than that of the latter and hence an inverse relationship is expected between BMI and the probability of sickness. However, the coefficient on BMI has an unexpected positive sign and is significant at 10 per cent level. The effect of temperature is positive but not significant. Duration of exposure shows a negative sign and is contrary to expectations. However, since the coefficient is not significant, the perverse sign can be ignored.

The expected predicted probabilities of illness estimated from the Probit model are presented in Table 5. The probability estimate for the applicator group (0.72) is significantly different statistically from that of the applicator group during the non-applying days (0.64) and from that of the agricultural labour group (0.63). The probability estimates in the latter two cases are the same. A reduction in dose of all chemicals by 10 per cent or a 25 per cent reduction in the dose of the most toxic chemical (red) yields the same effect, reducing the probability of sickness during application days to 0.61. This probability reduces to 0.56 if all chemical doses are reduced by 25 per cent. Hence, if people can be persuaded to substitute the safest chemical for the most toxic, the probability of falling sick as a result of exposure is again 0.64, which is identical to the probability of falling sick when not exposed.

Table 5 indicates that the health costs for applicators during both non-applying days and agricultural labour days are the same (Rs. 3 per day). Health costs for applicators are Rs. 41 per day. The difference, Rs. 38 (US$0.86), is the cost due to pesticide exposure. This amounts to 24 per cent of the average daily earnings from pesticide application. Health costs associated with other types of work amount to only 1.5 per cent of average daily earnings. Assuming 42 spraying days per year, the average annual welfare loss to an applicator from pesticide exposure amounts to Rs.1,596 (US$36) per applicator.

The results of this study reinforce the findings from other pesticide exposure studies. For example, Wilson (2002), following the cost-of-illness approach, estimated that a farmer in Sri Lanka on an average incurs a cost equal to a month’s income every year due to exposure to pesticides. Here, the annual welfare loss is equal to half a month’s income per year (assuming 42 days of spraying and 156 days of other work). In the Philippines, the health cost to farmers exposed to pesticides is reported to be 61 per cent higher than that of the unexposed farmers (Pingali et al., 1995). In our study, this difference is much higher. It is 14 times more than that for those not exposed. Compared to the estimates from Nepal, which is US$2.05 (Atreya, 2007), our estimate is very high. This can be attributed to the generally high level of insecticide use in Kuttanad (more of organo-phosphates) compared to fungicides, the high temperature gradient, the longer work hours, the higher wages and the higher expense associated with medical care.
**TABLE 5. AVERAGE HEALTH COST OF PESTICIDE EXPOSURE**

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Description</th>
<th>Estimation details</th>
<th>Applicator Non-applying days</th>
<th>Applicator-applying days</th>
<th>Avg. all doses decreased by 10 per cent</th>
<th>Avg. all doses decreased by 25 per cent</th>
<th>Avg. Red dose decreased by 25 per cent</th>
<th>Avg. Red dose replaced by Green Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Probabilities of illness per day</td>
<td>From the dose-response function</td>
<td>0.64</td>
<td>0.72</td>
<td>0.61</td>
<td>0.56</td>
<td>0.61</td>
<td>0.64</td>
</tr>
<tr>
<td>2</td>
<td>Average health cost per episode of illness (Rs.)</td>
<td>-</td>
<td>4.00</td>
<td>57</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Average expected health cost per event of spray/work (Rs.)</td>
<td>Row 1 x Row 2</td>
<td>3.00</td>
<td>41</td>
<td>35</td>
<td>32</td>
<td>35</td>
<td>36</td>
</tr>
<tr>
<td>4</td>
<td>Health cost due to pesticide exposure (Rs.)</td>
<td>Col.5-Col.4</td>
<td>-</td>
<td>38</td>
<td>32</td>
<td>29</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>5</td>
<td>Total expected health cost per applicator per year @42 spraying days (Rs.)</td>
<td>Row 4 x 42</td>
<td>-</td>
<td>1596</td>
<td>1344</td>
<td>1218</td>
<td>1344</td>
<td>1386</td>
</tr>
</tbody>
</table>
Through effective awareness creation programmes or other policy measures, it is possible to reduce the concentration of the spray fluid from the current level by 10 per cent, which would reduce the welfare loss by 16 per cent. The same effect can be generated by a concerted effort to reduce the dose of the most toxic category of chemicals (red) by 25 per cent. If this is completely replaced by the safest pesticides, the loss can be reduced by 13 per cent. Dose reduction can be achieved either through restricting the quantity of formulation or by merely increasing the dilution of the spray fluid via more water. In our sample, the quantity of water used was much below the recommended level while the quantity of chemicals used was above the scientifically recommended levels by 17-233 per cent. An extension strategy focusing on this aspect alone would result in an improvement in the health of the applicator without incurring any additional private cost. One way of achieving this is through the targeted training of pesticide applicators. The study indicates that none of the applicators have had any scientific training in pesticide handling and use. The study also revealed that they had wrong perceptions about the toxicity of the pesticides they handled.

IV

CONCLUSIONS

Occupational exposure to pesticides is very common among workers in the agricultural sector in developing countries. The study suggests that pesticide use is often unscientific at all levels of use – from the selection of chemicals and handling practices to averting behaviour. This results in health damages to the extent of Rs.38 per day (US$0.86) per individual. These costs can be reduced by improving the spray fluid dilution, that is, by either using more water or going for safer chemicals at a lesser quantity, or a combination of both. We note that these costs are a conservative estimate because they do not take into account long-term chronic illness, public expenditure on health care and are only based on self-reported symptoms.

The study shows that any programme with an investment of Rs. 18 crores for improving the welfare of this group of farm workers can be economically justified. Just as the State factories and Boilers Department assures the safety and health of industrial workers handling hazardous materials in the case of industries, the State Department of Agriculture could initiate a programme with a similar objective. The existing welfare fund board for agricultural labourers could also institute a special component for pesticide applicators.

Support could be provided by imparting training in safe-handling of pesticides and adoption of scientific dose, subsidised supply of protective gear, and awareness-creation programmes.

A labour bank of trained pesticide applicators could be maintained in each Panchayat which can serve the farm sector in a better and more efficient manner while minimising welfare losses. Simultaneously, insurance protection measures for
pesticide applicators could be introduced. Insurance companies could use the results of this and other studies for estimating the premium. The state could also bear a part of the premium as the social savings accrued by way of health damages can be avoided.

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NOTES

1. The private health care system in Kerala is often reported to be very costly. A recent study by Kerala Shastra Sahithya Parishad, a noted NGO in the state, estimates the annual per capita treatment cost in the state as Rs. 1722 and the cost per event of treatment as Rs. 830.70. This amounts to 1.9 per cent of family expenditure. On an average 64.4 per cent of the people depend on private medical systems. The average expenditure per hospitalisation is Rs.9680. In the case of the private system it is as high as Rs. 10,445 (Aravindan, 2006).

2. Averting behaviour corresponds to the habit of wearing personal protective gadgets (a face mask with replaceable filters, goggles, headcover, rubber gloves, full-sleeved shirts and full pants, boots etc.) while spraying. This is to avert the potential danger of exposure to the spray.

REFERENCES


Ngowi, A.V. (2002), “Health Impact of Exposure to Pesticides in Agriculture in Tanzania”, Ph.D. Dissertation Submitted to the Faculty of Medicine of the University of Tampere, Tampere, Finland.


