Pesticide Use in Nepal: Understanding Health Costs from Short-term Exposure

KISHOR ATREYA

Aquatic Ecology Center, Kathmandu University
Dhulikhel, Nepal

December 2007

South Asian Network for Development and Environmental Economics (SANDEE)
PO Box 8975, EPC 1056
Kathmandu, Nepal

SANDEE Working Paper No. 28-07

Published by the South Asian Network for Development and Environmental Economics (SANDEE)
PO Box 8975, EPC 1056 Kathmandu, Nepal.
Telephone: 977-1-552 8761, 552 6391 Fax: 977-1-553 6786

SANDEE research reports are the output of research projects supported by the South Asian Network for Development and Environmental Economics. The reports have been peer reviewed and edited. A summary of the findings of SANDEE reports are also available as SANDEE Policy Briefs.

National Library of Nepal Catalogue Service:

Kishor Atreya

Pesticide Use in Nepal: Understanding Health Costs from Short-term Exposure
(SANDEE Working Papers, ISSN 1893-1891; 2007 - WP 28)

ISBN: 978 - 9937 - 8015 - 4 - 6

Key Words:

1. Pesticides
2. Acute symptoms
3. Cost of illness
4. Dose-response function
5. Nepal

The South Asian Network for Development and Environmental Economics

The South Asian Network for Development and Environmental Economics (SANDEE) is a regional network that brings together analysts from different countries in South Asia to address environment-development problems. SANDEE's activities include research support, training, and information dissemination. SANDEE is supported by contributions from international donors and its members. Please see **www.sandeeonline.org** for further information about SANDEE.

SANDEE is financially supported by International Development Research Centre (IDRC), The Ford Foundation, Swedish International Development Cooperation Agency (SIDA) and Norwegian Agency for Development Cooperation (NORAD).

Technical Editor
Priya Shyamsundar

English Editor
Carmen Wickramagamage

Comments should be sent to Kishor Atreya, Aquatic Ecology Center, Kathmandu University Dhulikhel, Nepal, Email: atreyaku@yahoo.com

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract

Occupational health, well researched in developed countries, remains neglected in developing countries. One issue of particular importance is the use of pesticides on farms, which can have both chronic and acute impacts on human health. This paper focuses on acute health impacts associated with pesticide exposure in rural Nepal. Based on data from 291 households, the study finds that the magnitude of exposure to insecticides and fungicides can significantly influence the occurrence of health symptoms. The predicted probability of falling sick from pesticide-related symptoms is 133% higher among individuals who apply pesticides compared to individuals in the same household who are not directly exposed. Households bear an annual health cost of NPR 287 ($4) as a result of pesticide exposure. These costs vary with fungicide exposure. A ten percent increase in hours of exposure increases costs by about twenty-four percent. In aggregate, pesticide exposure contributes to a health burden of NPR 1,105,782 (US $ 15,797) per year in the study area. Although pesticide use in Nepal is low relative to many other countries in the world, this study, which is the first of its kind in Nepal, suggests that farmers and policy makers need to become aware of the health impacts of pesticide use as they continue to promote its use in Nepal.

Key words: Pesticides, acute symptoms, cost of illness, dose-response function, Nepal.

Pesticide Use in Nepal : Understanding Health Costs from Short-term Exposure

Kishor Atreya

1. Introduction

Human health is partly dependent on the environmental conditions people live in. Occupational health, which is well researched in developed countries, remains neglected in developing countries (Nuwayhid, 2004) including Nepal (Poudel, *et. al.*, 2005). One issue of particular importance is the use of pesticides on farms, which has a significant negative impact on farmers' health (Rola and Pingali, 1993; Antle and Pingali, 1995; Antle, Cole and Crissman, 1998; Ajayi, 2000). Pesticide pollution not only affects human health, but also affects multiple other environmental factors, such as soil, surface and ground water, crop productivity, micro and macro flora and fauna, etc. (Pimental, 2005). Despite such environmental and health effects, farm workers continue to use pesticides in ever increasing quantities (Wilson and Tisdell, 2001).

Pesticide exposure can have chronic and acute impacts on human health. Long-term, low-dose exposure to pesticides is increasingly linked to human health effects such as immune-suppression, hormone disruption, diminished intelligence, reproductive abnormalities, and cancer (Gupta, 2004). Farm workers also experience day-to-day acute effects of pesticide poisoning, including symptoms such as headache, dizziness, muscular twitching, skin irritation, respiratory discomfort, etc. (Antle and Pingali, 1994; Dung and Dung, 1999; Murphy, *et. al*., 1999; Yassin, Abu Mourad and Safi, 2002; Maumbe and Swinton, 2003). Several studies have attempted to value the effect of pesticide exposure on human health. A recent study (Pimental, 2005) estimated that the cost of the public health impact of pesticide use in the US was around US$ 1140 million per year. However, studies of health costs to farm workers and applicators in developing countries suggest much lower numbers (see Table 1).

The average consumption of pesticides in Nepal (142 gm/ha) is still very low compared to pesticides used in other countries such as India (500 gm/ha), Korea (6.6 kg/ha) and Japan (12 kg/ha) (Gupta, 2004). However, market-oriented production and agricultural intensification are leading farm workers to increase pesticide use at a rapid rate. There is also inappropriate and excessive use of chemical pesticides in some highly commercialized agriculture sectors. In response, Nepal's National Agricultural Perspective Plan has emphasized integrated pest management (IPM) to reduce pesticide use. However, there is a dearth of empirical research on occupational health (farmer's health) in Nepal. For example, a recent review paper by Poudel, *et. al*., (2005) found only seven scientific studies on occupational health in Nepal from 1966 to 2004—all were unrelated to pesticides and farmers' health.

Quantification and economic valuation of work place hazards to human health is important for effective allocation of resources as well as formulation of new rules and regulations. Furthermore, the health impacts due to exposure to pesticide use have been omitted from analyses of returns to pesticide use or in evaluation of specific agricultural policies or programs**.** Does pesticide use significantly affect farmers' health in Nepal? Do farmers incur any costs for treatment and avertive actions taken to protect their health? Are averting actions taken to reduce pesticides toxicity sufficient? What are the factors that significantly determine pesticide exposure and health damages? This paper attempts to answer the above questions in order to better inform pesticide policy in Nepal. The focus of the paper is restricted to acute health symptoms that appear during or after the spray of pesticides on vegetable crops in an area near Kathmandu, Nepal.

In the following section, we describe the study area and sampling procedures. This is followed by a discussion of the survey and general characteristics of the sample. We document the types and frequency of pesticide application by the sample and their exposure to the local environmental conditions. The methodology section discusses the techniques used for estimating costs of health damages due to pesticide pollution. In the results section, we tabulate the incidence of acute symptoms and defensive action, and identify the health costs of pesticide pollution. In the concluding section, the paper highlights issues of relevance to policy makers and other line agencies and makes recommendations to redress the problem.

2. Study Area

The study area is located in the mid-hills of Nepal and is 40 km east of Kathmandu (see Figure 1). The Araniko Highway that passes through the study area provides good access to the capital and three other major cities. For this study, Deubhumi Baluwa and Panchkhal Village Development Committee (VDC) of Jikhu Khola Watershed (JKW) were selected. These VDCs are the most commercialized in the watershed. Here farm families are switching from rice (*Oryza sativa* L.) based cropping systems to vegetable based cropping. Pujara and Khanal (2002) and Shrestha and Neupane (2002) have reported significantly high use of pesticides in cash crops, such as tomato (*Lycopersicon esculentum* Mill.) and potato (*Solanum teberosum* L.) in the JKW. They also stress that farmers experienced several health problems given that they use no protective measures. The other cash crops grown at the time of the study were bitter gourd (*momordica charantia* Linn.), cucumber (*Cucumis sativus* Linn.), cauliflower (*Brassica oleracea* var. *botrytis* L.), cabbage (*Brassica oleracea* var. *capitata* L.), pepper (*Capsicum* spp.), brinjal (*Solanum melongena* L.), lady's fingers (*Abelmoschus esculentus* Moench), pumpkin (*Cucurbita moschata* Duchesne), sponge gourd (*Luffa aegyptiaca* Mill.), radish (*Raphanus sativus* L.), ribbed gourd (*Luffa acutangula* Roxb), cowpea (*Vigna sinensis*), field bean (*Dolichos lab lab* L.), and snake gourd (*Trichosanthes anguina* L.). Generally, pesticides in the study area are used against pests such as brown plant hopper, fruit flies and diseases like the late blight of potato and tomato. Recent literature (Atreya, 2007 a, b, c) has shown that few individuals are trained in integrated pest management (IPM) and adoption of safety precautions and that pesticide hygiene is still minimal. Thus, exposure to pesticides as well as the risks farmers are facing consequently may be significant. Among the reasons that make individuals opt for pesticides in the area are the unwillingness to risk economic losses, ready availability of pesticides in local markets, and the low share of pesticides on total produce.

3. Data

3.1 Sampling Procedures and Size

Each selected VDC is comprised of 9 wards (the smallest administrative unit). We selected one or two villages from these wards. A ward may have more than one village. Therefore, one village, with the highest number of households, was selected in those wards with less than 100 households. Two villages with the highest and the second highest household numbers were selected from those wards which had more than 100 households. We assume that villages with the highest and the second highest number of households represent the population of the wards and that, therefore, conclusions can be generalized for the whole VDC. We selected a sample of 300 households proportionately and randomly from these villages.

We identified 2 pesticide users and one non-user from each of the sample households[1] (3 members where possible). User A refers to a household member who sprays pesticide most of the time in the selected household. User B represents the second member of the same household who sprays pesticides in the absence or instead of User A. Non-User refers to a third member of the household who never sprayed pesticides during the study period.

The sample is comprised of 295 of A Users, 148 of B Users, and 126 Non-Users.[2] We scheduled weekly interviews for 295 User As and 126 Non-Users. If User B substituted for User A for spraying operations, then User B was also interviewed. Four User As and 4 Non-users were not present during the single visit survey, and 61 Users Bs never sprayed pesticides even once during the study period. We excluded these respondents from the data analysis (see Figure 2). User A (or user B) did not necessarily spray pesticides every week. There were spraying as well as non-spraying weeks. However, each week, we interviewed User As (or User Bs) and all non-users. Therefore, we took the dose–response data obtained from either User As or User Bs during spraying days as 'treatment' data. Similarly, we took as data on the 'control' the sample data obtained from either User As or User Bs during non-spraying days, plus data collected weekly from all non-users.

3.2 Data Collection Methods

We collected the data for this study from individuals and households between January to July 2005 and developed the final questionnaire on the basis of a pilot survey of 25 households. We collected some of the data during a single visit and obtained the rest through repeated visits to individuals on a weekly basis.

We collected data on household demography, personal characteristics, farm size and characteristics, history of pesticide use, history of chronic illness, and property of the households from single visits to households. We gathered data on pesticide dose and exposure, appearance of acute symptoms, use of safety gear, number of work-days lost due to health symptoms, and type of medication through multiple visits. Other data collected in weekly visits include medical consultation fees, laboratory costs, medication costs, transport fare to/from health centers, dietary expenses during treatment, and the number of family members involved in nursing the victims as well as time spent by the family members.

---

1 In the study area, we could not find any household that had never sprayed pesticides before, and no household assured us that they would not spray pesticide during the study period. Therefore, user and non-user are different members of the same household.

2 There may be multiple users and non-users in a particular household, but data was obtained from a subset of these individuals. It was not possible to interview all family members due to time and budget constraints.

We recruited fourteen local field level assistants[3], with at least 10 years of education, to undertake the weekly interviews. All of them were experienced in household surveys and were involved in more than two household surveys conducted by other organizations. We provided them with three days of intensive training for this study. The research team monitored the field staff initially weekly for three months, and monthly for the rest of the period. We established a field office at the center of the study area and held bimonthly meetings (1st and 16th of each month) that included all field staff and the research team. During these bimonthly meetings, we checked and corrected where necessary the survey instruments for missing data, codes, spellings, and so on. We used these meetings to further train field staff. After completing weekly interviews, five field-level staff (the best among the 14-member) conducted the single visit survey. They received two days of training for the survey instrument.

The total data set contains 12721 observations of which 28.6% were spraying episodes while the rest are non-spraying episodes. User As sprayed pesticides 12 times (ranged from 1 to 31 times) while User Bs sprayed 5 times (ranged from 1 to 17 times) during the 31 weeks of the study period. A household, on average, sprayed pesticides 13 times during the study period.

We provide the general characteristics of the study population in Table 2. There were 291 User As, 87 User Bs, and 122 Non-users. Both males and females sprayed pesticides. Males accounted for 86% of A and 61% of B users. Females dominated the 'control' group. Pesticides applicators were younger. Even though the formal education was low in all groups, users were better educated. Only eight percent of the User As had taken IPM training. It was only four percent for the other two groups.

Time allocated for farm activities varies during pesticide spraying and non-spraying days. User As had worked 2.83 hours per day on their farms during the spraying days (spraying pesticides accounted 1.87 hours) under the average maximum temperature of 27.3^{o}C while during non-spraying days, the same User As worked 3.70 hours (nearly 31% more) with a higher maximum temperature of 29.7^{o}C. Similarly, User Bs were also exposed to 26.7^{o}C for 3.08 hours during spraying days (spraying pesticides accounted for 1.8 hours), while during non-spraying days they were exposed to the same number of hours (3.0 hours) with a higher daily maximum temperature (30^{o}C). For non-users, the exposure to 28.8^{o}C was for 2.16 hours per day during the study period. We found that most of the spray operations had been done when the days were cooler. It means that higher the day temperature is, the lower the spray operations are.

The pesticides found in the study area can be classified into five World Health Organization hazard categories: Extremely hazardous (Class Ia), Highly hazardous (Class Ib), Moderately hazardous (Class II), Slightly hazardous (Class III), and Unlikely to present acute hazard in normal use (Class U) (WHO/PCS, 2001). Different kinds of insecticides, such as parathion-methyl and phorate of class Ia; dichlorvos and methomyl of class Ib; cypermethrin, deltamethrin, fenvelerate, endosulfan, quinalphos, chlorpyrifos, and dimethoate of class II; and fungicides like copperoxychloride, metalaxyl and dinacap of class III and mancozeb; and carbendazim of class U with various concentrations were used in the study area. Almost all spray operations contained mancozeb, either mixed or alone, at an average concentration of 4.26 gm/l.

---

3 Five of them worked for ICIMOD/PARDYP as data recorders, especially weather and hydrological data (daily temperature, humidity, and rainfall and river discharge).

4. Methodology

The basis of the formal models that assess the health costs of pollution is that pollution results in morbidity, which in turn affects individual's welfare (utility). These effects are a result of discomfort and pain, loss of productive time, and expenditures on medical and avertive actions. In pesticide exposure studies, economists often model individual behavior as utility maximizing, subject to a health production function. Individuals who are exposed to pollution are assumed to choose optimal amounts of avertive and mitigating actions to reduce health impacts (Freeman, 1993).

While a formal model of a utility maximizing individual or a health production function is not developed in this paper, the approach used in estimating health costs is similar to these. Pesticide exposure in Nepal reduces people's wellbeing because of sickness, wage loss and medical expenses. In this study, we use the cost of illness and avertive cost approach to assess the pesticide health costs of pollution. Cost of illness is defined as lost productivity due to sickness plus the cost of medical care resulting from sickness (Freeman, 1993). Avertive costs are defensive expenditures taken prior to spraying pesticides to minimize health costs. The paper builds on the work of Dasgupta (2004) who estimated the probability of sickness from diarrhea to households in Delhi and identified the costs to the household from sickness. Other studies that have informed the methodology we use are pesticide specific studies such as those by Antle and Pingali (1994), Wilson (1998) and Dung and Dung (1999).

4.1 Dose-Response and Avertive Action Functions

In this study, individuals exposed to pesticides have a probability y_1 of falling sick. The probability of sickness is a function of exposure and individual health stock, education, and other household characteristics. Individuals also take avertive actions to reduce the effects of pesticide exposure. In the health production function literature this is referred to as a demand for avertive actions. In our study, we estimated the probability of undertaking avertive actions using a probit model which is also a function of pesticide exposure and individual and household characteristics.

The econometric model specification used in the dose-response and avertive demand analyses is:

$$y_1^* = \beta_1 x_1 + \varepsilon_1 \text{ , } y_1 = 1 \text{ if } y_1^* > 0\text{, 0 otherwise} \quad \text{............................} (1)$$

$$y_2^* = \beta_2 x_2 + \varepsilon_2 \text{ , } y_2 = 1 \text{ if } y_2^* > 0\text{, 0 otherwise} \quad \text{..........................} (2)$$

$$E(\varepsilon_1) = E(\varepsilon_2) = 0$$

$$Var(\varepsilon_1) = \sigma^2_1, Var(\varepsilon_2) = \sigma^2_2$$

The binary dependent variables y_1 is the probability of falling sick. It indicates whether or not an individual experiences a set of acute symptoms during and or within 48 hours of pesticides application. y_2 is the probability of an individuals taking avertive action while using pesticides. It indicates whether or not an individual adopts avertive actions such as wearing a mask, gloves, boots and long-sleeved shirts or pants during pesticides application. x_1 and x_2 are the vector of explanatory variables that may affect these probabilities. The variables reflect individual characteristics, pesticide dose and level of exposure, and environmental factors. We present definitions of independent variables and the way they are expected to affect the probability of sickness and probability of taking avertive actions in Tables 3 and 4 respectively. We selected these independent variables based on our understanding of the literature. $\varepsilon_{1,}$ ε_2 are random errors.

Equation 1 and 2 can be rewritten as the dose response and avertive action equation:

$$y_i = \beta_1 INSECT + \beta_2 FUNGI + \beta_3 TEMP + \beta_4 MIX + \beta_5 AGE + \beta_6 EDU + \beta_7 IPM + \beta_8 BMI + \varepsilon_1 \quad \text{....... (3)}$$

where i = 1, 2

INSECT and FUNGI refer to dose of insecticide and fungicide used. Pesticide dose is an important variable in this analysis. It is defined as concentrations (ml or gm/l) multiplied by spray duration (h/day), calculated as

$$D = \int_{t_1}^{t_2} C_n(t)dt \quad \text{....... (4)}$$

Where, dose (D) is the magnitude of exposure, $C_n(t)$ is the exposure concentration as a function of time (t), t_2-t_1 being the spray duration (defined as time interval of interest for assessment purposes during which exposure occurs, either continuously or intermittently). Thus, INSECT and FUNGI are the magnitude of exposure to insecticides and fungicides. Greater exposure to either insecticides or fungicides is expected to increase the adoption of avertive activities, and also increase the likelihood of acute symptoms.

TEMP refers to the average weekly maximum temperature, which would decrease the adoption of avertive activities due to discomfort, and would increase the occurrence of symptoms. MIX is a dummy variable that reflects whether or not more than one pesticide has been mixed together. In developing countries, pesticide sprayers mix more than one pesticide (insecticides are mixed with fungicides in most cases) to increase toxicity and to minimize crop losses. The mixing habits (MIX) of individuals would both increase the adoption of avertive activities due to increased toxicity of the mixture as well as increase the likelihood of occurrence of symptoms.

Older people have better experience in farm activities, especially pesticide spraying. This may enhance the adoption of avertive activities and reduce the occurrence of symptoms. Thus, age of the individual (AGE) was incorporated in the models.

Educated individuals prefer to adopt higher avertive activities to minimize the health risk because of their better knowledge of pesticide toxicity. Moreover, education opens up other employment avenues beside agriculture. Thus, education of the individual in terms of years of education (EDU) is likely to be positively related to the adoption of avertive activities and negatively related to the occurrence of pesticide-related acute symptoms.

Individuals trained in any IPM prefer to take more avertive actions than those without such training while spraying toxic pesticides. Arguably, IPM trained people use less pesticide doses and prefer to go for alternative pesticides which are thought to be environmentally safe, like green pesticides. It is, therefore, assumed that IPM is positively related to the adoption of avertive activities, and negatively related to the occurrence of symptoms. IPM is measured as dummy, if an individual had prior training = 1, 0 otherwise.

The occurrence of acute symptoms depends on individual nutritional status. The Body Mass Index (BMI), defined by weight/square height, is a proxy for nutritional status. It is, therefore, included in the model.

4.2 Estimating Health Costs

The cost of illness (COI) and avertive actions approach is used for valuing health damages due to pesticide exposure. COI is comprised of cost of treatment and productivity losses. To this, we add cost of averting behavior. These costs, however, do not capture discomfort, pain and suffering due to illness. The costs can be interpreted as an indicator of the minimum willingness to pay for reduced health risk from periodic exposure to pesticides.

The models described above are used for estimating health costs of pesticide exposure. From equation 1 in its empirical specification we can obtain estimates of the predicted probability of illness for users (P_u) and non-users (P_c). Similarly, Equation 2 estimates the predicted probability of taking avertive actions, P_a.

Thus, the average health costs of exposure are estimated as:

$C_u = P_u * COI_u + P_a * AC$ for users, and .... (5)

$C_c = P_c * COI_c$ for non-users .... (6)

Where,

C_u and C_c are the total predicted health costs of exposure to pesticide users and non-users respectively. COI_u and COI_c are the average annual treatment costs and productivity losses for users and non-users, respectively, and AC is the average costs of avertive actions for the sampled population.

Finally, actual health costs (HC) for an individual due to exposure to pesticides is calculated as:

$HC = C_u - C_c$ .... (7)

It is useful to explain why non-users, i.e., individuals who do not spray pesticides, may have positive probabilities of sickness and health costs, C_c. Non-users experience some of the same symptoms as users because they are fairly common (headaches, for example) and reflect an unrelated malaise, such as long hours of work outdoors. Thus, we think it is important to acknowledge these symptoms and costs and then subtract them from the costs experienced by users in order to isolate the correct health costs of pesticide exposure.

We estimated COI from the data collected on costs incurred by individuals, such as consultation fee, hospitalization cost, laboratory cost, medication cost, travel cost to and from clinics, time spent in traveling, dietary expenses resulting from illness, work efficiency loss in farm, loss of workdays in farm and time spent by family member (s) in assisting or seeking treatment for the victim.

Averting costs (AC) include costs associated with precautions taken to reduce direct exposure to pesticides, such as masks, handkerchiefs, long-sleeved shirts/pants, sprayers, etc. These averting equipments may also have multiple uses, but each individual was asked whether they have separated such measures used especially for spraying pesticides. Hence, averting equipments purchased specifically for the use and handling of pesticides only were considered. For example, a long-sleeved shirt may have multiple uses, but if an individual had separated it for spraying pesticides, it was considered for estimating costs. These averting equipment were annualized with the expected life span.

The effect of exposure changes on health costs can be decomposed into the effects of increased chemical concentration and increase in the hours of application. Marginal effects of pesticide concentration and hours of application to health costs were estimated as follows:

$$\Delta \text{ Health costs} / \Delta \text{ insecticide concentration} = \eta_{c_i} * \text{COI}_u + \psi_{c_i} * \text{AC} \quad (8)$$

$$\Delta \text{ Health costs} / \Delta \text{ fungicide concentration} = \eta_{c_f} * \text{COI}_u + \psi_{c_f} * \text{AC} \quad (9)$$

$$\Delta \text{ Health costs} / \Delta \text{ hours of insecticides application} = \eta_{h_i} * \text{COI}_u + \psi_{h_i} * \text{AC} \quad (10)$$

$$\Delta \text{ Health costs} / \Delta \text{ hours of fungicides application} = \eta_{h_f} * \text{COI}_u + \psi_{h_f} * \text{AC} \quad (11)$$

Where,

η_{c_i} Δ prob. sickness / Δ insecticide concentration evaluated at mean hours of exposure,

η_{c_f} Δ prob. sickness / Δ fungicide concentration evaluated at mean hours of exposure,

η_{h_i} Δ prob. sickness / Δ hours of spray evaluated at mean concentration of insecticides,

η_{h_i} Δ prob. sickness / Δ hours of spray evaluated at mean concentration of fungicides,

ψ_{c_i} Δ prob. avertive action / Δ insecticide concentration evaluated at mean hours of exposure,

ψ_{c_f} prob. avertive action / Δ fungicide concentration evaluated at mean hours of exposure,

η_{h_i} Δ prob. avertive action / Δ hours of spray evaluated at mean concentration of insecticides, and

η_{h_f} Δ prob. avertive action / Δ hours of spray evaluated at mean concentration of fungicides.

5. Results and Discussions

5.1 Incidence of Acute Symptoms

Both users A and B have a higher probability of contracting almost all documented acute symptoms when they spray pesticides compared to days when they do not spray (see Table 5). Interestingly, users B who were the substitute sprayers for user A in the same household had a higher chance of having acute symptoms relative to users A. In every thousand exposure to pesticides, users A experienced headaches 193 times, muscle twitching/pain 158 times, chapped hand 149 times, excessive sweating 136 times and eye irritation 81 times. Whereas user B had these acute symptoms 282 times, 256 times, 239 times, 144 times, and 115 times respectively. We think that this data shows that user B is more aware of acute symptoms than user A. It also suggests that either Users A have acquired more tolerance to pesticide pollution or underestimate symptoms because they think that the symptoms are a “normal” part of their work.

5.2 Avertive Actions

Individuals do not take enough protective measures during spraying against pesticide toxicity to reduce health hazards. They generally prefer to wear only long-sleeved shirts (68 percent of total events) and long pants (58 percent). They did not use other averting equipment, which are recommended and thought to be effective, on many occasions. Users wore caps (15 percent), handkerchief (14 percent), shoes (11 percent) and masks (10 percent). Spraying operations were undertaken without any protective equipment 15 percent of the time (see Table 6). The low levels for adopting safety gear while spraying pesticides were not surprising. Our results are consistent with the findings of other studies done in developing countries (Wilson, 1998; Gomes, Lloyd and Revitt, 1999; Murphy, *et. al.,* 1999; Yassin, Abu Mourad and Safi, 2002; Salameh, *et. al.,* 2004). These studies suggest that the low level of awareness and education, the humid hot environment, low income and discomfort are the main factors for not adopting such protective gear while using pesticides in developing countries.

5.3 Dose – Response and Avertive Actions Estimations

We regressed the response to pesticides use, i.e., whether or not an individual experienced symptoms during the study period, on the magnitude of exposure to pesticides, exposure environment, and personal characteristics. Defensive or avertive behavior is a choice variable that the individual chooses based on a variety of factors. Thus, we ran a second regression with the probability of adoption of defensive actions on the left hand side and the same explanatory variables.

We give the summary statistics of the independent variables used in the dose-response and avertive actions functions in Table 7. We provide the dose-response and avertive action estimations in Table 8 and Table 9 respectively. In both regressions, dependent variables are binary (if outcome occurs = 1, 0 otherwise).

In the dose-response function, except IPM, other explanatory variables are statistically significant at the 1% level. Exposure to insecticides (INSECT) and fungicides (FUNGI) positively determine the probability of occurrence of symptoms as we expected. Thus, this result empirically shows that the use of insecticides and fungicides affect farmer health in Nepal. A one unit rise in the INSECT and FUNGI increases the probability of occurrence of symptoms by 3.8 and 1.4 % respectively. Identification of chronic and long-term health impacts, which also exist, is beyond the scope of this paper.

The expected sign for the coefficient of the maximum average weekly temperature (TEMP) is negative. This is because of the higher rate of pesticide application during cooler days.[4] Mixing of pesticides (MIX) has a positive impact on the likelihood of symptoms. Mixing two or more pesticides in a container before application to the field is believed to be more potent in killing pests and is thus common in developing countries (Kishi, *et. al.*, 1995; Cole, *et. al*., 2000; Yassin, Abu Mourad and Safi, 2002; Lu, 2005).

AGE of individual negatively affects the probability of occurrence of symptoms. Age can be taken as proxy of experience on the farm. Experience in farm activities increases defensive actions and reduces the probability of occurrence of symptoms due to pesticide exposure. Formal education of an individual (EDU) also decreases the probability of acute symptoms. This is because educated individuals may have a better knowledge of safe handling practices.

The expected sign for IPM is positive; however the coefficient itself is insignificant. The adoption of IPM[5] technology is a choice between two alternatives: the traditional practices that demand high use of pesticides and IPM technology, which reduces pesticides use but may also contribute to a decline in productivity. Our results may reflect the possibility that individuals may not use their IPM training, even if they have had some. In Nepal, where people are very poor, IPM training may not necessarily enable individuals to reduce pesticide use significantly on their crops.

Health and nutritional status (BMI) is negatively correlated with the incidence of acute symptoms, which is consistent with results from Dung and Dung (1999) and Antle and Pingali (1994).

5.4 Health Costs of Pesticide Use

The dose-response function allows us to determine the probability of a user (both users and non-users) being sick due to pesticide use and exposure. Thus, the predicted probability of an outcome (the probability of observing pesticide-related acute symptoms) is estimated for users and non-users. The average predicted probability of being sick due to pesticide use for user is 0.41 while that for non-users is 0.18. Similarly, the avertive action model allows us to determine the probability of an individual adopting avertive action while spraying pesticides. The average predicated probability of taking avertive actions is 0.52 (see Table 10).

---

4 Late blight of potato caused by a fungus, Phytophthora infestans, is the most important disease in the study area, against which farmers spray pesticides. The high relative humidity and low day temperature strongly favor its germination, growth and infection (Singh, 1990). This may be another reason for spraying more pesticides in cooler days.

5 The slow rate of IPM adoption is well described by Trumble (1998). Feder, Murgai and Quizon (2003), who also evaluated the impact of farmer field school in terms of improved yields and reduced pesticide use, found no evidence of expected environmental benefits of the program.

We use these predicted probabilities to obtain the health costs of pesticide use. We also calculate the average costs of treatment and defensive actions for an individual for the sample. We assume that the cost of defensive activities for non-users is zero.[6]

In the case of this particular sample, the average annual costs associated with health effects and productivity losses from pesticide exposure are NPR 172.54 for users and NPR 105.34 for non-users for similar illnesses. The annual average cost of avertive activities for users is NPR 175.

Average health costs of pesticide use are calculated for users and non-users by multiplying the above health cost numbers with the predicted probability of falling sick and taking avertive actions (see Equations 5 and 6). The total health cost per year of exposure to pesticide pollution is estimated to be NPR 162.34 for a pesticide user; for a non-user this is NPR 18.62. Following Equation (7), the difference between these values is NPR 143.72 (US $ 2.05), which is the actual annual cost of pesticide use and exposure for a user individual. It is important to deduct costs of non-users from costs for users because some of the health symptoms are very similar and may arise from other factors. With regard to gender, health costs of pesticide use for a man were estimated to be NPR 151 per year and that for a woman at NPR 102 per year (see Table 11).

The estimated pesticide-induced health costs constitute 0.2 percent of annual household expenditure, 13.16 percent of annual household expenditure on pesticides, and 10.32 percent of the annual household expenditure on health care and services due to chronic and non-chronic illnesses, injuries and birth deliveries (Hotchkiss, *et. al*., 1998). The low proportion of pesticide health costs makes households underestimate health costs in their farm production decisions. This could be a major reason why human health issues arising from pesticide use are given little attention in household decisions, which may further accelerate the use of pesticides in their farms.

In order to estimate the total health costs from acute exposure to pesticides in the study area, we make the assumption that all households in the study area apply pesticides and two members in each household generally undertake this operation. We estimate that the total annual pesticide related health costs for the study area are NPR 1,105,782 (US $ 15,797) per year. Each VDC gets developmental and administrative funds from the government of NPR 10 lakh per year. Thus, the aggregate health cost is equivalent to 55% of the annual development and administrative budgets of these two VDCs.

We list the impacts of increased chemical concentration and hours of application in Table 12. A one unit rise in insecticide concentration (1 ml/l) would increase sickness by 6.8 percent, avertive action by 10 percent and health costs by nearly NPR 30, which was evaluated at mean hours of pesticide application. Similarly, one unit rise in fungicide concentration would result in increased sickness by 2.4 percent and health costs by NPR 13.17. We also observed that a unit increase in fungicide application hours would result in more health costs than a unit increase in insecticides concentration. The sensitivity analysis shows that sickness, avertive actions and health costs are invariant to increase in fungicide concentration and insecticide application hours, but they

---

6 Non-users did not use masks, gloves, aprons, or any other defensive measure during the study period even if they worked on the farm and were exposed in some fashion to pesticide sprays.

significantly increase with insecticide concentration and hours of fungicide applications. The main fungicide used in the region is mancozeb, which is considered to be relatively non-toxic. Hence, increases in the concentration of fungicides do not seem to matter, but the build up that occurs by increasing the hours of exposure does have an effect. Table 13 shows that a 10 percent increase in fungicide application hours leads to increased sickness by 6 percent, averting action by 13 percent and health costs by NPR 34, which are comparable to the increase in insecticide concentration by the same amount.

The estimated costs of pesticide use in Nepal are at the lower end when compared to costs estimated from pesticide exposure in other studies (see Table 1) from India (Devi, 2007), Sri Lanka (Wilson, 1998), Vietnam (Dung and Dung, 1999), Mali (Ajayi, *et. al*., 2002), Ecuador (Cole, Carpio and Leon, 2000; Yanggen, *et. al*., 2003) and United States (Pimental, 2005). For example, Devi (2007) finds that in India the annual cost of illness per applicator is around US $36. However, the costs estimated here are consistent with estimates from studies in Africa undertaken by Ajayi (2000) and Maumbe and Swinton (2003).

The low costs of pesticide exposure in this study could be the domination of mancozeb in spray events. Out of 3637 spray events during the seven-month study period, mancozeb was sprayed 3464 times either alone or mixed with other pesticides (Atreya, 2007c). Mancozeb is relatively non-hazardous. Further, the average amount of pesticide used in Nepal is lower than in many other countries. It is also clear that individuals treat symptoms as unrelated to pesticide exposure and as part of their agricultural life, thus underestimating their effects. Moreover, acute symptoms do not last for long periods. And, lastly, people use locally made alcohol to get rid of these symptoms and this may lead to a certain reluctance to discuss symptoms with outsiders.

It is also useful to note that most of the other studies considered a recall period of either one year or a crop season (Atreya, 2005; Wilson, 1998; Dung and Dung, 1999) and also measured long-term chronic illness (Wilson, 1998; Maumbe and Swinton, 2003) and intentional pesticide poisoning (Pimental, 2005; Cole, Carpio and Leon,. 2000). A longer recall period distorts assessment of costs. For example, in the pilot study, estimated costs due to pesticide use based on a one-year recall period produced a higher value of NPR 1261 per household per year (Atreya, 2005). The present study did not value long-term chronic illness, pain and discomfort. Nor did it value intentional pesticide poisoning.

A final qualification is that our cost estimates are based on self-reported symptoms, which may not fully reflect health changes. A study on pesticide exposure in Vietnam by Dasgupta, *et. al*. (2005) shows, for example, that self-reported symptoms have weak associations with actual poisoning.

6. Conclusions and Policy Recommendations

This is the first empirical study of its kind in Nepal to focus on pesticides use and its health costs in rural Nepal. The study shows that the use of insecticides and fungicides has a significant negative effect on human health.

This empirical investigation provides some policy inputs for planners at local, district and national levels. IPM training may not necessarily reduce health damages even though it increases averting activities significantly. This suggests that agricultural and environmental planners need to review the implementing strategies of the IPM program from a health perspective. Avertive measures like wearing masks and long-sleeved clothes do not help individuals reduce pesticide damage to health. Furthermore, only a small percentage of individuals adopt such avertive gear. Mixing more types of pesticides increases health damages. Awareness programs about safe handling and management of pesticide use would help reduce health symptoms.

The cost of illness estimated in this study area is an indicator of the hazards pesticides pose to individuals. The study shows that on average a person who is involved in pesticide application and is exposed to pesticides on average for 1.8 hours during spraying days bears an annual cost of NPR 143.72. This cost is indeed small, which is the reason why we see very limited avertive action being undertaken by individuals. Due to the low costs, when a farmer is faced with a choice between human health costs (indirect) associated with pesticides use and increases in farm production costs (direct), s/he tends to give greater priority to pesticides technology. However, this cost is nearly 8 times higher for the user population compared to the non-user population in the same household. The total annual costs of illness plus costs of avertive action for the population of the Panchkhal and Baluwa VDCs are estimated to be NPR 1,105,782 (US $ 15,797). This is assumed to be the lower bound when it comes to costs of pesticide pollution.

Pesticide pollution not only affects short-run health effects, but can also result in chronic diseases such as cancer. Pesticides also cause deaths of domestic animals, loss of natural pests, increase pesticide resistance, crop losses, bird and fishery losses, and surface and sub-surface water contamination. Therefore, the cost of pesticide pollution for the society is likely to be significantly higher than the cost estimated here. The low level of awareness on pesticides and health costs may lead to sub-optimal decision-making on the use of pesticides (Ajayi, 2000). However, the estimated cost here could be taken as reason to launch programs that focuse on pesticide use and safety measures.

7. Acknowledgements

The author acknowledges the financial support provided by the South Asian Network for Development and Environmental Economics (SANDEE). He is also thankful to Priya Shyamsundar, Enamul Haque, M. N. Murty, S. Madheswaran, Indira Devi, Purnamita Dasgupta, and Joyshree Roy for valuable suggestions and comments. He acknowledges with gratitude the logistical support for the research provided by Subodh Sharma and Roshan Man Bajracharya. Participants at the different SANDEE workshops are also acknowledged for their comments. Khadak Rokaya deserves my sincere thanks for data entry and field monitoring. Finally, the author would like to thank the 14 enumerators and all respondents for their endurance and cooperation during the period of this study. Without their assistance, this work could not have been completed.

References

Ajayi, O. C. (2000), *Pesticide Use Practices, Productivity and Farmers' Health: The Case of Cotton-Rice Systems in Cote D'lvoire, West Africa*, Pesticide Policy Project, Special Issue Publication Series No 3, University of Hanover, Germany.

Ajayi, O.C., *et. al.*, (2002), *Socio-economic Assessment of Pesticide Use in Mali*, Pesticide Policy Project Special Issue Publication Series No 6, University of Hanover, Germany.

Antle, J. M., D. C. Cole and C. C. Crissman (1998), 'Further Evidence on Pesticides, Productivity and Farmer Health: Potato Production in Ecuador,' *Agricultural Economics*, 18: 199-207.

Antle, J. M. and P. L. Pingali (1994), 'Pesticides, Productivity, and Farmer Health: A Philippine Case Study,' *American Journal of Agricultural Economics*, 76: 418-430.

Antle, J. M. and P. L. Pingali (1995), 'Pesticides, Productivity, and Farmer Health: A Philippine Case Study,' Ed. P. L. Pingali and P. A. Roger, *Impact of Pesticides on Farmer Health and the Rice Environment*, IRRI, pp. 361-385.

Atreya, K. (2005), 'Health Costs of Pesticide Use in a Vegetable Growing Area, Central Mid-Hill, Nepal,' *Himalayan Journal of Sciences*, 3: 81-84.

Atreya, K. (2007a), 'Pesticide Use, Knowledge and Practices: Gender differences in Nepal,' *Environmental Research*, 104:305-311.

Atreya, K. (2007b), 'Farmer's Willingness to Pay for Community Integrated Pest Management Training in Nepal,' *Agriculture and Human Values*, 24: 399-409.

Atreya, K. (2007c), 'Probabilistic Assessment of Acute Health Symptoms related to Pesticide Use under Intensified Nepalese Agriculture,' *International Journal of Environmental Health Research*, in press.

Cole, D. C., F. Carpio and N. Leon (2000), 'Economic Burden of Illness from Pesticide Poisonings in Highland Ecuador,' *Pan American Journal of Public Health*, 8: 196-201.

Dasgupta, P. (2004), 'Valuing Health Damages from Water Pollution in Urban Delhi, India: A Health Production Function Approach,' *Environment and Development Economics*, 9: 83-106.

Dasgupta, D, C. Meisner, and D. Wheeler, *et. al.*, (2005), '*Pesticide Poisoning of Farm Workers: Implications of Blood test Results from Vietnam,'* World Bank Policy Research Working Paper 3624, The World Bank, Washington, D.C., USA.

Devi, I. P. (2007), 'Pesticide Use in the Rice Bowl of Kerala: Health Costs and Policy Options,' SANDEE Working Paper 21, South Asian Network for Development and Environmental Economics (SANDEE), Kathmandu, Nepal.

Dung, N. H. and T. T. Dung (1999), 'Economic and Health Consequences of Pesticide Use in

Paddy Production in the Mekong Delta, Vietnam,' Economy and Environment Program for Southeast Asia (EEPSEA) - RR2, Singapore.

Feder, G., R. Murgai, and J. B. Quizon (2003), 'Sending Farmers Back to School: The Impact of Farmer Field Schools in Indonesia,' *Review of Agricultural Economics*, 29: 45-62.

Freeman, A. M. (1993), *The Measurement of Environmental and Resource Values: Theory and Methods*, Resources for the Future, Washington D. C.

Gomes, J., O. L. Lloyd, and D. M. Revitt (1999), 'The Influence of Personal Protection, Environmental Hygiene and Exposure to Pesticides on the Health of Immigrant Farm Workers in a Desert Country,' *International Archive on Occupational & Environmental Health*, 72:40-45.

Gupta, P. K. (2004), 'Pesticide Exposure—Indian Scene,' *Toxicology*, 198: 83-90.

Hotchkiss, D. R., *et. al.*, (1998), 'Household Health Expenditures in Nepal: Implications for Health Care Financing Reform,' *Health Policy and Planning*, 13:371-83.

Kishi, M., *et. al.*,, (1995), 'Relationship of Pesticide Spraying to Signs and Symptoms in Indonesian Farmers', *Scandinavian Journal of Work, Environment & Health*, 21:124-133.

Lu, J. L. (2005), 'Risk Factors to Pesticide Exposure and Associated Health Symptoms among Cut-Flower Farmers,' *International Journal of Environmental Health Research*, 15: 161-169.

Maumbe, B. M.and S.M. Swinton (2003), 'Hidden Health Costs of Pesticide Use in Zimbabwe's Smallholder Cotton Growers,' *Social Science & Medicine*, 57: 1559-1571.

Murphy, H. H., A. Sanusi and R. Dilts, *et. al.*, (1999), 'Health Effects of Pesticide Use among Indonesian Women Farmers: Part I: Exposure and Acute Health Effects,' *Journal of Agromedicine*, 6: 61-85.

Nuwayhid, I. A. (2004), 'Occupational Health Research in Developing Countries: A Partner for Social Justice,' *American Journal of Public Health*, 94: 1916-1921.

Pingali, P. L., C. B. Marquez, F. G. Palis, *et. al*., (1995), 'The Impact of Pesticides on Farmer Health: A Medical and Economic analysis in the Philippines,' Ed. P. L. Pingali and P. A. Roger, *Impact of pesticides on farmer health and the rice environment*, pp. 343-360, Philippines: IRRI.

Pimental, D. (2005), 'Environmental and Economic Costs of the Application of Pesticides Primarily in the United States,' *Environment, Development and Sustainability*, 7: 229-252.

Poudel, K. C., M. Jimba and K. Poudel-Tandular, *et. al.*, (2005), 'Lack of Occupational Health Research in Nepal,' *American Journal of Public Health*, 95: 550.

Pujara, D. S. and N. R. Khanal (2002), 'Use of Pesticides in Jaishidhi subcatchment, Jhikhu khola Watershed, Middle Mountain in Nepal,' Ed. A. Hermann and S. Schumann, Proceedings: international workshop on environmental risk assessment of pesticides and integrated pest management in developing countries, 6-9 November 2001, Kathmandu, Nepal.

Rola, A. C. and P. L. Pingali (1993), *Pesticides, Rice Productivity, and Farmers' Health: An Economic Assessment*, Philippines: IRRI & WRI.

Salameh, P. R., I. Baldi and P Brochard, *et. al.*, (2004), 'Pesticides in Lebanon: A Knowledge, Attitude, and Practice Study,' *Environmental Research*, 94:1-6.

Shrestha, P. L. and F.P. Neupane (2002), 'Socio-economic Contexts on Pesticide use in Nepal,' Ed. A. Hermann and S. Schumann, Proceedings of the international workshop on environmental risk assessment of pesticides and integrated pest management in developing countries, 6-9 November 2001, Kathmandu, Nepal.

Singh, R. S. (1990), *Plant Diseases* (Sixth Ed.), New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd.

Trumble, J. Y. (1998), 'IPM: Overcoming Conflicts in Adoption,' *Integrated Pest Management Reviews*, 3: 195-207.

Wilson, C. (1998), *Cost and Policy Implications of Agricultural Pollution with Special Reference to Pesticides*, Ph D Thesis, Department of Economics, University of St Andrews, Scotland, UK.

Wilson, C. and C. Tisdell (2001), 'Why Farmers Continue to Use Pesticides Despite Environmental, Health and Sustainability Costs,' *Ecological Economics*, 39: 449-462.

Yassin, M. M., T. A. Abu Mourad, and J. M. Safi, (2002), 'Knowledge, Attitude, Practice, and Toxicity Symptoms Associated with Pesticide Use among Farm Workers in the Gaza Strip,' *Occupational and Environmental Medicine*, 59: 387-394.

Yanggen, D., D. Cole, and C. Crissman, *et. al.*, (2003), '*Human Health, Environmental and Economic Effects of Pesticide Use in Potato Production in Ecuador*,' Lima, Peru: International Potato Centre.

WHO/PCS (2001), *The WHO Recommended Classification of Pesticide by Hazard and Guidelines to Classification 2000-2002*, Rome: UNEP/ILO/WHO.

TABLES

Table 1: Environmental and Social Cost of Pesticide use in Different Countries

Ecuador	The immediate costs of a typical intoxication (medical attention, medicines, days of recuperation, etc.) equaled the value of 11 days of lost wages.	Yanggen, *et. al*., (2003)
Ecuador	The median cost associated with pesticide poisoning was US$ 26.51/case/worker	Cole, *et. al*., (2000)
India	The average annual welfare loss toof an applicator from pesticide exposure amounts to US$ 36a(US$ 36).	Devi (2007)
Mali	Annual indirect and external cost of pesticide use = US$10 million	Ajayi, *et. al.,* (2002)
Philippines	61% higher health costs for farmers exposed to pesticides than those not exposed	Pingali, *et. al*., (1995)
Sri Lanka	Ill health cost to farmers from pesticide exposure = income of 10 weeks	Wilson (1998)
USA	Total estimated annual environmental and social costs from pesticides in the United States = US$ 9645 million (public health impact = US$ 1140 million)	Pimental (2005)
Vietnam	Health cost of over US $ 6.92 per individual per rice season	Dung & Dung (1999)
West Africa	The economic value of the pesticide-related health costs equal US$ 3.92 per household per season in the case of cotton-rice systems	Ajayi (2000)
Zimbabwe	Cotton growers incur a mean of US $ 4.73 in Sanyati and $ 8.31 in Chipinge on pesticide related direct and indirect acute health effects.	Maumbe & Swinton (2003)

Table 2: Descriptive Statistics of the Respondents*

Category	% of Male	Age(Years)	Education (Years)	IPM Training (%)
Users A (N = 291)	0.86 (0.35)	33.6 (10.64)	5.5 (4.06)	8.2
Users B (N = 87)	0.61 (0.49)	30.0 (11.94)	4.8 (4.67)	3.4
Non-users (N = 122)	0.24 (0.43)	35.2(13.95)	2.9 (4.08)	4.1

* Figures in parenthesis are standard deviations.

Table 3: Explanatory Variables and Hypothesis for Dose-response Function

Variable	Expected sign	Description
INSECT	+	Exposure to insecticides (ml/l/h)
FUNGI	+	Exposure to fungicides (g/l/h)
TEMP	+	Average weekly maximum temperature (^oC)
MIX	+	Dummy for mixing of pesticides (if mixed = 1, 0 otherwise)
AGE	-	Age of the individual (years)
EDU	-	Formal education of the individual (Years of schooling)
IPM	-	Dummy for IPM training (if trained = 1, 0 otherwise)
BMI	?	Body Mass Index (wt/ht^2)

Table 4: Explanatory Variables and Hypothesis for Avertive Function

Variable	Expected sign	Description
INSECT	+	Exposure to insecticides (ml/l/h)
FUNGI	+	Exposure to fungicides (g/l/h)
TEMP	-	Average weekly maximum temperature (^oC)
MIX	+	Dummy for mixing of pesticides (if mixed = 1, 0 otherwise)
AGE	+	Age of the individual (years)
EDU	+	Formal education of the individual (Years of schooling)
IPM	+	Dummy for IPM training (if trained = 1, 0 otherwise)
BMI	?	Body mass index (wt/ht^2)

Table 5: Frequency of Acute Symptoms (Incidence per 1000 Spray)

SN	Symptoms	Users A		Users B		Non-users
		Spraying Days	Non-spraying Days	Spraying Days	Non-spraying Days	
1	Headache	193	24	282	37	68
2	Muscle Twitching/Pain	158	55	256	75	96
3	Chapped Hands	149	43	239	56	89
4	Excessive Sweating	136	57	144	51	96
5	Eye Irritation	81	4	115	5	14
6	Skin Irritation/Burn	79	1	110	2	2
7	Weakness	61	17	89	19	36
8	Respiratory Depression	50	4	104	12	13
9	Chest Pain	37	11	104	23	36
10	Throat Discomfort	30	8	75	7	24

Table 6: Use of Protective Equipment during Pesticides Spraying

Protective Equipments	% of Total Spraying Episodes*
Long-sleeved Shirt	67.72
Full Pants	58.26
Cap	15.34
Handkerchief	14.19
Shoes	11.22
Mask	9.76
Gloves	1.48
Spectacle	0.47
Boots	0.11
Others (Plastic, Shawl)	4.12
Without any Protective Equipments	14.8

* Total % is >100 since an individual may use more than one protective gears in a spray

Table 7: Summary Statistics of the Variables Used in the Dose-response and Avertive Functions

Variable	Mean	Std. Dev.	Min	Max
INSECT	0.22	0.9559	0	20.74
FUNGI	2.37	5.4594	0	67
TEMP	28.75	5.0893	18.10	36.10
MIX	0.18	0.3860	0	1
AGE	33.98	11.7902	10	71
EDU	4.74	4.2491	0	14
IPM	0.06	0.2435	0	1
BMI	19.90	3.12	12.92	38.45

Table 8: Dose-response Function+

Variables	Coefficient	Marginal Effect	T-Statistic
INSECT	0.1269(0.0142)	0.0380(0.0043)	8.92***
FUNGI	0.0452(0.0029)	0.0135(0.0008)	15.58***
TEMP	-0.0509(0.0026)	-0.0152(0.0007)	-19.08***
MIX	0.2506(0.0408)	0.0794(0.0135)	6.14***
AGE	-0.0049(0.0012)	-0.0015(0.0004)	-4.10***
EDU	-0.0322(0.0034)	-0.0096(0.0010)	-9.47***
IPM	0.0947(0.0522)	0.0292(0.0165)	1.81
BMI	-0.0271(0.0043)	-0.0081(0.0012)	-6.27***
CONSTANT	1.3772(0.1287)	-	10.70***

\+ *Figure in parenthesis are standard errorLog likelihood = -6252.96, Pseudo R^2 = 0.119, No of observation = 12721*

*** *Indicates significant at 1% level*

Table 9: Avertive Action Function

Variables	Coefficient	Marginal Effect	T-TEST
INSECT	0.2203(0.0232)	0.0563(0.0060)	9.49***
FUNGI	0.1116(0.0037)	0.0285(0.0010)	30.37***
TEMP	-0.0076(0.0034)	-0.0019(0.0008)	-2.21*
MIX	1.4770(0.0455)	0.4914(0.0159)	32.44***
AGE	0.0072(0.0015)	0.0018(0.0003)	4.65***
EDU	0.0040(0.0044)	0.0010(0.0011)	0.93
IPM	0.3190(0.0615)	0.0918(0.0196)	5.19***
BMI	-0.0052(0.0054)	-0.0013(0.0013)	-0.97
CONSTANT	-1.4900(0.1636)	-	-9.11***

+ *Figures in parenthesis are standard errorLog likelihood = -3582.29, Pseudo R^2 = 0.483, No of observation = 12721*

* *and *** indicate significance at 10% and 1% level respectively*

Table 10: Annual Costs of Illness for Users and Non-users due to Pesticide Exposure

Predicted probability of a user being sick (P_u)	0.4116
Predicted probability of a non-user being sick (P_c)	0.1768
Predicted probability of taking avertive actions (P_a)	0.5218
Average costs of treatment for users (COI_u)	172.54 (Rs)
Average costs of treatment for non-users (COI_c)	105.34 (Rs)
Average costs of avertive actions for users (AC)	175 (Rs)
Average costs of exposure for users: $C_u = P_u*COI_u + P_a*AC$	162.34 (Rs)
Average costs of exposure for non-users: $C_c = P_c*COI_c$	18.62(Rs)
Actual health costs for a user to pesticide exposure $HC = C_u - C_c$	143.72 (Rs)
Total annual health costs for the study area (3847 households), assuming that at least two members in a household spray pesticides	11,05,782 (Rs)

Table 11: Estimation of Cost-of-illness by Gender

	Male	Female
Predicted probability of a user being sick	0.4027	0.4306
Predicted probability of a non-user being sick	0.171	0.1882
Predicted probability of taking avertive actions	0.5089	0.5494
Average costs of treatment for users (Rs)	178	156
Average costs of treatment for non-users (Rs)	78.78	172.47
Average costs of avertive actions for users (Rs)	180.16	122
Average costs of exposure for users (Rs)	164	134
Average costs of exposure for non-users (Rs)	13.47	32.43
Actual health costs for a user to pesticide exposure (Rs)	151	102

Table 12: Change in Health Costs from Changes in Concentrations and Hours of Application

	Results
Marginal effect of insecticide exposure to sickness	0.0380
Marginal effect of fungicide exposure to sickness	0.0135
Mean insecticide concentration (ml/l)	0.52
Mean fungicide concentration (g/l)	4.26
Mean hours of exposure (h/day)	1.80
Marginal effect of insecticide exposure to avertive action	0.0563
Marginal effect of fungicide exposure to avertive action	0.0285
Costs of treatment (Rs)	172.54
Costs of avertive action (Rs)	175
Δ prob. sickness / Δ insecticide concentration evaluated at mean hours of exposure	0.0684
Δ prob. sickness / Δ fungicide concentration evaluated at mean hours of exposure	0.0243
Δ prob. sickness / Δ hours of spray evaluated at mean concentration of insecticides	0.0198
Δ prob. sickness / Δ hours of spray evaluated at mean concentration of fungicides	0.0575
Δ prob. avertive action / Δ insecticide concentration evaluated at mean hours of exposure	0.1013
Δ prob. avertive action / Δ fungicide concentration evaluated at mean hours of exposure	0.0513
Δ prob. avertive action / Δ hours of spray evaluated at mean concentration of insecticides	0.0293
Δ prob. avertive action / Δ hours of spray evaluated at mean concentration of fungicides	0.1214
Δ health costs / Δ insecticide concentration	Rs. 29.53
Δ health costs / Δ fungicide concentration	Rs. 13.17
Δ health costs / Δ hours of insecticides application	Rs. 8.53
Δ health costs / Δ hours of fungicides application	Rs. 31.17

Table 13: Policy Simulation

Percentage Increase in Policy Variables	Probability of Sickness			
	Concentration		Hour of Spray	
	Insecticide	Fungicide	Insecticide	Fungicide
10%	0.0752	0.0267	0.0217	0.0633
20%	0.0821	0.0292	0.0237	0.0690
50%	0.1026	0.0365	0.0296	0.0863
100%	0.1368	0.0486	0.0395	0.1150
	Probability of Avertive Action			
10%	0.1115	0.0564	0.0322	0.1336
20%	0.1216	0.0616	0.0351	0.1457
30%	0.1520	0.0770	0.0439	0.1821
100%	0.2027	0.1026	0.0586	0.2428
	Health Costs			
10%	32.49	14.49	9.39	34.29
20%	35.44	15.80	10.24	37.40
30%	44.30	19.76	12.80	46.75
100%	59.07	26.34	17.07	62.34

FIGURES

Figure 1: Location of the Study Area

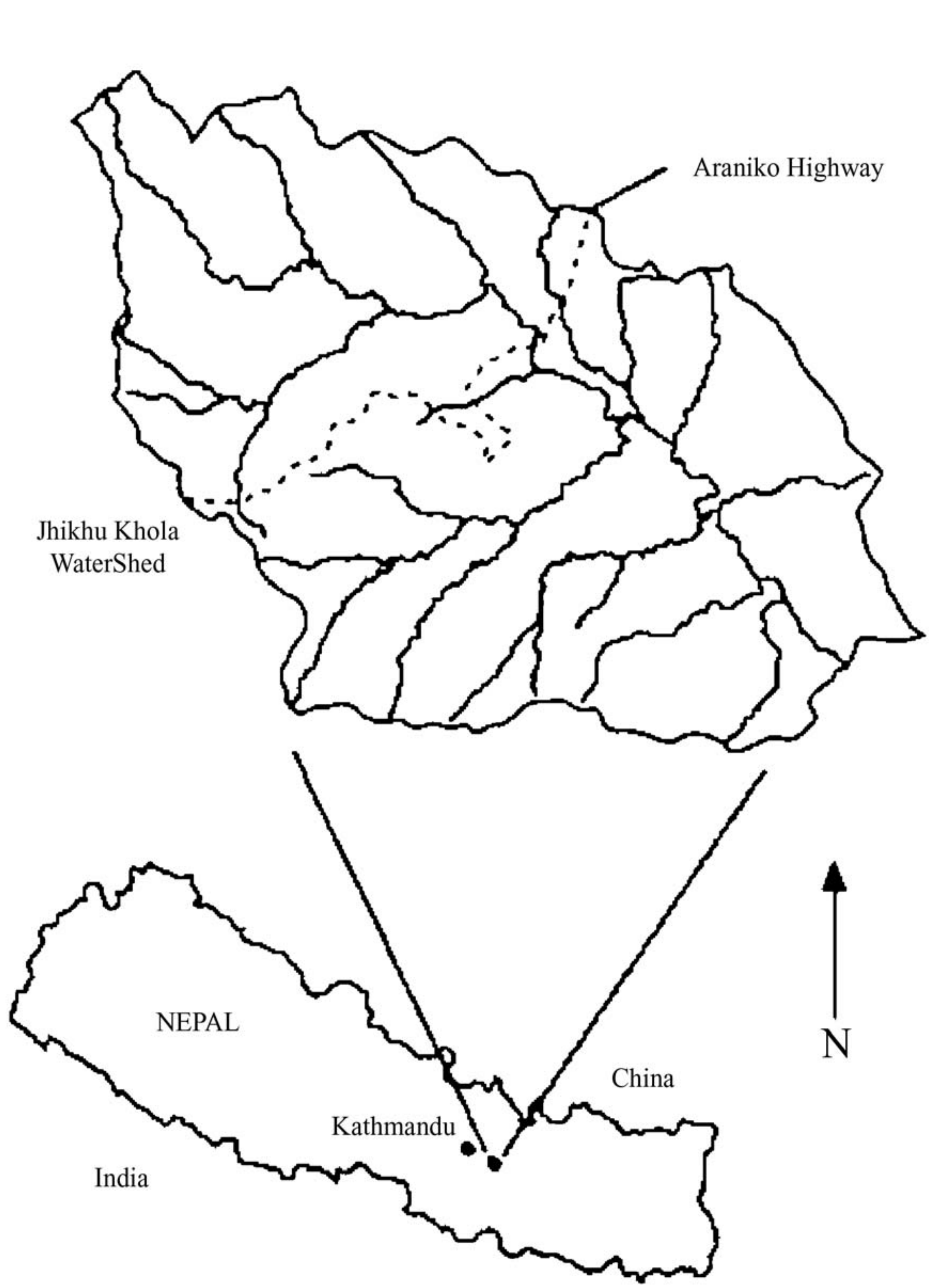

Figure 2: Scheme of the Important Steps used in the Households and Individual Sampling