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FARMER'S HEALTH EXTERNALITIES IN PESTICIDE USE PREDOMINANT REGIONS IN INDIA

P. K. Shetty[1], M. B. Hiremath*[2], M Murugan and R B Nerli [2]

[1] School of Natural sciences and Engineering, National Institute of Advanced Studies, Indian Institute of Science Campus, Bangalore 560 012

[*2] KLES Kidney Foundation, KLE University's JN Medical College, KLES Dr Prabhakar Kore Hospital & MRC, Belgaum 590010

Corresponding author e-mail: murigendra@gmail.com

Abstract

The use of pesticides in Indian agriculture, though beneficial in reducing crop loss both before and after harvest, has been associated with threats to human health often due to the misuse of these chemicals. This study was an initial attempt to explore health externalities of farmers and agricultural labourers in pesticide use predominant 28 districts in 12 Indian states. Doctors, pesticide vendors and agricultural officers of regions were interviewed to study the health externalities related to pesticide use. Data were collected through pre-tested schedules by trained field investigators. From a total sample size of 1577 and analysed. The results revealed a steady decrease in overall consumption of pesticides since 1990. About 19.4% of the respondents had experienced negative side effects on health after handling pesticides. The symptoms include headache, weakness, dizziness, fever, blurred vision, and nausea/vomiting. Most of the respondents are aware of pesticide-related symptoms and possible routes of absorption, during application of pesticides. Farmers make only short-term assessments of pesticides and spray these chemicals without taking proper protective clothing. Records on serious pesticide poisoning cases were available only in a few government hospitals, but such details were not even accessible from private hospitals as pesticide poisoning incidences are subjected to medico-legal cases. Training for agriculture and health workers in safety measures, recognition, and management of pesticide-related ill health is a matter of exigency. There is a tremendous scope for agricultural extension activity through which pesticide stewardship can be achieved in India.

Keywords: India, Farmers, Pesticide poisoning, Health externalities.

Introduction

Quantitative and descriptive analyses of pesticide use in different agro-ecosystems in India illustrate unquestionable complexity of usage patterns. They are driven by many factors viz., biological, management and regulatory, which continually fluctuate in relative importance from year to year. With these fluctuations changes occur in both the types and amounts of pesticides applied. Pesticide use in Indian agriculture has a positive externality insofar as it increases grain production. However, its indiscriminate and improper use in a few agro-ecosystems has given rise to several negative externalities. Most of the benefits of pesticide use are in terms of direct crop returns. Such assessments do not include the indirect environmental and economic costs associated with pesticides, such as the fact that long-term and highly concentrated applications of pesticides pose serious threats of residues in the products / commodity and agro-ecosystems. Besides negative externalities like pesticide poisoning, problems of residues, development of resistance, resurgence of insect pests, and health costs, also need to be accounted for. In order to facilitate the development of sound policies and their implementation, these costs must be examined. Reliance on pesticides as the main tool in insect pest management strategy is not only unsustainable, but also extracts penalties in terms of human and environmental health. These penalties are sometimes borne by pesticide users themselves, but in many cases, it is the other sectors of society who may be adversely affected. A pesticide used to manage a pest, imposes costs on others if it leaks away from fields to contaminate public drinking water, or if it builds up as a residue in foods. Types of externalities encountered in the agricultural sector have four distinct features: i) their costs are often neglected; ii) they often occur with time lags; iii) they often damage groups whose interests are not represented; and iv) the identity of the producer of the externality is seldom known. These externalities result in economic costs that are not reflected in the price of pesticides, and there is therefore no direct market incentive for users to change their pest management practises to reduce these costs. Most research has been devoted to investigation of the health impacts of pesticides. Knowledge about this is far from complete, but evidence is building up that even low exposure over a long term may have significant effects, with some studies implicating pesticides in the rising incidences of cancer, genetic mutation, and reproductive disorders (Council on Scientific Affairs, 1988; WHO, 1990). Yet more research even suggests that the benefits of pesticides have been exaggerated and that they pose substantial danger both to the environment and to human health. Obsolete-pesticide disposal is another major cost to be added into the externalities equation. This paper is the outcome of national level field survey and a review of the literature on pesticide poisoning in India. The paper attempts to analyze the reasons for the high incidence of pesticide poisoning cases and discusses ways of monitoring the problem. Both, the field survey and the literature review, focus on health externalities of pesticides.

Methods

Study area

The study was carried out in 28 districts from 12 Indian states selected based on the type of crops grown and pesticide consumption pattern. The focus was on farmers and agricultural labourers who handle pesticides in crops such as paddy, cotton, sugarcane, wheat, apple, pomegranate, mango, grapes and vegetables covering different agro-ecological zones in India. Primary data were collected from farmers, agricultural labourers, pesticide vendors and agricultural officers with the help of pre-tested schedules. A total of 1577 samples from 290 randomly selected villages across the 12 Indian states were drawn. Data collected through schedules were keyed in to Visual Basic front end in MS Access data base. Schedules of farmers, agricultural officers, vendors, labourers had a separate software package and data were then analysed through suitable statistical technique.

Survey Questionnaire

The survey questionnaire for the farmers, agricultural labourers, Agricultural Officers and pesticide vendors and doctors were designed with pre-coded options based on existing understanding of secondary research and pilot surveys. Specific information was collected from individual schedules served to agricultural labourers, Agricultural Officers and pesticide vendors. To measure the awareness of respondents regarding the ill effects of pesticides, awareness questions were asked with two possible answers, i.e., complete awareness and no awareness with scores of 1 and 0 respectively. These responses by the farmers were recorded against the appropriate statement and were classified into two groups using mean as measure of check. Respondents with total score less than mean was categorised as low awareness group and others as high awareness group. Data were compiled and mean as well as percentages for the intended parameters were calculated to draw conclusive results.

Necessity, health costs related to pesticide use in India

Pesticides constitute an important component in agriculture development and protection of public health in India since our tropical climate is very conducive to pest breeding. There are about 20 major diseases, which have been brought under control by the use of pesticides. The most significant among them are malaria, filariasis, dengue, Japanese encephalitis, cholera and louse-borne typhus. DDT spray was instrumental in reducing the annual incidence of malaria in the country from 75 million in 1952 to the present 2−4 million (Park, 1997). To quote Nobel Laureate Norman Borlaug, 'complete ban on the pesticides would result in 50% reduction in production and would rise food prices by 4−5 times' (Ravi, 2001). Thus in this context, pesticides emerge as indispensable for agriculture. Given the prospects of India's food situation and the growing population, intensive cropping systems are likely to take place through increasing the area under irrigation and intensive use of agro-chemicals. Reliance on pesticides for plant protection is expected to increase the dependence on and enhance the use of these chemicals due to rapid development of resistance among insect pests. In a study it was observed that farmers, the major pesticide users, were not fully aware of the risks related to pesticide use (Rola and Pingali, 1993). Misuse (and overuse) of pesticides was often observed in the developing countries (Warburton *et al*., 1995; Heong *et al*., 1995; Yudelman, 1998). A clear understanding of farmers' knowledge, attitudes, and practises regarding pesticide use is the first step towards understanding the reasons for overuse of pesticides by farmers. In an analysis and evaluation of true costs and benefits of pesticide use, there are some important ecological and socio-economic consequences that do not feature in conventional economic analysis of pesticides.

It is difficult to assess the impact of pesticides on health in developing countries because of lack of data, non-availability of hospital records and monitoring. These problems are magnified because of conditions prevalent in these countries. These include lack of access to clean water for drinking, absence of medical facilities or other access to antidotes, lack of training, shortage of technical and cultural controls to minimize pesticide hazards, inability to afford protective clothing or equipment; high rates of illiteracy and inability to read complex label instructions; labels not being in the language of the user, virtual impossibility of wearing protective clothing in hot and humid climates, mixing of hazardous active ingredients by hand, reuse of containers for food or water storage and so on (Dinham 1996).

The World Health Organization (WHO) has estimated about three million acute cases of pesticide poisoning and as many as 20,000 unintentional deaths each year, primarily in developing countries (WHO, 1990). A WHO study indicated that three per cent of agricultural workers in developing countries suffered a poisoning incident each year, resulting in 25 million occupational poisonings (Jeyaratnam, 1990). Farmers make only short-term assessments of pesticide use. In the process, they put in all efforts to maximize the net returns by minimizing crop losses. They take into account the money saved from preventing crop loss versus the cost of pesticide and other farm resources required for pesticide application. Unfortunately, important factors such as the health risks involved, loss of money spent on health care, loss of labour due to sickness, decreasing efficiency of work, long-term health effects of pesticides and downstream effects are not accorded equal attention. Studies in the USA and Philippines have shown that farmers themselves spend as much money on health care as they do on pesticides (Pimentel *et al*. 1993; Rola and Pingali, 1993). Humans also suffer from the harmful effects of pesticides in the form of residues in food and in the environment. The external cost of illnesses in the community due to pesticide residues is a major cause of concern. The use of plant protection chemicals in the irrigation intensive areas has increased rapidly over the years. However, respondents in the study area have little knowledge and concern regarding safe and efficient use of pesticides.

There is now overwhelming evidence that some of these chemicals do pose potential risks to humans and other life forms, and unwanted side effects to the environment (Jeyaratnam, 1985; Igbedioh, 1991; Forget, 1993). No segment of the population is completely protected against exposure to pesticides and their potentially serious health effects, though a disproportionate burden is shouldered by the people of developing countries and by high-risk groups in each country (WHO, 1990). No agency regularly monitors pesticide residues in market samples or undertakes diet basket surveys to assess actual exposure of consumers from pesticide residues in food or water and to project the health risk, if any. Such activity comes under the purview of the Ministry of Health but no comprehensive regular monitoring programme is being conducted in India (JPC Report, 2004). Household use of pesticides for personal protection is also prevalent, using coils, mats, aerosols, space sprays and insecticide-treated nets. Information on the amount of these retail purchases is not available. Vector control is conducted with annual indoor residual spray for malaria and use of larvicides as well as larvivorous fish for both malaria and lymphatic filariasis control. These products undergo government oversight in the same manner as other pesticides (Kanungo, 2002).

To analyse the possible side effects of pesticide use on human health, a distinction has to be made between occupational health hazards and pesticide residues in food products and drinking water. Meeting the minimum requirements of occupational health standards is regarded as one of the elements of sustainable agricultural development. Apart from a limited number of case studies, there are no countrywide statistics on the extent of poisoning of farmers through pesticide application. There are at least four reasons for this. (1) Farmers seek medical attention only in cases of serious health problems owing to the cost involved, (2) most farmers are not aware of the specific symptoms of pesticide poisoning, so health workers are not informed and therefore cannot draw the right conclusions. (3) the system of health statistics does not clearly specify cases of poisoning, (4) in many cases of poisoning or death no further investigations are done due to the lack of technical facilities for autopsies.

Results and Discussion

Externalities arise when certain actions of an individual have unintended external (indirect) effects on another individual. There are two kinds of externalities, i.e., positive and negative externalities. The former arises when an action by an individual produces a beneficial result to the society or another individual. A technological spillover is a positive externality and it occurs when a firm's invention not only benefits the firm but also enters into the society's pool of technical knowledge and benefits the society as a whole. Negative externalities arise when an action by an individual or group produces harmful effects on others. The study team examined some of these externalities related to use of pesticides by farmers in the pesticide use predominant regions of India. Many cases of intoxication due to occupational exposure may not require admission to a hospital and are therefore not included in routine health statistics. There are no estimates of the incidence of occupational poisoning in India based on self-reported episodes by farmers. In 28 districts 19.4 % of the respondents had experienced negative side effects on health after handling pesticides. The symptoms include headache, weakness, dizziness, fever, blurred vision, and nausea/vomiting. These symptoms are more prevalent among the agricultural labourers (Figure 1). The amount spent by the farmers and agricultural labourers on health costs for ailments caused by pesticides in a cropping season range from Rs. 100/- to Rs. 500/-. The average number of working days lost due to sickness range from 1 to 5 days depending upon the severity of poisoning. According to a study conducted in the United States by Pimental (1992), the total health cost of hospitalization after poisoning and number of working days lost accounts to about $ 787 million per year. Furthermore, there were direct linkages between knowledge and the protective equipment of farmers on the one hand and the extent of negative side effects on the other hand. Most of the respondents are aware of pesticide-related symptoms and possible routes of pesticide absorption. General awareness of protective devices seems to be common. However, the transfer of knowledge into practise seems to be weak.

Health specialists in the pesticide use predominant areas pointed out that the health effects might be underestimated due to the farmers' limited awareness of the risks involved. Sometimes farmers take the risk of applying cheap and hazardous pesticides in order to save agricultural produce for their livelihood. They are therefore prepared to take the health risks. Only cases where pesticide application has had acute consequences are reported to the hospitals. Farmers do not relate negative long-term effects of pesticides to the practise of using inadequate protective clothing. Another issue is that health care centres cannot easily diagnose acute poisoning. The experts agree that there is a need for building up capacities for control and management of poisoning in general and for poisoning resulting from pesticide use in particular.

Consumers may be affected by relatively low doses of pesticide residues in drinking water and through food products (long-term effects) or acutely through high doses caused by misuse, wrong application or overdose at the farm level. Different groups and segments of a population are exposed to pesticides in different ways and to different degrees. These are intentional (suicides and homicides) and unintentional exposures (occupational and non-occupational exposure to the pesticide-affected water, air and food). The occupational hazards in industrial settings and the ecological repercussions in the environment could be grouped as under: (i) Operational hazards, which arise during production and formulation of pesticides in industrial settings and their distribution and use in field conditions. (ii) Direct toxic effects on non-target animal life such as pollinators, predators and wildlife, during application of pesticides. (iii) Post-application hazards or indirect toxic effects which involve risk to non-target animals due to toxic residues of pesticides in food or due to pollution of the ecosystem and habitat as a whole, such as water bodies or soil (Dinham, 1993).

WHO has classified commonly used pesticides into four different groups based on (lethal dose) LD_{50} values. The LD_{50} value is a statistical estimate of the toxicity in terms of milligram of toxicant/kilograms of body weight required to kill 50 per cent of a large population of test animals. Pesticides that are commonly used by the farmers of study area are classified under various categories of WHO classification (Table 1). It may be observed from the table that out of the 189 chemicals registered, only 43 pesticides are extensively used in the study area of which 29 pesticides fall under the Ia, Ib, II, and III categories of WHO classification. Of the main class of insecticides used, organophosphorous (OP) compounds are the most hazardous and affect the nervous system. Organochlorines are highly persistent in nature, and most are banned for agricultural purposes in India. However, some of these pesticides like DDT, BHC etc., are allowed to use under malaria control programme. Because of poor regulation they are being illegally marketed and used in agro-ecosystems as they are available cheaply. Food and Agriculture Organization recommends that WHO Ia (extremely hazardous) and Ib (Highly hazardous) pesticides should not be used in developing countries (PAN UK, 2001). Class Ia, Ib, II, and III pesticides must be stored in premises where the ambient conditions are not likely to alter the pesticide, its container or label. The pesticide must also be stored in such a manner that its content is not released into the environment. Most class-I technical grade pesticides are banned or strictly controlled in the regulated industrialized world, but in India, still two class-I classified pesticides are freely available in places that do not have the resources for their safe use.

Assessment of Health Costs Related to Pesticide Use

Proper assessment of health hazards due to pesticide use in study area rises some difficulties as many minor poisoning cases are not reported to a doctor or there is no systematic monitoring of poisoning cases in these regions. It was observed that records on serious pesticide poisoning cases were available mostly intentional in a few Government hospitals, but such details were not even accessible from private hospitals as pesticide poisoning incidences are subjected for medico-legal cases. Many were hesitant to share information on such pesticide poisoning and deaths in these regions.

The Poison Information Centre at the National Institute of Occupational Health (NIOH), Ahmedabad reported that OP compounds were responsible for the maximum cases of poisoning (73 %) among all agricultural pesticides (Dewan and Saiyed, 1998). In a study on patients of acute OP poisoning (n=190), muscarinic manifestations such as vomiting (96 %), nausea (82 %), miosis (64 %), excessive salivation (61 %), and blurred vision (54 %) and CNS manifestations such as giddiness (93 %), headache (84 %), and disturbances in consciousness (44 %) were the major presenting symptoms (Agarwal, 1993). Cardiac manifestations such as sinus tachycardia (25 %), sinus bradycardia (6 %) and depression of ST segments with T wave inversion (6 %) were also observed. Incidence of intermediate syndrome in cases of OP poisoning has also been reported (Shailesh *et al*., 1994; Samuel *et al*, 1995). There were a number of reports from northern India on the abuse of aluminium phosphide, a grain preservative taken for self-poisoning (Saraswat *et al*., 1985: Singh *et al*., 1985; Raman *et al*., 1991).

In human beings, the pesticide residue level is an index of exposure, which may be acute, occupational or incidental. In acute exposure, the residue level has a diagnostic potential, and in occupational exposure, the residue level merits an insight reflective of industrial exposure. However, in the general population, the residue level is a measure of the incidental exposure and/or average levels of persistent pesticides, is mainly absorbed through the food chain. Residues of OC insecticides, especially DDT and HCH, have been detected in man and his environment the world over (Jensen, 1983; Hayes and Laws, 1991). However, by comparison, very high levels of these pesticides have been reported in human blood, fat, and milk samples in India (ICMR, 2001). In India pesticide residues in human fat samples reported way back in 1977 itself (Chawla *et al*., 1977).

There are several incidences of non-fatal poisoning cases in the selected districts owing to the use of improper and inadequate safety measures while spraying, lack of experience in spraying and improper methods of application. The majority of the respondents who take up spraying reported that they often suffer from headaches, dizziness, nausea, nasal discharge, skin and eye irritation while handling and spraying pesticides. There is lack of proper monitoring of pesticide-related poisoning cases and deaths in these regions. Moreover, as these cases are medico-legal in nature, farmers are reluctant to undergo many rounds of police inquiry. Therefore, many poisoning cases also go unreported in government hospitals. Only serious cases of poisoning are reported to primary health centres (PHC) or rural hospitals.

Though there are several pesticide-related poisoning cases reported during field investigations, pesticide-related deaths are rare, unless the operators involve themselves in chewing tobacco or taking food or drinks during spraying. Cases of intentional poisoning are high in these districts, often resulting in deaths. The easy accessibility of pesticides in these regions has turned out to be a potent means of committing suicide. There were also cases of accidental consumption of pesticides by children in these districts. According to a government district hospital doctor in the Murshidabad district of West Bengal, some farmers take their children to the field where spraying activities are taken up (Photo 1). As a result, accidental poisoning among children is very high in these regions. Earlier studies also reported such higher accidental death rate in children in India (Singh *et al*., 1995). *After coming into contact with pesticides it is difficult to 'wash off at once' when there is no water available and even more to 'see a doctor immediately' when the nearest is many miles away (Bull, 1982; Dinham, 1993).*

During the years 2002 and 2003, Warangal, Karimnagar, Ranchi, Raipur and Nashik hospital records and discussions with the concerned authorities indicated a large number of poisoning cases (Table 2). Among these, Warangal District in Andhra Pradesh recorded the highest number of poisoning cases. During this year, Warangal and neighbouring districts faced severe drought and crop losses. As there are a large number of pesticide-related poisoning cases and intentional deaths in these districts, it is essential to have a proper monitoring system in accordance with the WHO either by health ministry of central government or by a private body.

As a result of lack of adequate information on the total number of poisoning incidents, the available data in Table 2 may serve as a 'lower limit' for the assessment of implied health costs. It would be desirable to conduct in-depth studies on health effects, which includes non-reported poisoning cases. This would increase current knowledge of the extent of occupational poisoning. For assessment of health costs, the expenses for medical treatment and loss of income due to the inability to work during illness have to be calculated. In case of poisoning deaths, the value of fatalities would have to be considered. Additionally, long-term effects of pesticide poisoning also contribute to the implied health costs. However, no information about the extent and related costs of long-term effects is available, for example, costs of factors like emotional, psychological, spiritual, which are difficult to quantify.

Externalities on Non-target Organisms

There are several cases of animal poisoning reported from different agro-ecosystems in India. The respondents in the study also reported such incidents. By and large, respondents are aware of pesticide poisoning and report that they prevent animals, particularly cattle, from entering pesticide sprayed fields. It was difficult to estimate the economic value of animal poisoning as it is rarely reported to veterinary hospitals. However, there are reports about animal products such as meat, milk and eggs being contaminated by pesticide residue (ICRA, 2005). There are several other incidents that have occurred in various parts of the country and attracted the attention of society and the media. For instance, in the year 2000, about 100 wild peacocks died in Madhya Pradesh due to consumption of endosulfan-treated bajra seeds. Similarly, a large number of such cases were also reported in Rajasthan and Punjab. In 2005, some parts of North Karnataka also reported unusual deaths of peacocks after the consumption of seeds treated with pesticides (DH, 2005).

Pesticides are necessarily poisons and hence have adverse effects on any organism having physiological functions similar to the target organisms. Some pesticides have greater detrimental effects on non-target organisms than on target organisms. With the present pesticide use pattern, the sustenance of non-target organisms, i.e., beneficial organisms, natural enemies of pests, parasites, pollinators etc., is greatly jeopardized. Pesticide runoffs that reach water bodies kill fish, water bugs, snails and aquatic plants, which are part of the food web and play an important role in maintaining the eco-balance. Overuse of pesticides has brought about significant decline in the bio-diversity of non-target organisms in the study area.

About 70 per cent of the respondents report significant decline in populations of beneficial organisms. According to them, populations of natural enemies of pests like ladybird beetles, green lacewings, spiders and parasitoids, like *Apanteles* spp., *Trichogramma* spp., *Chelonus blackburni* etc., have come down drastically in the last few years. A large number of respondents also reveal that significant decline in populations of birds and earthworms are seen in fields treated with pesticides. When outbreaks of secondary pests occur in the absence of natural enemies, additional and sometimes more expensive pesticides have to be used in order to sustain crop yields. As a result of this, the overall cost of cultivation increases. Major concerns among small and marginal farmers are the declining populations of beneficial organisms, and natural enemies of pests, and also the increased expenditure on synthetic pesticides. However, it is difficult to fix a price tag on the loss of natural enemies and beneficial organisms and to estimate the overall economic loss in agricultural production. In the United States, estimated $ 520 million as costs of additional pesticide application and increased crop loss, both of which follow the destruction of natural enemies by pesticides applied to crops (Evans, 1993).

Development of Resistance

One of the most important pesticide-induced problems in the study areas is the development of resistance by insect pests. The use of pesticides creates a selection pressure on the population. It kills some of the susceptible pests within the population, and those that are not killed are resistant to varying extents. These resistant pests may have developed certain genetic properties such as less permeable cuticles, faster storage of toxin in fat or better enzyme systems for metabolising the toxin (Anon, 1984).

When the competition from susceptible individuals is eliminated due to pesticide application, the survivor population multiplies rapidly and passes on these properties to their offspring, which continue to develop further resistance against that particular chemical. Repeated reproduction of these pests finally gives rise to pest populations containing high proportions of resistant individuals. The phenomenon of resistance development is greater with pests that have shorter life cycles (Agnihotri *et al.*, 1999). Another problem associated with the use of insecticides over a long period of time is the development of cross-resistance in insect pests. It is generally observed that when an insect develops resistance to a particular insecticide, it automatically becomes resistant to all other pesticides that have the same target or activity. Insect pests also become resistant to different groups of insecticides, which is termed multiple resistance. Frequent applications of insecticides in higher or sub-optimal doses may also lead to resistance. In India, pesticide resistance in agriculture was first noticed in 1963 when a number of serious pests were reported to have become resistant to two of the most commonly used pesticides during the 1960s and 1970s, DDT and BHC. Since then, the number of pests with pesticide-resistance has increased.

In India, about 31 insect pests have already developed resistance to different pesticides (Saxena, 1996). A rapidly increasing number of species have developed resistance to the action of individual as well as groups of chemically related active ingredients (Weber 1992). Due to the dynamic responses of local ecosystems to pesticide use (and other agricultural measures), such as the build-up of resistance and the occurrence of secondary plagues, attempts to control the side effects of pesticide use seems like hitting a moving target. In this respect, Clough and Godfrey (1995) observed that: 'As methods of crop production have become more intensive, the incidence and severity of fungal diseases have increased'. The repeated use of the same pesticide over time leads to the evolutionary selection of those pest organisms that have developed resistance to a particular pesticide or family of pesticides. Accordingly, an increasing number of fungi, weeds and insects have become resistant to pesticide sprays. Indeed, some observers have noted a perverse effect of the general use of pesticides, namely that crop losses due to insect invasion have actually increased with increasing pesticide use (Dalzell, 1994). Many policy makers and some donors regard pesticides as indispensable for agriculture and continue to promote their use. Direct and indirect subsidies on pesticides encourage their application at unsustainable rates and discriminate against safer and more sustainable forms of pest management.

The problem of development of resistance by insect pests has increased in recent years. This has prompted the farmers to go in for higher doses and frequent applications of pesticides, and also resort to combinations of insecticides. Large-scale and repeated applications of pesticides over long periods in the selected districts, for the control of BPH in paddy, *Helicoverpa* in cotton and Dimond back moth (DBM) in vegetables, have led to the development of resistance in these key pests. In Guntur and Warangal districts, the excessive use of synthetic pyrethroids has resulted in the development of resistance in *Helicoverpa*. Defective spraying, over dosage coupled with spraying of spurious insecticides have aggravated the problem of pest resistance (Table 3). The problem of resistance is of great concern not only to farmers but also to pesticide manufacturers, scientists, regulatory authorities and the general public. Sequential application of pesticides from different chemical groups and also the adoption of IPM practises are the viable techniques for managing the resistance problem.

Resurgence of Insect Pests

Resurgence is again one of the most common problems faced by farmers. It is an abnormal increase of pest population, often exceeding the economic threshold level following insecticide application (Chelliah, 1979). Resurgence of pests occurs in two ways: (i) rapid resurgence of pest populations exposed to the pesticide, and (ii) minor pests or unimportant target species developing into major pests or serious pests as a result of decreased competition for food and shelter (Dudani, 1999). The phenomenon of resurgence of insect pests has brought about serious economic losses to crops like cotton and paddy in the country. The loss due to bollworm was estimated at around 50−60% in cotton, whereas loss from BPH was estimated to be 10−70% on paddy (Puri *et al*., 1999).

Continuous use of pesticides over a long period of time in the study areas has resulted in decline of natural enemies of pests, which is one of the reasons for resurgence of insect pests. For instance, the large-scale use of broad-spectrum pesticides for the suppression of cotton bollworm led to the mortality of the natural enemies of the insect pests and resulted in the resurgence of cotton bollworm in 1977, 1983, 1993 and 1997 (Dhawan, 1999). In the study areas, particularly in Andhra Pradesh, Karnataka and Chattisgarh, resurgence of Brown plant hopper (BPH) is a serious problem (Table 4). Similarly, in the cotton-growing districts of Andhra Pradesh and Punjab, resurgence of whitefly, occur after spraying of monocrotophos and dimethoate respectively. In addition, unexpected or delayed rains and other changes in climatic conditions are also identified as causes for the resurgence of insect pests. It was reported that applications of sub-lethal doses of insecticides brought about changes in the reproductive cycles of the insect pests leading to resurgence (Chelliah, 1979). The whitefly menace is a typical example of how a minor pest can attain the status of a major pest even in cardamom cropping pattern.

In accordance with the previous literature, farmers experienced a variety the signs and symptoms related to pesticide in California, USA (Soloman *et al*., 2000). This study confirms that there is an increased incidence of intentional pesticide poisoning in India. Similar high rates of intentional self-poisoning with pesticides are reported from the few other neighboring Asian countries where it has been investigated. For example, in China, suicide is the fifth most important cause of death and the majority is due to ingestion of agricultural chemicals (Phillips *et al*. 2002). Several other studies have documented that restricting the availability of toxic pesticides can reduce the total death rates from intentional poisoning (Eddleston *et al.,* 2002).

Conclusion

A regular analysis of economic, health and environmental impacts of use of pesticides is essential in the country. There is limited information available on the total quantities of pesticides used in the agricultural sector in different districts. Some issues raised in this paper, though not exhaustive, indicate the scope for further research that is needed for the detailed analysis of pesticide use, externalities and policies in India. The present study, with the available information on intentional or unintentional poisoning data, illustrates certain ambiguities in situations where people undergo lifelong exposure. Therefore, the need of the hour is to develop proper health−education packages based on knowledge, aptitude and practises, and to disseminate them within the community for minimising human exposure to pesticides.

There is urgent need for agricultural production models or policies that internalise the external costs of pesticide use and incorporate prevention of ill health and environmental contamination, and promote the conservation of biological capital into production processes and markets. A first step is to raise the awareness levels of the economic costs of pesticide use among the farming community. This requires serious efforts by decision makers, as well as pressure on governments from civil society. Alternate methods of pest control are needed if these damaging social and environmental impacts are to be reduced. Organic farming offers many opportunities. It has substantially lower negative externalities than conventional farming.

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