STUDIES ON EXPOSURE TO PESTICIDES IN KIBIRIGWI IRRIGATION SCHEME, KIRINYAGA DISTRICT.

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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DEDICATION

This thesis is dedicated to my daughter

Martha Wamaitha Kimani

AND

my late mother

Martha Wamaitha Kabugi

TABLE OF CONTENTS **PAGE**

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

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Virginia Wamuyu Kimani

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LIST OF ABBREVIATIONS

2,4,5T	2,4,,5, Trichlorophenoxy acetic acid
2,4,D	2,4, Dichlorophenoxy acetic acid
ADI	Acceptable Daily Intake
BCPC	British Crop Protection Council
BHC	Benzene hexachloride
CI	Confidence Interval
DBCP	Dibromochloropropane
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethane
DDT	Dichlorodiphenyltrichloroethane
DNOC	Dinitro- ortho cresol
EBDC	Ethylenebisdithiocarbamates
EDI	Estimated Daily Intake
EHC	Environmental Health Criteria
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
FCI	Farm Chemicals International
FIFRA	Federal Insecticide Fungicide and Rodenticide Act
FSH	Follicle Stimulating Hormone
GIFAP	Groupement International des Associations Nationales de Fabricants de Producits Agrochimiques
GLC	Gas Liquid Chromatograph

HCB	Hexachlorobenzene
HCH	Hexachlorohexane
IARC	International Agency for Research on Cancer
ICI	Imperial Chemical Industries
IDRC	International Development Research Center
ILO	International Labour Organization
IPCS	International Programme on Chemical Safety
IPM	Intergated Pest Management
LH	Leutinising Hormone
MCPA	Methylclorophenoxy acetic acid
MRL	Maximum Residue Limit
NIOH	National Institute of Occupational Health
NOAEL	No-Observable Adverse Effect Level
NRC	National Research Council
OMAF	Ontario Ministry of Agriculture
PCPB	Pest Control Products Board
TDE	Tetrachlorodiphenylethane
TDI	Theoritical Daily Intake
TEPP	Tetraethylpyrophosphate
TMRC	Total Maximum Residue Concentration
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency

STUDIES ON EXPOSURE TO PESTICIDES AT KIBIRIGWI IRRIGATION SCHEME, KIRINYAGA DISTRICT

GENERAL ABSTRACT

Studies on household and agricultural exposure to pesticides were carried out at Kibirigwi Irrigation Scheme. A questionnaire based survey investigated the practices that farmers used in handling, storage and disposal of pesticides. A sample of sixty-five farmers was selected from a total of 282 residing in the scheme. All farmers were interviewed guided by the format of a questionnaire covering data on farm size, education level, cropping practices, crop and household pesticide usage, animal husbandry, pesticide storage, handling, labelling and disposal, foods consumed and health history. It was found that pests and diseases were a major constraint to production and that 85% of the farmers used pesticides either on crops or animals.

Fifty-five pesticide formulations were used or stored including organochlorines, organophosphates, synthetic pyrethroids, dithiocarbamates and other groups. It was also found that although farmers were concerned about potential adverse health effects of pesticides they took little responsibility for handling them carefully. Farmers associated various complaints with handling and spraying pesticides, including: chest pains, coughing and sneezing, colds, swellings, itchiness, stomach upsets, eye irritations, dizziness, fatigue, diarrhoea and uneasiness.

To investigate the general level of pesticide residues in people in the irrigation scheme, 36 breastfeeding mothers residing in the scheme were sampled for milk and the milk was analysed for organochlorine and organophosphorous pesticides. A wide range of organochlorines were detected; *p'p'*DDE(100%), β-BHC(69%), γ-BHC (31%), α-BHC (25%),

heptachlor(17%), dieldrin(8%), *p'p'*DDT(8%), aldrin (8%), *o'p'*DDT(3%), and DDD(3%). Out of twenty-nine samples analysed for organophosphates, nine had peaks which were not identified.

Studies on exposure while spraying were also carried out. Thirty-nine farmers were randomly selected from the sixty-five surveyed farmers. All exposures were conducted using an organophosphorous pesticide, dimethoate, sprayed on french beans. This was the most common crop-pesticide combination in the scheme. The dimethoate used in the study was provided to the farmers. Prior to mixing and spraying, farmers were fitted with cotton garments covering hands, legs and the back. A mask covering the nose and the mouth was also provided. After spraying, all garments were collected and analysed for dimethoate and omethoate, a metabolite formed on oxidation of dimethoate. For dimethoate, the hands were the most contaminated (mean= 12.6 ug/cm^2) and the face the least (mean= 0.2 ug/cm^2). In almost all the farmers, one body part was the most contaminated; usually this was the right hand (21/39), followed by the left hand (10/39), the right leg (4/39), left leg (2/39) and the back (2/39). Omethoate was found in 25% of the samples (range 0.01-228 ug). The highest mean omethoate was on the left hand (6.41ug) followed by the right hand (2.77 ug). In addition, blood samples collected 3 days before and a day after spraying were analysed for acetycholinesterase using a pH test. There was variation in levels of acetylcholinesterase in whole blood among farmers before spraying (85-191 units) and after spraying (102-176 units). In eleven farmers the enzyme level was lower after spraying, in two cases the depression was above 20% and in one of these cases, the level was depressed by 26%. The means for the farmers (before = 138 units and after = 142 units) were significantly different from that of a control group sampled at Kabete Campus (mean = 239 units).

In a study to investigate the enzyme levels of Kibirigwi and Kabete residents, 47 persons from Kibirigwi and 15 from Kabete Campus were sampled for serum and plasma and enzyme measurements were taken. It was found that the mean enzyme in serum in pH units for Kibirigwi residents (106.05, s.e=3.27) was significantly lower than that of Kabete Campus residents (124.1, s.e = 6.32) and for plasma, they were 91.234.(s.e. = 2.48) units and 109.86 (s.e.= 5.77) units for Kibirigwi and Kabete residents respectively.

Dimethoate exposure during weeding of bean crops was assessed using a sub-sample of five randomly selected farmers. Each of these farmers was advised on the date to spray his beans with dimethoate. Four and ten days after spraying, each farmer was fitted with cotton garments on the hands and legs and he reentered his field to weed for five minutes. Then the garments were collected and taken to the laboratory for analysis. It was found that the cotton garments contained a mean of 0.02 ug dimethoate\patch and 0.01ug omethoate\patch. The right hand contained the most dimethoate followed by the left leg while left leg contained the most omethoate followed by the left hand.

The forty farmers used in the spraying study were further recruited into a study to assess for exposure during harvesting on re-entering sprayed fields. In this study, farmers were asked to spray a synthetic pyrethroid, 5% cypermethrin. It had been established earlier that farmers were advised by extension staff to spray dimethoate on beans from germination to flowering stage after which they switch to the cypermethrin. Harvesting was done on two different days: on the third or fourth day and on the eleventh or twelveth day. Before the start of harvesting, each farmer was again fitted with armsleeves on each arm and leggings for each leg. Each farmer would then harvest for five minutes and the garments were removed and taken to the laboratory for analysis. It was found that the garments contained residues of dimethoate, omethoate and cypermethrin. The mean levels were 0.19 ug/patch and 0.20 ug/patch for dimethoate and omethoate respectively. Mean levels of cypermethrin were 8.9 ug/patch.

Bean samples obtained during the harvesting study were analysed for dimethoate, omethoate and cypermethrin. Mean residues detected were 0.17 ppm, 0.02 ppm and 2.09 ppm for dimethoate, omethoate and cypermethrin respectively.

A study was carried out to investigate whether homes in the scheme are generally contaminated with pesticides. In each of forty randomly selected homes in the scheme, a table that is commonly used for meals was swabbed with a cheese cloth measuring 30 cm by 30 cm dipped in methanol. The clothes were extracted and analysed for a wide range of organophosphorous and synthetic pyrethroids. Twenty-three samples contained organophosphate pesticides. The range was 0.01-8.72 ug/cm^2 of table area. These were diazinon (5/40), dimethoate (4/40), malathion (9/40), chloropyrifos (4/40), fenitrothion (1/40) Among the synthetic pyrethroids, cypermethrin was detected(9/40). The range was $2.4*10^{-6}$-$5.82*10^{-3}$ ug/cm^2 table area.

It was concluded that small scale farmers in Kibirigwi who routinely use pesticides receive substantial exposures to pesticides due to mishandling and poor storage of pesticides around the home. Exposures also occur during farm work such as mixing and spraying pesticides as well as weeding and harvesting crops that are sprayed with pesticides. Farmers may also be experiencing adverse health effects for which epidemiological investigations should be carried out in order to quantify the extent to which they occur.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

Pesticides have been widely used in controlling pests and diseases in agriculture, forestry, veterinary and public health. They also play a major role in maintaining weed-free lawns, sportsgrounds and in clearing roadsides. Pest- induced losses due to plant diseases, arthropod and vertebrate pests as well as weed infestations were estimated to be as high as 30-35% in the field (FAO, 1983). Post harvest losses were estimated at 40-50%. It was estimated that without pesticides, world losses caused by pests in agriculture are in the order of US$ 75,000 million annually or about 35% of potential production (Cramer, 1967).

Pesticides have played a major role in reducing deaths due to insect-borne and tick-borne diseases of man such as malaria, trypanosomiasis, typhoid, yellow fever, tick fever and others. For example, after the discovery of DDT, malaria was eradicated for some 619 million people who lived in malarious areas (Hayes, 1991) and in India, the number of malaria cases dropped from 100 million between 1933-1935 and 150,000 in 1966 (WHO, 1968). Vector-borne diseases of livestock have also been controlled.

Despite their beneficial effects, pesticides can be detrimental to humans. Misuse, mishandling and failure to use protective clothing while handling them may lead to exposure and poisoning. Hazards due to occupational exposure were reported in a group of railroad workers who sprayed herbicides (Donna **et al**., 1984) and in a population of workers packing pesticides in Egypt

(El- Ghazali **et al**., 1990).

Pesticides have been shown to cause many adverse effects in exposed individuals. In a case control study of workers exposed to herbicides in agriculture and forestry between 1950 and mid-1970s, cases had a 5.3 times increased risk for soft-tissue sarcoma (Burmeister, 1981). In another study, the effect of pesticides on a flower growing population in Colombia was assessed by Restrepo **et al**., (1990). They found that there was an increase in abortions, premature birth and congenital malformations for pregnancies occurring after the mothers began floriculture. Exposure to the nematocide dibromochloropropane (DBCP) caused suppression of spermatogenesis and increased production of follicle stimulating hormone (FSH) and leutinising hormone(LH) (Whorton **et al**, 1977).

The difficulty in assessing the balance between the beneficial and detrimental effects of pesticides has led to what is termed as the "pesticide dilemma" (McEwen and Stephenson, 1979). Clearly, the balance can be shifted by minimizing the adverse effects through safe usage and maximizing the benefits by better and more efficient application methods.

Worldwide, it is estimated that pesticide trade is worth $25 billion (FCI, 1994). There are about 600 active ingredients which have been formulated to over 3000 formulations. This number has remained constant over the last twenty years or so (Hayes,1991). Many of these pesticides are used in Kenya. According to the Pest Control Products Board (1993b), an average of 6000 tonne are imported into Kenya annually. The 1992 estimates show that pesticides worth one billion Kenya Shillings were imported into Kenya. Ninety-five percent of all pesticides imported were used locally and only 5% percent were exported (PCPB, 1993).

Pesticides are a common cause of death in Kenya. Records available from the Government

Chemist Department indicate that fatal cases resulting from pesticide poisoning have been increasing in the last two decades. In 1973, there were fifty-seven cases compared to one hundred and one in 1991 (Maitai, 1994). In three major hospitals in Kenya an average of two cases of poisoning were treated every week in 1985 (Obel, 1985). These cases are likely to be only a small proportion of all known cases. Furthermore, many cases of morbidity go unreported. Information is lacking on actual pesticides handling practices that may explain how exposure occurs. The few studies carried out suggest that a problem exists. In a study by Mwanthi and Kimani (1989), it was shown that in Kiambu District, farmers regularly used pesticides and frequently mishandled them. These findings were confirmed by Karembu (1990). Actual exposures have, however, not been quantified. Obel (1983) attributed many cases of pesticide poisoning to occupational exposure in agriculture. He did not quantify the actual rates of exposure.

Studies are therefore required to investigate and quantify the extent and amount of pesticide exposure among farmers and rural people in Kenya. When combined with data on usage and handling practices, such information would assist in identifying how exposure occurs in the field and around the home. This would help extension workers to advise farmers on better pesticide handling procedures to reduce the risk of the adverse effects of pesticides.

1.2 OBJECTIVES

Given previous reports on mishandling of pesticides in Kenya, this study was therefore designed to document pesticide usage practices and to investigate the routes and levels of pesticide contamination to farmers routinely using pesticides. Since the Kibirigwi Irrigation Scheme is typical of other small-holder intensively- farmed areas of Kenya, it was chosen as the study site with the following objectives:

1. To catalogue pesticides used (types and uses), handling procedures (storage, safety precautions, container and pesticide disposal) and agricultural practices used.
2. To collect information on the health status of people in the scheme.
3. To identify and quantify the levels of organochlorines and organophosphates in mothers milk of mothers residing in the Scheme.
4. To investigate whether kitchen tables in households in the scheme are contaminated with pesticides.
5. To investigate whether farmers are exposed to dimethoate and its oxygen analogue during mixing and spraying the pesticide.
6. To find out whether there is depression in the level of acetylcholinesterase in the farmers after spraying dimethoate, an acetylcholinesterase inhibitor.
7. To investigate whether farmers are exposed to dimethoate, omethoate and cypermethrin during weeding and harvesting french beans in treated fields.
8. To identify and quantify the levels of dimethoate, omethoate and cypermethrin in beans harvested

during the harvesting study above.

This information is required to facilitate extension workers in advising farmers on better pesticide handling procedures. Poor handling procedures predispose farmers and their family members to contamination and exposure to pesticides. Therefore, advice on handling and storage around the home would help to reduce the risk of poisoning around the home. The information obtained from the spraying exposure study will be useful in pinpointing which practices lead to exposure during spraying and which body parts are more at risk of contamination. In Kenya, there are no set times to be observed by agricultural workers before entering pesticide sprayed fields. The results of the reentry study will be useful in setting Kenyan reentry intervals for dimethoate, omethoate and synthetic pyrethroids as well as setting pre-harvest intervals for these pesticides on beans.

1.3 LITERATURE REVIEW

1.3.1 Global Usage of Pesticides

From ancient times man has competed with other species of animals and plants for the available resources. In practising agriculture, crop yields have often been diminished due to insects and rodent damage, plant disease and weed competition. In addition, man has been a host for a variety of disease-causing organisms vectored by pests. Thus, through the ages there has been great interest in compounds and methods to control or eliminate pests and diseases. As early as 1500B.C., preparations against lice, fleas and wasps were used (Byran, 1931). Around the eighth century B.C, Homer composed a poem about the "rinsing" of a cup with sulphur.

Systematic studies on the use of chemicals to control pests, however, date back to the mid-nineteenth century. One of the most notable of these was Prevosts' classical experiments in 1807 in which he demonstrated the fungistatic effect of copper sulphate (Sheets and Pimental, 1979) and in 1882, a mixture of copper sulphate and lime was discovered to be effective in controlling downy mildew of grapes (Millardet, 1885).

The modern chemical pesticide revolution began with the discovery of DDT and the herbicide 2,4-dinitro-chlorophenoxy acetic acid (2,4-D) in the 1940s (Ramulu, 1979). After this, many insecticides, fungicides and herbicides were synthesized. The Pesticide Manual (Worthing and Walker, 1987) has about 584 entries. These are the pesticides in current world usage. The Pesticide Index, however, has about 1500 entries since it includes even those pesticides not being manufactured (Weisweiser, 1976). In total, there are approximately 600 active ingredients, with about 3000 different formulations available for purchase (Hayes, 1991). This number has remained relatively constant for the last twenty years. Since the 1980's pesticides have been produced by genetic engineering. Also in plant breeding, specific pest resistance is being incorporated into new varieties of crops and domestic animals (Stephenson **et al.**, 1993). The emergence of transgenic plants, for example, is expected to play a wider role in the future of crop protection and especially in reducing the need for high applications of pesticides and therefore will also help in environmental conservation (Caulder, 1994).

World production of pesticides has increased considerably in recent years. In 1992, it was estimated that world pesticide usage stood at 5 million tonnes (Albert **et al.**, 1992) worth about $16.3 billion (US) compared to US$ 10-12 billion in 1980 (FCI, 1994). This trend is expected to continue. The world population is projected at 6 billion by the year 2000. World food production must also increase proportionately to cater for the increased demand for food, energy and fibre. Since good land is already in use, there must be significant gains in average yields. The use of pesticides is expected to continue to make a major contribution to this need (FCI, 1994).

1.3.2 Pesticide usage in Kenya.

Chemical pesticides have been recommended as pest control agents for many years in Kenya. As far back as 1908, carbon disulphide was used as a preservative to store maize grain (Anonymous, 1909). At that time, Paris Green was also in use for control of cutworms on wheat and tomatoes. Various insecticidal mixtures were tried in 1933 in coffee and LePelley (1933) reported that a pyrethrum-kerosene extract was found superior in control of antestia bugs.

For the control of dodder, a noxious parasitic weed, Nattrass (1941) recommended a mixture of sulphuric acid, iron sulphate or copper sulphate. In 1944, Harris published a list of "recipes" to be used for control of insect pests. Most of these contained arsenic and a few of them were pyrethrum based. Various copper compounds were already in the market in the 1940s (Nattrass, 1944) and were being used for the control of potato blight and other fungal diseases. At around the same time, DDT and Lindane were received enthusiastically for control of field and household pests. A disquieting voice was, however, sounded by V.A. Beckley who described the two pesticides as "tommy guns with faulty mechanisms-easy to start but difficult to stop" (Agricultural Department, Kenya Colony, 1945).

The auxin herbicides were already in Kenya by 1947 and both 2,4-dichlorophenoxy acetic acid (2,4-D) and methylchlorophenoxy acetic acid (MCPA) were tested in 1947 at the Scott Agricultural Laboratories (Agricultural Department, 1949). They were reported to be effective, selective herbicides. Organophosphate insecticides were introduced by 1960 and by 1967 a wide range of both organochlorines and organophosphates were in use (Anonymous, 1967).

One of the highlights in the history of pesticide usage in Kenya was the appointment of a committee that was charged with the responsibility of investigating the "toxic chemicals that were being used in agriculture" in 1952 (LePelley, 1952). The focus was on parathion and tetraethylpyrophosphate(TEPP), which were being used as insecticides in a wide variety of crops. A problem arose in Molo area of Nakuru District where there was a serious problem of wheat aphids. Pesticide poisoning was reported and there were casualties supposedly due to lack of skill in handling the products. Three out of nine people who sprayed were admitted to hospital (LePelley, 1952). In another incident, the use of dinitro-ortho cresol (DNOC) resulted in casualties requiring hospital treatment when the pesticide was used in dusting against locusts (LePelley, 1952).

At the time, the usage and handling of pesticides was controlled by the Voluntary

Precautions Scheme (LePelley, 1952). In this scheme, the obligation to handle pesticides safely was placed on the employer and was voluntary. It was found that this system did not protect the worker and it was therefore agreed that legislation was needed on the use of pesticides. Thus, the Control of Pesticides Act was enacted and was valid for all countries within the East African Community. After the break of the Community in 1977, a Pest Control Products Act was drafted and finally enacted in 1982 (Pest Control Products Act, 1982). To administer the act, the Pest Control Products Board was launched in 1983 and started its operations in 1984 (Ministry of Agriculture, 1986). This Board is charged with the responsibility of regulating all aspects of pesticide usage in Kenya today.

Statistics are lacking on the usage of pesticides before the formation of the Pest Control Products Board in 1984. Records available since then indicate that importations increased gradually from 7000 tonnes imported in 1984 (PCPB, 1986) to reach a peak in 1987 at 10,371 tonnes. From then on there has been a decline in tonnage to the lowest level of 3533 tonnes in 1993. The total figure for 1994 is unavailable but there has been a slight upward trend (Mutai, 1996). This decline in tonnage is due to decreased usage of copper based pesticides which were widely used in coffee in the 1980s but are not used due to the decline in the coffee industry. In addition many currently used pesticides are effective at low concentrations. Therefore, the decline in tonnage suggests an increase in the use of active ingredients which are effective at low concentrations and not a decline in total usage.

Today, all classes of pesticides are being imported into the country. These include organophosphates, carbamates, synthetic pyrethroids and organochlorines as well as various classes of fungicides, nematocides and rodenticides. However, there are 16 pesticides which are either banned or restricted (PCPB, 1986). DDT, aldrin and dieldrin are restricted to non-agricultural uses.

Lindane is recommended only as a seed dress. A group of organochlorines are banned; heptachlor, chlordane, endrin, chlordimeform and 5 isomers of hexachlorocyclohexane. Other classes of pesticides that are banned include dibromochloropropane, ethylene dibromide, and the phenoxy herbicide, 2,4,5,trichlorophenoxy acetic acid. The fungicide captafol was banned due to reports of possible carcinogenicity. The plant growth regulator Alar, and the miticide, cyhexatin were also banned recently (PCPB, 1993a). In all there are about 200 fully registered pesticides and a further 200 applications that are pending registration.

1.3.3 The Benefits of Pesticides.

The benefits of pesticides to humankind are well known. In agriculture, for example, it was estimated that without pesticides, world losses caused by pests are in the order of US$ 75,000 million annually or about 35% of potential production (Cramer, 1967). Towards this loss, insects contribute 13.8%, fungi,11.6%, weeds,9.5% and other pests 0.1%. These figures compare to later ones by the FAO/WHO (1983). According to the latter, field losses were estimated at 30-35% and postharvest losses up to 50%. Pesticides have been widely accepted as an essential input in curtailing these losses (Reynolds, 1985).

In addition to preventing loss in yield, pesticides assure the producer of high quality goods. Insect infested fruits, vegetables and root crops fetch low prices in the market.

In general, the use of pesticides is thought to reduce food prices. For example, a study commissioned in the United States to assess the importance of pesticides and fertilizers, estimated that if chemical use was stopped, the increase in the annual food budget for the U.S family would be US $428 (Stephenson **et al.**, 1993).

It is argued that pesticide use permits stability in food production. Carlson (1979) asserts that they do so in three ways: the increased storage life of foods, enhanced global trade in food between regions by reducing pest transfer and increased possibility of using substitute food crops from other areas for emergency food relief.

On cash crops, pesticides play a major role in controlling pests and diseases and allow producers to secure markets for their produce. The use of orthodifolatan, for example, a fungicide previously used extensively in the control of coffee berry disease allowed Kenya to be a major coffee exporter in the 1970s and 80s (Mukunya, 1989).

Pesticides are important in the maintenance of forests. Outbreaks of pests and diseases on forest trees in the past have been controlled with pesticides. In the 1950s, DDT was used to control the spruce budworm in North American forests (Stephenson **et al**., 1993). Also, in the last century, a fungal disease of American chestnut trees was controlled with fungicides. Likewise, in Kenya, the cypress aphid was partially controlled by spraying with systemic insecticides (Njeru, 1993).

The protection of wood and wood products against attack from bacterial, fungal and insect agents has been practised for centuries. Wood preservatives are needed to ensure longterm wood preservation for structural purposes and the short-term protection of wood during shipping and storage (Stephenson **et al**., 1993).

Another area in which pesticides have had a major impact is in public health. Vector-borne diseases of man have been a major problem for centuries with diseases such as malaria having a great impact on mankind throughout history. Malaria was thought to have killed Alexander the Great in 32 B.C. and many early popes are also said to have died from malaria. In addition, Charles

Darwin suffered from Chagas disease, a form of trypanosomiasis, carried by blood sucking bugs (Stephenson **et al**., 1993). The control of vector-borne diseases since the introduction of organochlorine pesticides has been summarized by Hayes (1991). Initially, organochlorine pesticides, principally DDT were used extensively to control malaria and more than 20 other human diseases. Because of the persistence of DDT and other organochlorine pesticides, they have been largely replaced by organophosphorous compounds, synthetic pyrethroids and carbamates in vector control.

In domestic animals, pesticides are essential in controlling ticks and other insects that are vectors of various diseases such as East Coast Fever, heartwater, redwater, trypanosomiasis and others. In the tropics, parasitic tick-borne diseases are an obstacle in the development of profitable livestock industry (Lee, 1978). In companion animals, the use of pesticides is also aesthetic, to reduce external parasite burdens especially fleas and ticks (Oehme, 1991) as well as the control of internal parasites some of which infect both man and animals.

There are a number of other uses of pesticides. In developed countries, herbicides are widely used in clearing lawns, sportsgrounds and roadsides (Stephenson **et al**, 1993). Pesticides are also used in the treatment of leather and textiles (particularly wool) to prevent attack by fungi and insects in some parts of the world.

1.3.4 Problems associated with pesticide usage

General Problems

Despite their benefits, the use of pesticides has been associated with a number of problems. After the discovery of the synthetic organic pesticides and especially the manufacture of DDT in the 1940s, there was a shift in insect control techniques with emphasis on the use of chemicals. Sanitation, mechanical and biological control methods were essentially abandoned in favour of chemical pesticides (Perkins, 1982). Due to the heavy and repeated usage of insecticides, secondary pest problems developed. Insects such as bollworms in cotton and rollers on apples and peaches increased as their insect predators such as bollweevils on cotton, and codling moths on apples were eliminated by insecticides (Horn, 1988). Thus in some cases, all insecticides did was to shift the major and minor pest species.

Pesticides are often disruptive to trophic relationships between species in an ecosystem. A loss of balance may result and can lead to a change in behaviour. Migration may result causing introductions of pests in areas not previously infested (Horn, 1988).

One of the best recognised negative effects of the use of pesticides is the development of pesticide resistant strains of a pest. An early case of resistance was reported in 1908 (Melander,1914) when lime sulphur failed to control the San Jose scale on Washington State apples in the United States. Since then, more than 500 species of arthropod pests are known to have evolved resistant strains to one or more pesticides (Georghiou and Saito, 1983). Furthermore, there are many reported cases of plant pathogen resistance to fungicides. Fungicides to which important resistance has developed include benzimidazoles, dicarboximides, pyrimidines and organotins (Delp, 1981).

The accumulation of pesticides in the global ecosystem and their effect on species of birds and fish caused a major problem in many parts of North America in the 50s and 60s and was brought to public attention by Rachel Carson (1962) in her book "Silent Spring". One example was the effect of accumulated DDT on populations of the Antlantic salmon in the 1950s (Elson, 1967). DDT was persistently used to control spruce budworm in Canadian forests. As DDT accumulated in rivers, it reduced the supply of insects eaten by fish which resulted in fewer and smaller fish in affected streams. Given the persistence of organochlorines, such problems are still being recorded.

A major effect of persistent chemicals is their biomagnification and thus major effect on animals high on the food chain. For example, the treatment of Clear Lake in California with TDE (tetrachlorodiphenylethane) for gnat control resulted in biological magnification of the pesticide; the plankton had 10 ppm, the fat of plankton eating fish 903 ppm, the fat of fish eating fish 2,690 ppm and the fat of fish eating birds 2,134 ppm. The decline in the numbers of fish eating birds such as osprey and the pelican was attributed to this biomagnification (Herman **et al.**, 1969). Effects such as egg-shell thinning and resultant decreased hatching for falcons and other fish eating birds have been attributed to pesticides in a number of places (Cooke, 1973).

The use of pesticides in the control of pests on crops and animals can lead to residues in foods. These were reported as far back as the 1940 when DDT was found in apples (Harman,1946). Today, for many crops, maximum residue levels (MRLs) have been calculated to ensure food safety. Based on the no-observed adverse effect level(NOAEL) in the most sensitive animal species, MRLs are calculated as follows (Stephenson **et al**. (1993): An Acceptable Daily Intake(ADI) is calculated by dividing the NOAEL with a factor considered to be the margin of safety, usually 100. This is based on the convention that humans are 10 times more sensitive than the most sensitive animal and some humans may be 10 times more sensitive than the least sensitive humans. The next stage is to propose an MRL. This is usually done by the manufacturer and it can be for a variety of crops. Based on this, the Theoretical Daily Intake (TDI) can be calculated for each crop for the amount of that crop that can be consumed in a day. This is also done for worst case scenarios, for example, infants.

The total TDIs added together gives the Total Maximum Residue Concentration (TMRC) given in mg/person/day. It is then assumed that if the worst case is considered in which 5 times the expected amount of food is eaten, then the highest TMRC is calculated by multiplying by 5. The total TMRC must be less than ADI. If the MRL chosen leads to such a TMRC, then the former can be accepted. To assist growers to meet the MRL at harvest, labels should direct growers to comply with all usage instructions particularly, the stage of application and the pre-harvest interval. Standards have been set in this way, by many countries(e.g. Food and Drug Act, Canada). Otherwise, the FAO/WHO Committee on Pesticide Residues in Food has established guidelines which may be adapted by countries without their own standards (FAO/WHO, 1993).

The inherent toxicity of pesticides is also a major concern. Many are non-selective, affecting both target and non-target crops and animals. The short-residual organophosphates and carbamates are highly to moderately toxic and are therefore generally hazardous in small amounts. According to the WHO "Classification of Pesticides by Hazard", a large number of organophosphates are classified as extremely, highly or moderately hazardous (Copplestone, 1982) with oral LD_{50} s ranging from less than 5 mg/kg to 50 mg/kg. In comparison, most of the organochlorines are moderately hazardous or less. Due to their higher inherent toxicity, many acute poisonings have been attributed to organophosphates. For example, in a list of 94 outbreaks of pesticide poisoning reported between 1933 and 1986 (compiled by Levine,1991), 33 were attributed to organophosphates compared to 23 due to organochlorines.

Due to the risk associated with pesticides, care is needed while handling them. Protective devices and clothing are needed during all stages of pesticide handling from manufacture, through application to safe disposal. Failure to take adequate precaution has resulted in poisonings among both farmers (LePelley, 1952) and manufacturing workers (Whorton **et al**., 1977).

Pesticides are an expensive input in both crop and animal production. A major reason is the high cost of development of new compounds and the need for rigorous testing to satisfy regulators of their safety for all users. Recently, the cost of developing a pesticide has been estimated at $20-30 million (Garbett, 1984) as compared to $1.2million in earlier years (Field, 1964). These costs are for pesticides that reach registration stage. Smaller but substantial amounts are spent on the large number of compounds that do not reach this stage (Hayes, 1991). These costs are incorporated into the wholesale and retail cost of marketed pesticides.

Health effects of pesticides

It is widely accepted that pesticides can be detrimental to human health. These effects have been classified into three categories. Acute effects develop promptly and may resolve rapidly or cause death (Morgan, 1980). Sub-acute effects last longer and with continued exposure may develop acute responses. Their effects may also cause chronic disease over time. There are inapparent effects associated with accumulation of pesticides in living organisms.

Acute Poisoning

Estimates of the total number of fatal poisoning from pesticides are imprecise and controversial. In 1973, WHO estimated that there were 5,000 deaths worldwide annually. This estimate was for accidental exposures calculated from a mathematical model based on data for 19 countries. Copplestone (1977) estimated 20,640 deaths occur annually based on case reports from countries in 1974. Bull (1982) estimated fewer deaths and more cases. Based on worldwide pesticide production, case fatality rate and yearly growth in pesticide usage between 1972-1982, he estimated 13,800 deaths per year in 1982. Later figures by WHO (1986) estimated 20,000 deaths annually. In the same year, the importance of pesticides as suicidal agents was highlighted by Jeyarantnam (1985) who estimated that 1.9 million cases and 200,000 deaths could be attributed to intentional poisoning alone. This put world fatality estimates at 220,000. The main problem in assessing the importance of pesticides as a mortal agent is the lack of records. For example, all estimates presented above are based on mathematical models developed from any available survey or case series data. These data are often unevenly distributed over time and are of uneven quality and space (Levine, 1991). Initially, arsenic and mercury compounds were the major pesticides responsible for pesticide mortality (Levine, 1991). Data available from the United States, for example, indicate that arsenic was the major cause of pesticide related deaths in the late fifties and early sixties (Cann, 1963). In contrast, from a study carried out over a six year period (1979-1984), of accidental mortalities attributable to pesticides, organophosphate pesticides accounted for the most number (49/167=29.3%) (Stanely **et al.**,1986). Another study by Litovitz and Veltri (1985) confirmed this pattern. The case fatality rate for organophosphates was 13% compared with 9% for all other classes of pesticides. However, in one WHO (1986) study of countries that report pesticide poisoning incidence under the four digit code (E863), herbicides mainly were found to be a more common cause of pesticide related death.

Levine (1991) has compiled a summary of pesticide poisoning outbreaks from 1933 to 1986. 24,895 cases and 94 outbreaks were included. There were 1,031 deaths for a case fatality rate of

4.1%. These cases do not include the estimated 60,000 cases and 2,500-5,000 deaths from the Bhopal disaster in India (Bucher, 1987). The toxicant at Bhopal was a chemical used in the production of carbamate pesticides. Among the 94 outbreaks , 42 were related to contamination of food or water by pesticide formulations. Occupational exposure was the next most common accounting for 28 outbreaks.

Of occupational exposures, crop worker poisoning has been identified as the most common type of acute poisoning. Between 1973 and 1975, 2974 cases of poisoning occurred in California. Out of this number, 3 died and the poisoning was attributed to exposure while working with sprayed crops (Maddy, 1976). Parathion poisoning of crop workers was recorded in Brazil, where there were 96 cases of parathion poisoning and 13 deaths in one year (Levine, 1992), and in Mexico in 1964-65 mortality of workers who were directly exposed was 0.8-2.9% and in the general population, the mortality rate was 100-380 per million (Almeida, 1966). Some less toxic pesticides have been reported to cause acute poisoning but no deaths. For example, 118 people were poisoned with ethylene dibromide in the United States but none died (Peoples **et al**, 1978).

In Kenya, acute poisoning from pesticides is considered a common occurrence. In 1952, three out of nine people who sprayed parathion on wheat in Molo in Nakuru district were hospitalised (LePelley, 1952). The details of this incident, however, could not be traced. In 1981, 221 cases of poisoning were treated at Kenyatta Hospital, 13 of whom died. In three major hospitals in Nairobi, an average of 2 cases of pesticide poisoning were treated every week in 1985 (Obel, 1985). Data available from the Government Chemist Department from 1973 to 1991 (Maitai, 1994) show that an average of 69 Kenyans died from pesticide poisoning per year during this period (data for 1983 was unavailable). A three year retrospective study (1991-1993) on poisoning in Kenya in

19 hospitals has recently been carried out (Guantai **et al**., 1994). 1963 cases of poisoning were identified. Among these, 687 were caused by pesticides (35%). 119 of these cases died (case fatality rate of 6.1%) and the fate of 129 others was unknown. As a class, pesticides were identified as the most important cause of poisoning compared to drugs and household agents. The study noted that more than 40% of the pesticide poisoning cases were accidental and involved persons between the ages 21-50 years. In a study that appears to confirm the findings of Guantai and coworkers, Mbakaya **et al**. (1994) investigated the incidence of poisoning in twenty hospitals in Kenya between 1989 and 1990. They reported 455 cases that were due to organophosphate pesticides.

The situation is similar in other African countries. In South Africa, a study conducted on acute poisoning cases in Johannnesburg hospital indicated that pesticides were second only to drugs as a cause of poisoning (Kallenbach, **et al**., 1981). Organophosphates and organochlorines were the main pesticide classes identified. In another study on childhood poisoning in South Africa in 1987, 7/1116 cases were attributed to pesticides among outpatients and 12/263 among inpatients (Roberts **et al**., 1990). However, the classification of poison category was vague and many agents were classified as unknown or miscellaneous.

In Zimbabwe, pesticides were recorded as the major cause of mortality among poisoning cases reported over a ten year period (1980-1989) (Kasilo, 1991). 8% of the cases that ended in death were due to pesticides, 2.4% due to traditional medicines, and 2.1% due to therapeutics. 942 admissions were due to insecticides, 10.3% of these were attributed to organophosphates. Carbamates, organochlorines and warfarin were responsible for the rest.

In Tanzania, 741 cases of pesticide poisoning were reported from a retrospective study carried out by Mbakaya **et al**., (1994) covering the years 1989 to 1990. The details were not reported. In addition to mortality, there are other pesticide effects referred to as acute including reactions from foul odours, solvents and dusts which do not constitute a big risk (Morgan, 1980).

Some pesticides may also produce severe shortlived skin irritations which at times may be so severe that they cause disability (Morgan, 1980).

Sub-acute effects of pesticides

The magnitude of the problem of sub-acute effects of pesticides is difficult to quantify. Furthermore, to a large extent it depends on the breadth of disease classification. Early figures by the WHO (1973) estimated that there were 500,000 cases of subacute poisoning per year. Recently, however, the role of pesticides in sub-acute illness has been highlighted and reevaluated (UNEP\WHO, 1989). Current estimates have been revised upwards to 2 million cases a year (Levine, 1992). Jeyarantaram (1985) argued that at least 1.9 million cases can be attributed to incidental poisoning alone. In addition, skin related illness has been estimated to be responsible for not less than 750,000 cases per year (UNEP/WHO, 1989). Sub-acute adverse effects of pesticides were summarised by Morgan (1980).

Several epidemiological studies have described associations between exposure to pesticides and sub-acute illness. One of the best, demonstrated the association between occupational exposure to dibromochloropropane (DPCP) and male sterility (Whorton **et al**., 1977). The major effects of azoospermia and oligospermia were seen in 14/25 non-vasectomized men. Reproductive disorders plus nervous system effects were also seen in workers in Virginia, U.S. A. in a factory that manufactured chlorodecone (Kepone')(Cohn **et al**., 1978). Similar effects were observed in workers manufacturing leptophos indicating the neurologic effects of the latter pesticide (Abon Donia and Pressing, 1976).

Hypertension and related heart disorders have been associated with organochlorine exposure (Morgan, 1980). In studies on the effect of pesticides on liver, a variety of effects have been observed. Liver microsomal changes were attributed to DDT and dieldrin (IARC Monograph, 1973).

Exposure to sub-lethal levels of organophosphorous and carbamates pesticides results in a lowering of serum and red blood cell cholinesterase levels (Morgan, 1980). In addition, Levin (1976) has reported that similar exposure could cause increased levels of anxiety particularly for workers who used organophosphorous pesticides on a daily basis.

Skin related diseases have been described as one of the most important sub-acute effects of pesticides (UNEP/WHO, 1989). In the United States for example, of the 4,200 illnesses reported in agriculture in 1980, 2,800 were skin related. Most of these resulted from chemical exposures (Galli and Marinovich, 1987)). Pesticides may affect the skin as direct irritants while some cause allergic responses in sensitized subjects. For example, pyrimidilium herbicides are delayed skin irritants and methyl bromide produce gross blisters on skin (Stephenson **et al.**, 1993). There are various types of allergic dermatitis due to pesticides. Allergic dermatitis has been observed on exposure to phenoxy herbicides and anilides. Contact allergic dermatitis has been observed with a number of pesticides: benomyl, lindane, malathion, simazine, trifonate and zineb. The third type of allergic dermatitis is provoked by sunlight and referred to as photo-allergic dermatitis. Compounds that have been implicated in this are atrazine, benomyl, thiram and zineb (Stephenson **et al.**, 1993).

One of the issues in assessing pesticide effects on health is their role as carcinogens. Many widely used pesticides have been shown to be carcinogenic on the basis of animal testing or in short term in vitro mutagenicity testing (Davis, undated). The problem with observational studies of pesticides in cancer causation is the multiplicity of pesticide exposures, changes in pesticide use patterns, a rapid turnover of work subjects and the long latency of cancer. Despite these difficulties, a large number of case reports, cross sectional studies, case control and cohort studies have been carried out (Davis, undated).

Observational studies on insecticides were carried out by Wang and Grifferman (1981) and Wang and MacMahon (1979). In the 1981 study, there was no significant difference in mortality between observed (12) and expected (9) cancer deaths on exposure to chlordane and heptachlor. In another study, however, Ditraglia **et al**. (1981) reported that there was a slight excess of cancer in one site used in a study on occupational exposure in the manufacture of organochlorines. In what appears to be a case of causal association, the length of arsenic exposure was related to lung cancer incidence (Mabuchi **et al**., 1980). Studies on herbicides indicate a limited carcinogenic risk of phenoxy-acetic acid and chlorophenol herbicides with soft tissue sarcoma. The first indication that herbicides might be associated with increased risk of soft tissue sarcoma was described by Hardell (1977) who discovered that five out of seven patients with tumours were workers with confirmed exposure to phenoxy-acids. Cook (1981) and Moses and Selikoff (1981) later reported deaths of workers exposed to 2, 4, 5- Trichloro phenoxy acetic acid (2,4,5,T) in the United States. Subsequent case control studies confirmed increased risk to cancer on exposure to chlorophenoxy acids (Hardell and Sandstrom, 1978 and 1979). It has been suggested that this increased risk could have been caused by contamination of these herbicides with chlorinated dibenzodioxins. In a case control study in Southern Sweden, a five fold increased risk of soft tissue sarcomas in people exposed to chlorophenoxy and chlorophenol herbicides was estimated (Ericksson **et al**., 1981).

Other effects of pesticides in humans have also been observed. Pyriminil, a substituted urea also used as a rodenticide was found to cause severe diabetes and chronic neurological disorders (Levine, 1991). Another rodenticide, warfarin, is an anticoagulant and increases haemorrhage during gestation. When administered as a drug, it is teratogenic in humans although there is controversy about this (Levine, 1991). Among herbicides, paraquat is known to be acutely toxic on ingestion. In addition, a case occurred in which paraquat was found to be toxic on skin contact as well. Skin contamination from a leaking sprayer caused the death of one worker and reduced lung function in several others (Levine, 1979).

Pesticides therefore cause a wide range of effects including cancer, sterility, lung damage, diabetes, gross brain damage and bone necrosis. In the absence of surveillance, important human effects may be missed (Bull, 1982).

In Kenya, it is not known how many people suffer from sub-acute pesticide exposure. The few epidemiological studies done have been mainly on hospital cases which are usually acute (Guantai **et al**., 1994., Kahuho, 1980). Others have been criminal cases that are non-hospital based (Maitai, 1994). However, there are indications that pesticide poisoning of subacute nature is common especially in large plantations where most workers are semi-skilled or unskilled (Obel, 1985). No data were presented.

Pesticide accumulation in humans with inapparent health effects.

The third category of pesticide effects is concerned with the occurrence of pesticides in the general population and the environment. The public health impact of residues is not well understood. Exposure is more subtle than in cases of sub-acute poisoning and occurs usually as a result of contaminated foods, beverages, and/or other environmental components (Levine, 1991). The assessment of pesticide accumulation in humans is complicated by several factors: the technical inability to measure exposures, the metabolism of some pesticides to non-specific metabolites, the inability to assign a particular tissue level to a particular type of exposure and the need to identify sources and routes of human exposure prior to harmful contact (Kutz, 1983).

Identification of pesticides in the general population is not new. The storage of DDT in humans was first reported in 1948 (Howell, 1948). In the United States, routine monitoring of pesticides in humans started in 1967 (Stanely **et al**., 1986). In one study, 50 identified chemicals and a number of unidentified compounds were found in samples of human tissue (Stanely, **et al**., 1986). In Canada, 570 human adipose tissues were analyzed for organochlorine residues over a ten year period (Frank **et al**., 1988). The tissues showed the presence of DDT residues though there was a declining trend. Residues of dieldrin, heptachlor epoxide, chlordane, hexachlorobenzene (HCB) and mirex were also detected in most individuals. The levels were less or equal to 0.1mg/kg in extractable fat. This declining trend in organochlorine residues in tissues subsequent to the ban of most organochlorine pesticides has been confirmed lately by Mes **et al**. (1990).

In India, civilians were found to have deposits of DDT related compounds as well as hexachlorobenzene in their body fat. They also had dieldrin and heptachlor epoxide residues although the levels were low (Dale **et al**., 1965). The presence of chlorinated hydrocarbon residues has also been demonstrated in Australia (Ahmad **et al**., 1988), in Zimbabwe (Mpofu, 1986) and Turkey (Karakaya and Osalp, 1987).

In Kenya, human adipose tissues were analyzed by Wasserman **et al**. (1972). DDT and related compounds were detected. In 1988, Kanja **et al.** (1992) analyzed maternal adipose tissues, cord blood and placenta for organochlorine pesticides. They found mean levels of 5.9 ppm of DDT in subcutaneous fat. Much lower levels of β-BHC were also found. Human milk from Kenyan mothers was also analyzed by Kanja **et al.** (1986). Samples were collected from eight rural districts with varying climatic conditions. All samples were analyzed for organochlorine pesticides. The main contaminants found were *p'p'* DDT and the most persistent metabolite was *p'p'* DDE. Mean levels of the sum DDT compounds ranged from 1.69-18.73 mg/kg milk fat. All samples analyzed contained DDT. Other pesticides found were HCB, γ-HCH, β-HCH, aldrin and dieldrin. The mean of these was lower than the sum DDT but, the mean levels for aldrin and dieldrin were higher than those reported for other countries (Jensen, 1983). Beyond organochlorine pesticides there is little information on the accumulation of other pesticides in Kenyans.

1.3.5 Epidemiological Studies on the Health Effects of Pesticide Exposure.

There are two methods of assessing pesticide effects. The first is experimental studies on laboratory animals to assess specific toxic effects and to establish tolerance levels under controlled conditions. The second is to assess the effects of pesticides in the environment. The latter method is complicated by difficulties in separating the effects of multiple and usually correlated exposure variables. However, while usually well controlled and easier to assess, experiments are often not easily generalized beyond their specific laboratory environment. In both cases the study design is important.

Study Methods

Epidemiology is the study of disease occurrence in populations (MacMahon and Pugh, 1970). A more holistic definition by Martin **et al.** (1987) states that epidemiology is the study of the frequency, distribution and determinants of health and disease in populations. Disease investigations associated with toxic chemicals have been undertaken throughout the modern epidemiological era. Initial studies focused on hospital cases where risk factors for diseased patients were examined. Later large-scale cohort studies became the design of choice (Monson, 1990). Persons with different exposure levels were compared over time. A number of large scale cohort studies investigating the risk of exposure to carcinogenic compounds have been compiled by Breslow and Day (1987).

Whatever study design is used, the main emphasis is on unbiased comparisons between study groups of interest. Designs may be experimental or observational. For ethical reasons experimental studies in pesticides are mainly done on laboratory animals (Hayes, 1991).

Observational studies are either descriptive or explanatory. Descriptive studies assist in describing the factors and circumstances that may determine the occurrence of a particular disease (Martin **et al.**, 1987). One major advantage of descriptive methods is that they present results as a range of possible values in a natural setting (McDermott, 1995). The great complication in observational explanatory studies is that the researcher has no control over the allocation of exposure status (MacMahon and Pugh, 1970). Thus it can be difficult to separate the effects of agricultural, from other potentially confounding factors such as poor nutrition, poor medical access, etc. In experiments, random allocation avoids these problems.

One of the important criteria in testing causal hypotheses is to determine that exposure occurred before disease onset. This is easier to assess in prospective studies where non-diseased exposed and unexposed groups are first established and then followed longitudinally to disease occurrence (MacMahon and Pugh, 1970). In case-control studies, the relative timing of exposure and disease is more difficult to establish.

Fuelled by fears of the harmful effects of chemical exposures, many epidemiological studies have and are being conducted to assess the health effects of such exposures (Maroni and Fait, 1993)). An important task in such studies is to quantitatively establish exposure. This is often difficult because of the relatively long exposure periods required to induce disease. In early studies, the number of person-years of exposure were counted and relative exposure levels established (Breslow and Day, 1980). Quantification of chemical levels in the environment was an added source of information (EPA, 1980). Such measures can be usefully supplemented by measurement of chemicals and /or metabolites in body fluids (Saracci, 1983). Biological monitoring as an important method for obtaining data on chemical exposures was accepted at a symposium in Finland in the early 80s (Norseth, 1983). In biological monitoring, physical,chemical and immunological tests can be used (Van Sittert, 1983).

In addition to defining exposure, disease outcomes have to be carefully defined. In pesticide exposure, acute and chronic effects can result. A difficulty in studies on pesticide exposure is the frequent non-specificity of symptoms. For example, a study of an outbreak of febrile illness in newborns was observed and treated as an infection but was later found to be poisoning from pentachlorophenol, a wood protectant (Robson **et al.**, 1969). The fungicide was mistaken for soap and used to wash diapers for newborn infants. Therefore, studies in which specific effects are known or suspected are generally more informative. Examples of specific disease effects have been demonstrated. Axelson and Sundell (1974) and Axelson **et al**. (1980) demonstrated an excess of lung cancer in railway workers spraying phenoxy-herbicides. Male fertility as measured by low sperm counts and increased production of reproductive hormones was associated with long-term exposure to 1,2, dibromo-3- chloropropane (DBCP) (Whorton **et al**, 1977). Organophosphate and carbamate poisoning can be suspected if there is severe depression of acetylcholinesterase levels in body tissues. In the case of carbamates, however, the reaction is reversible and the patient may recover within a short period of time. Therefore, measurement of depression in the enzyme levels has been most used to assess for organophosphate poisoning (Ngatia and Mgeni, 1982., Copplestone, 1976).

Exposure Studies.

Studies on pesticide effects are meaningful only if it established that exposure occurred. Exposure to pesticides can occur in a wide variety of occupational settings ranging from manufacturing plants to the farm where the compounds are applied (Spear, 1991). The agricultural workplace, however, presents special opportunities for worker exposure. After the introduction of organophosphorous pesticides, it was recognised that it was possible to get sufficiently exposed from the work environment to become intoxicated (Abrams and Leonard, 1950). Later, Quinby and Lemmon (1958) published a review of case reports in which they drew a convincing association between poisoning symptoms experienced by workers and exposures to parathion residues during harvesting. Earlier, Batchelor and Walker (1954) had shown that farmers are exposed to pesticides during mixing, loading and applying pesticides. This was also confirmed by Durham and Wolfe

(1962). Total exposure was found to vary by work practices and between different workers.

1.3.6 Techniques for measuring exposure

Pesticide applicators and workers are exposed through the oral, inhalation and dermal routes. It has been shown that the dermal route is the most important (Durham and Wolfe, 1962., Copplestone, 1976). Once absorbed, the pesticide may be excreted, metabolised and excreted, or in the case of some compounds, stored in fat tissues.

There are direct and indirect methods of measuring exposure. The direct methods include passive dosimetry and video imaging. The use of biological markers is considered an indirect method. There are a number of published reviews of methodologies of estimating exposure to farm workers (Davies, 1980., Popendorf and Leffingwell, 1982). Among the direct methods, the most commonly reported is passive dosimetry. This method involves the measurement of dermal deposition of pesticide on the skin and in the air surrounding the worker (inhalation exposure). Its main advantages are that it is noninvasive and the analysis of samples is generally uncomplicated. Furthermore, the method can be used to determine the areas of greatest dermal exposure and separate dermal and inhalation values can be obtained (Dubelman and Cowell, 1989). The disadvantages are that, in order to estimate total body dose, two assumptions are required: there is uniform deposition of pesticide over each body region and the rate of absorption through the skin and the lungs is known. In many cases, the amount of deposition is variable and the rate of absorption can only be adduced from animal data and from skin models (Keeble **et al**., 1993). In addition, the cost of analysis is usually high due to the large number of samples needed per worker

(EPA, 1987).

The use of biological markers involves the measurement of pesticides or their metabolites in various biological samples such as urine, faeces, perspiration, blood, milk, hair and nails. The most commonly used of these are the measurement of blood cholinesterase inhibition following exposure to organophosphorus and carbamates compounds and the analysis of pesticides and /or their metabolites in urine. Acetylcholine is used in transmission of messages across the synapse in the central and peripheral nervous system of animals. After transmission it is hydrolysed by the enzyme acetylcholinesterase to choline and acetic acid so that excess of quantities of acetylcholine do not accumulate. Organophosphate and carbamate pesticides mimic acetylcholine and bind the enzyme making it unavailable to hydrolyse acetylcholine. With organophosphates, the enzyme is phosphorylated so that normal activity is blocked for 12 hours or more until a slow hydrolysis occurs and the enzyme is slowly released. Carbamate pesticides also carbamylate the enzyme but the rate of hydrolysis is faster. A measurement of the level of depression of acetylcholinesterase gives an indication of the amount of pesticide that has been absorbed.

There are various methods used to measure the activity of acetycholinesterase in either brain or blood. All methods measure the change in acidity that results from a reaction between the available enzyme and acetylcholine substrate. The Warburg manometric method measures the amount of carbon dioxide that results when sodium carbonate is added to the enzyme-substrate reaction. The amount of carbon dioxide evolved is indicative of the amount of enzyme in the sample. Electrometric methods measure the increasing acidity in solution using a pH meter under carefully controlled conditions of temperature and pH. These are considered to be the most accurate (Vandeker, 1980). There are also titrimetric methods. A useful simplification of these methods was made by Limpero and Ranta (Edson, 1958) when they realised that bromothymol blue changes its colour from blue-green to yellow-brown within the range of acidity produced by a small drop of normal blood reacting with a solution of acetylcholine for 25-30 minutes. The change in colour can be measured spectrometrically at a certain wavelength. This is the basis of the field kit first described by Edson (1958). Measurements can be made for either whole blood, plasma or erythrocyte acetycholinesterase. Erythrocyte cholinesterase is more susceptible to depression than plasma acetylcholinesterase (Hayes, 1982). However, there are difficulties in maintaining red blood cells under field conditions and therefore emphasis has been mostly on measuring the enzyme activity in whole blood (Vandeker, 1980). Furthermore, erythrocyte acetylcholinesterase contributes 80% of the activity (Vandeker, 1980). Commercial kits are also available that are portable and easy to use in the field. However, the method has low sensitivity and is therefore not recommended when laboratory methods can be used (Hayes, 1982a). The measurement of urine metabolites of pesticides combines levels obtained via inhalation, oral and dermal exposure and does not require estimates of dermal absorption or of penetration of clothing when estimating exposure (Bristol **et al**., 1984). However, its values in assessing exposure depends on a thorough knowledge of the metabolism and pharmacokinetics of the pesticide in question (Weisskopf **et al**, 1988). The technique also requires more complex and costly analytical techniques. It is unable to determine the relative importance of the various routes of entry. Lastly, despite its noninvasive nature, it requires excellent cooperation from volunteers to ensure that samples are collected at the right time to prevent variation due to non-uniform sample collection and handling.

The use of video imaging in exposure assessment is a recent development. Fenske **et al**. (1985) developed video imaging as a technique to assess dermal exposure. A fluorescent tracer dye is added to the spray mix and the pattern of deposition of the tracer on the skin of workers is used to estimate dermal exposure. Quantification of the amount of chemical deposited is done by video imaging and computer analysis. This method has the advantage over other passive dosimetry techniques because it can pinpoint localised sites of the body being exposed and reveal which work practices or deficiencies in spray equipment lead to such exposures (Fenske **et al**., 1985,.. Fenske **et al** ,1986(a)., Fenske **et al**, 1986(b)). However, the equipment is expensive to set up and requires initial standardization for different skin pigments between individuals and within an individual with varying skin pigments on different parts of the body. A series of linear standard curves for use in estimating different exposure levels for various skin tones were recently developed by Archibald **et al**. (1993). However, other shortcomings of the technique have not been overcome; the necessity for cooperative subjects, the difficulty of using the method under field conditions subject to various environmental factors and the choice of tracer with properties similar to the pesticide being handled. Furthermore, "quenching" occurs when very high levels of florescence are detected creating an upper limit of detection (Fenske **et al**., 1986b).

There are advantages to assessing exposure by combining both direct and indirect methods of measurement (Cowell **et al**, 1989). More comprehensive data is obtained on both the routes of exposure and total body dose. However, the cost of analysis is prohibitive. Furthermore, information on metabolism and excretion kinetics for some pesticides is still unavailable and can only be adduced from animal data. In addition, some pesticides are metabolized to non-specific metabolites (Kutz, 1983).

1.3.7 Pesticide Exposure Studies in Agricultural Workers

One of the earliest attempts to measure applicator exposure was carried out by Batchelor and Walker (1954). They used cellulose filter pads to collect pesticides falling on the skin during spraying. Durham and Wolfe (1962) modified this method by affixing patches of blotter paper to the skin or to the outside of clothing with tape. The amount of pesticide extracted from the central portion of the pads on a per unit area basis, was then assumed to characterize the exposure of adjacent parts of the body. This method was also used by Davis (1980a) to extrapolate respiratory exposure and has remained relatively unchanged ever since. The method makes certain basic assumptions: that the pesticide will adhere to the clothing in the same way it adheres to the skin and that the distribution of the pesticide will be uniform over the area represented by the patch (Durham and Wolfe, 1962). These assumptions are not always valid. For example, a splash of concentrate on a patch would lead to an erroneously high value when patch data are extrapolated to reflect the regional surface area (Franklin **et al.**, 1981). The converse would also be true and a spill that misses the patch would result in a considerably lower exposure being estimated.

To overcome the shortcomings of the patch method, Ware **et al**. (1973) used cotton garments that cover the entire body part during the exposure period. Although this method forms part of the protocol for exposure measurement by the World Health Organization (1971), it has a major disadvantage given the difficulty of extracting pesticides from whole items of clothing; especially given the large amounts of solvents required. For this reason, Spear (1991) recommended the use of gloves for the hands, socks for the feet and tops of socks for both ankles and wrists. Other modifications have also been used. Ritcey **et al.**,1987 placed gloves and leggings on workers harvesting strawberries. The captan was found to adhere to the clothing and although more total pesticide was found on the leggings than on the gloves, the contamination per surface area was similar. In addition, exposure to the face has been measured by the use of paper masks (Hattula **et al.**, 1979).

Fenske **et al.** (1985) used a fluorescent tracer to estimate dermal exposure. This method was seen to be useful especially in pinpointing localised sites on the body being exposed and reveal which work practices or deficiencies in spray equipment lead to such exposure (Fenske **et al.**,1985, 1986a, 1986b) of the body. Archibald **et al.** (1993) used the method to study exposure to greenhouse workers during chrysanthemum production. The workers concluded that the method can be used to estimate exposure to pirimicarb. There was high correlation between results of the VITAE method and excretion of the metabolites in exposed subjects ($r^2 = 0.98$).

Other less widely used methods in dermal exposure are skin swabbing (Durham and Wolfe, 1962), analysis of patches cut from various types of clothing worn during spraying (Knaak **et al.**, 1978) and hand rinses (Lavy **et al.**, 1993). The advantages and disadvantages were reviewed by Davis (1984).

Measurement of dermal exposure during reentry has been estimated in the same way as exposure during application, mixing and loading. The adverse potential of pesticide residues on field workers was recognised more than forty years ago (Carman, 1952). It was observed that workers would fall ill if they entered treated fields soon after application and at times long afterwards. The first large scale investigation on worker poisoning arose after a prolonged episode involving one hundred workers exposed to parathion residues in peach orchards (Milby **et al.**, 1964). Workers were poisoned after reentering a field one month after the last spray. Milby and coworkers attempted to account for sufficient parathion exposure to cause the observed symptoms but they could not. This led them to suggest that the isomers of parathion or the oxygen analogue, paraoxon all of which are more toxic than parathion might be involved. It was later confirmed that paraoxon was the cause of poisoning (Spear **et al.**, 1977). Paraoxon is estimated to be 10-50 times as toxic than parathion through the dermal route (Spear, 1991). Later, a rather unfortunate accident occurred when 142 students detasselled maize which was mistakenly treated with carbofuran a few hours earlier. Seventy-four were mildly poisoned, twenty-nine were seen at a hospital and one was held overnight (Spear, 1991).

Studies on exposure during spraying have been carried out. Batchelor and Walker (1954) estimated that an orchard sprayman received a dermal contamination of 55.8 mg/hour when using a high-pressure hand-sprayer and 77.7 mg/hour during air-blast spraying. Later, Fletcher **et al.**, (1959) using the patch technique, as in the previous workers, estimated dermal exposure of spraymen using dieldrin at 1.8 mg/kg per day. Exposure to dimethoate during mixing, loading and spraying was investigated by Copplestone (1976). He estimated the mean dermal exposures to applicators in the Sudan to range between 25.5 ug /25 cm2 on the lower leg and 0.11ug/25 cm2. In the United States, the combined dermal and inhalation exposure for applicators, mixers, loaders, pilots and agricultural workers has been estimated to range between 0.00005 and 0.39 mg/kg/day of dimethoate. For a sixty kilogram worker, the range would be-0.03-23.4 mg/day. These figures are relatively low compared with the more recent findings of Al-Jaghbir **et al.** (1992). The latter workers found mean dermal exposures of 914 mg/4 hour day (range 8.34-1008). The work was done under greenhouse conditions where there is less drift, the number of plants per unit area in plastic houses is much higher than in field conditions and plant heights in plastic houses are much higher

(Al-Jaghbir **et al**., 1992). In addition, the study subjects were only six and variance was high (8.34-1008). The workers concluded that applicators may be receiving substantial exposures that lead to significant depression in acetylcholinesterase. Lander **et al**. (1992) measured cholinesterase activity in and out of season for greenhouse workers and non-exposed controls. An in-season depression was seen in the workers indicating uptake of anti-Ache agents during cultivation of greenhouse flowers. Inhibition exceeding 20% was detected in a few of the workers. Baseline levels for the exposed group were not determined and therefore, an underestimation of the in season insecticides uptake cannot also be excluded.

The most notable case of reentry poisoning was an episode involving one hundred workers exposed to parathion residues in peach orchards (Milby **et al.**, 1964). Other poisoning episodes due to reentry have been reported due to sulphur pesticides, carbamates, chlorinated hydrocarbons and organophosphates (Wicker **et al**., 1979). Among these, the organophosphate are the most commonly implicated in reentry poisoning due to their inherent toxicity and the relative ease with which the oxon metabolites are formed under field conditions. They are also absorbed through the skin (Hayes, 1982a). Compounds that have been implicated are parathion (Milby **et al**., 1964., Spear **et al.**, 1977), azinphos-methyl, ethion, dioxathion, malathion (McEwen, 1977) and dimethoate (Wicker **et al.**, 1979).

Several studies on reentry exposures have been carried out. Brouwer **et al**. (1992) used cotton gloves to assess for exposure from avermectin B1, dodemorph and bupirimate to the hands and the forearms during cutting, sorting and bundling roses in the Netherlands. They observed mean dermal exposures of 10.1 mg/hr (CI=3.1) during cutting and 7.3 mg/hr (CI=4-6) over the same area. In a different study, Jongen **et al**.(1982) found slightly higher levels. These workers reported levels of 0.5-10 mg of pesticide per pair of gloves. Since the area of each glove was not reported, it is difficult to compare the results with those reported by Brouwer **et al.** (1992). Furthermore these results were very variable. Ritcey **et al.** (1987) used gloves and leggings to assess dermal exposure from captan while harvesting strawberries. Mean residues on gloves were 2.13 ug/cm^2 ,0.71ug/cm^2 on sleeves and 0.49 ug/cm^2 on the leggings. The highest amount of captan was however found on the leggings due to the larger surface area. In a later study, Fenske **et al**. (1989) reported higher residues than the preceding workers. Mean exposure rates for gloves were 25.75 g/hr and 16.4 g/hr for handwashes. Kundiev **et al**. (1986) studied the health status of women working in greenhouse crops which were treated with pesticides. The workers reported a decrease in serum acetylcholinesterase of the women. However, they also reported considerable variabil' y within test groups and were not eager to make conclusions about causality.

Several workers have reported poisoning cases that resulted after reentering fields treated with dimethoate. Hayes (1982) reviewed a case in which a sixteen year old boy developed weakness, nausea, headache and severe depression after picking hops previously treated with dimethoate. Wicker **et al.** (1979) also reported three incidencies in which dimethoate was implicated in reentry poisoning. In a different study, Leisivuori **et al**., 1988) reported dermal exposures of 1.1 mg/cm^2 for dimethoxon and 0.48 mg/cm^2 dimethoate . However, the workers did not report any illness due to the exposure. The major source of exposure in reentry studies can be estimated by measuring the amount of dislodgable residue on the foliage while minor exposure can be estimated from the amounts of residue in the soil in the treated area and in the surrounding air (Quinby and Lemmon, 1958).

Dislodgable foliar residues have been shown to have a typical pattern of decay. Initial deposits often range between 1 to 10 ug/cm^2 but decay during the first few days (Leffingwell **et al.**, 1975). For thiophosphates, however, the oxygen analogue is often formed in the residue. Since these are often more toxic than the parent compound and many last for several weeks after application (Spear **et al**, 1977), the danger from reentry poisoning is still present.

For exposure to occur, the residues must come into contact with the skin or mucous membrane of the worker or with the clothing. If the rate of absorption through the skin is known, the amount of chemical on clothing or on skin gives an indication of the extent of exposure that is likely to occur. This may be reported as a percentage of toxic dose and compared with the acute dermal LD_{50} of animals (Levine, 1991). Exposure may be reported in milligrams (or microgrammes) of the pesticide per person per hour (Al-Jaghbir **et al**, 1992) or as the amount of pesticide per skin surface area. This approach assumes that for each body part studied, exposure is uniform.

The measurement of dermal exposures is subject to many variables and gives variable results. Fenske **et al**. (1989) proposed that assessment studies could be improved by careful monitoring of dislodgable residues, work rates and sampling time in order to validate the methods used.

1.3.8 Household Exposure

Household exposures may occur from air, food, water or from contact surfaces in the home environment (Albert **et al**., 1992). Indoor air may be contaminated with pest control sprays or from stored pesticides that are volatile. Unwashed garden produce may contain pesticide residues and water may be contaminated by poor agricultural practices. In addition, poor storage and handling of pesticides within the home can lead to contamination of the home environment. Therefore monitoring of the environment, referred to as "media monitoring" can characterize the patterns of exposure (Albert **et al**., 1992).

The magnitude of household exposure to pesticides was highlighted by Levine (1991) who reviewed 94 outbreaks of acute pesticide poisonings between 1933 and 1987. Forty-two were related to contamination of food or water by pesticide formulations. This occurred in relation to use of seed grain as food (7), improperly applied pesticides (12), spillage in storage or transportation (13), accidental substitution of pesticide for an ingredient normally used as food (14) and due to indirect emergence of pesticide in the food chain (3).

Studies on household exposure have been carried out by several workers. The best demonstrated of these are the U.S based market basket surveys. In one such study, a wide range of foods constituting a balanced diet to feed a 16-19 year old boy was purchased from ordinary grocery stores in cities in different parts of the country (Durham **et al**., 1965). Some samples contained DDT. Later surveys (Gartrell **et al**., 1986) showed a general declining trend in organochlorine residues (except endosulfan) and a slight increase in the organophosphate malathion. Among the various classes of food, vegetables generally have a high surface: volume ratio. It has been predicted that due to this, they would be likely to carry more surface residues than other foods (Spear, 1991). This has been confirmed in residue studies (Gartrell **et al**. 1986).

Studies on ground and well water were also carried out in the United States. Both types of water were reported to have been contaminated with pesticides (Cohen **et al.,** 1986) but the levels were low. Routine water purification reduced DDT by 98% but only partly removed parathion, 2, 4, 5-T ester, dieldrin and endrin. Only 10% of lindane was removed.

A major portion of pesticides applied eventually enters the air as vapour. Albert **et al**. (1992) asserted that only 0.1% of pesticides applied actually meet the target pest and that 99% contaminate the environment. Direct exposure, however, is likely to be of concern for those individuals engaged in application or living or working near application sites (Spear, 1991). However, exposure to pesticide laden indoor air can occur. For example, three-week old twins were treated for laboured breathing after being in a house neighbouring one that had been sprayed with diazinon to control cockroaches the day before. Other occupants were not affected but only the twins had remained indoors the entire time (English **et al**., 1970). The most common reasons for use of pesticides in and around buildings are termite control, pest control in food stores and in vector control programs. Pesticides applied in this way have been shown to persist in the air for periods of up to one year. For example, in houses treated with chlordane, there was little difference in the amount of pesticide immediately after application and one year later (Wright and Leidy, 1982).

The situation was, however, different for organophosphoro pesticides applied against cockroach control (Wright **et al.**, 1981). Residues declined to less than 1 ug/cm^3 /air for all pesticides after three days. Wright and eidy (1980) also studied the air-borne concentrations of several organophosphorous pesticides in indoor settings. In food stores that had received a crack and crevice application of chlorpyrifos, air levels immediately after application ranged from 0.02 to 1.5 ug/m^3. All levels had dropped to 0.36 ug/m^3 or less in 24 hours.

Information is unavailable on studies of exposure from indoor sources other than air. For example, the use of table swabs to assess for household contamination was not found in the literature though the method has been used by the Ontario Ministry of Agriculture and Food (Frank, 1993). The results of the study were not published. However, Spear (1991) in his review of exposure to pesticides from environmental media, states that residues of some pestioides can be absorbed dermally from sprayed surfaces.

1 3 9 Pesticide Exposure Control

The principal aim of assessing exposure is to formulate strategies to minimise or eliminate exposure. The modern approach to hazard management utilises the Hazar ' Assessment and Critical Control-Procedure Principal (NRC, 1993). This approach has been found applicable to pesticides (Stephenson **et al**, 1993, Waltner-Toews an McEwen, 1994). The first step in controlling exposure is to assess the risk associated with the exposure.

Risk assessment

Risk assessment is the characterization of the potential adverse health effects of human exposure to environmental hazards. It involves four steps. Hazard identification is the evaluation of activities that utilize pesticides and the determination of whether these activities pose a potential risk to health and to the environment. The second step, exposure assessment, evaluates the populations that are, or may be, exposed and the levels of exposure expected. The third step is to establish the dose-response relationship between intensity of exposure and probability of environmental and health effects. The final stage is risk characterization to estimate the probability of various outcomes for a given exposure scenario (Edelman, 1991). These are then combined to formulate management strategies to minimize exposures (Stephenson **et al**, 1993).

In many workplaces well established toxicology and occupational health procedures have been used to minimise exposure to all chemicals over time. Monitoring the health of workers producing or using pesticides has been found useful for the early detection of health effects (Edelman, 1991). In addition, all persons using or handling toxic chemicals should have a medical evaluation appropriate to the exposure (Edelman, 1991). Such medical evaluations should be appropriate to the risk of exposure (Edelman, 1991). The International Labour Office (ILO, 1977) has also published guidelines on the medical supervision of workers. Many local, state, and institutional agencies have published information on the recognition, treatment and management of pesticide exposure (Morgan, 1980, GIFAP, 1986., Bayer, 1993). Exposure may be maintained at a safe level through substitution, reduced usage, education, and protection. Regulations can then define the different measures that will help to control exposure and also ensure that they are carried out (Edelman, 1991).

Substitution

Substitution involves the replacement of a toxic chemical with a less hazardous one. The decrease in hazard may be due to lower inherent toxicity or to different physical properties. Factors such as vapour pressure, skin permeability, bio-persistence and viscosity are important parameters to be considered.

The use of a less toxic active ingredient is the most obvious improvement that can be made (Edelman, 1991). The substitution of DDT for lead arsenate and other arsenicals, for example, has been described as a change that has contributed most to human safety. Instances of chronic lead poisoning associated with orchard spraying were reported (Farner, 1949), while acute poisoning by arsenicals forms an important proportion of fatal accidental poisoning by pesticides (Stephenson et al, 1993). DDT, however, maintained a good record and there are no confirmed cases of chronic poisoning from DDT (Edelman, 1991). The choice of formulation can also minimise hazard. Some formulations are less easily absorbed. In some formulations, the solvents used actually constitute the major hazard (Jacobnizer, 1966). Benzene, for example, is very toxic and should be avoided (Gehring **et al**., 1991). Some formulations have been shown to be safe as pastes as compared to liquids. In an experiment with dieldrin, the same dermal dose of 100 ug/kg produced only 20-30% mortality when applied as a paste compared to 95% mortality that followed applications of solutions (Hayes and Pearce, 1953) to mice. Liquid concentrates of parathion were found safer when they were compared to the wettable powders of the same compound. This was attributed to the higher respiratory exposure experienced with the solid formulations (Hayes and Pearce, 1953). Other safer formulations are granules (Sawyer, 1983), baits, slow release pesticides and microencapsulations (Tsuji, 1986).

Edelman (1991) has discussed the possibility that safer pesticides may be developed as new technologies develop. An understanding of the mechanism of action of pesticides and especially the specific biochemical site involved in pesticide action is likely to lead to safer usage. For example, the organochlorines, organophosphates and carbamates target the nervous system of the insect while pesticides such as diflubenzuron, a substituted urea insecticide, targets the insect cuticle and acts by interfering with the synthesis of chitin (Stephenson **et al**., 1993), a much more insect specific effect. Improved knowledge on the behaviour of pesticides in the environment and in the target pest (translocation, evaporation, movement in soil, plant uptake and general metabolism) can be used in modelling and predicting environmental impacts in a way that has not been possible in causal analysis using simplistic information such as customary criteria like LD_{50} s (Edelman, 1991). Pesticides with less non-target effects would then be preferred. Non-pesticide control alternatives are expected to play a bigger role in crop protection in future. For example, general repellents or systems to avert insect feeding on crops are potentially useful and more safe than current chemical pesticides. In addition, pheremones, growth hormones, plant derived compounds, microbial systems and sterilization techniques are alternatives to conventional pesticides. Genetically engineered plants and animals that are incorporated with genes for pest control are expected to be produced in future and will play a wider role in crop protection (FCI, 1994).

Integrated pest management (IPM) involves the use of multiple modalities in crop protection (Edelman, 1991). The use of this approach gives chemicals a lower priority by requiring that they be used in smaller concentrations in combinations with other methods. Thus, improved agronomic practice, improved land use management, plant selection and ecological manipulations are aspects of integrated pest management that are likely to reduce the amounts and thus hazards associated with pesticide usage.

Reduced usage

It has been suggested that some of the problems associated with the use of pesticides are as a result of unnecessary use (Stephenson **et al**., 1993). Traditionally, use instructions for protectant fungicides usually advise farmers to spray before the onset of disease. In the 1960s and 1970s, routine application of soil insecticides in the United States before planting corn was a common practice (Blair, 1977). In many cases, farmers could not identify the specific pest they were controlling. Stephenson **et al**. (1993) suggested that substituting 'treat when necessary' applications for the conventional routine treatment schedules would reduce drastically the amount of pesticides applied. The authors also assert that 100% control of most pests is not required to prevent economic loss and that the objective should be to prevent pest damage from exceeding economic thresholds.

Various workers have suggested ways in which pesticide usage may be reduced while effective pest control is maintained. Knowledge of the behaviour of the pest, crop and environment and their interactions is needed to better target pest control strategies that have both acceptable safety and cost (Glass, 1977). For example, Stephenson **et al**. (1993) suggest that pests can best be controlled if carefully timed suppressive applications are targeted at weak points in the pest's life cycle. To achieve this, life tables of both the pest and the crop have to be prepared. Pest control is then directed at that stage of the crop when it is most susceptible. For example, the cabbage crop in Ontario, Canada, is affected by numerous insects but the most serious one is the cutworm. Studies on the life cycle of cabbage have shown that the critical periods in control are in the early stages when cutworms cause the most mortality of plants and in the heading stage due to damage by caterpillars. An effective pest control strategy would therefore be directed early in the life cycle of the plant and later during heading (Stephenson **et al**., 1993).

Timing of the spray period needs to consider other factors than the pest. For example, spraying should be timed to minimise the mortality of beneficial insects. Thus, the life cycles of parasites, predators and beneficial insects should be studied and the pesticide can then be applied at the stage when harmful effects to pests are maximised and to beneficial insects minimised. This strategy requires the application of non-persistent pesticides.

Selective application of pesticides to coincide with behaviourial characteristics of the pest species has also been used effectively to reduce pesticide usage. Insecticides which are toxic to honeybees have been recommended for application after bloom is completed or in the evening when bees are not foraging on crops (Cooper, 1991). Similarly, insecticidal paints have been used to control mosquitoes. The adult mosquito usually rests on walls and ceilings after ingesting blood from humans. A small percentage active ingredient of lindane is incorporated in paints prior to their application on walls (PCPB, 1991).

The degree of efficiency in pesticide application is widely recognised as a factor that may influence the amount of pesticide used in pest control. Joyce **et al.** (1977) reported that in crop spraying operations, for example, the pesticide is usually aimed at a false objective since many operators identify a target area, not pest, and try to provide an even cover of pesticide over the total plant surfaces. The workers argue that the pest occupies a special niche in the crop environment and this should be the target area. The nature of the biological target would then determine the droplet size and therefore also the pesticide formulation required. The status and outlook of pesticide application was reviewed by Adam (1977). He observed that pest control programmes fail in achieving their objectives due to factors related to application equipment and its calibration, usage and maintenance. These shortcomings result in high costs, waste of pesticides, intoxication hazards, destruction of beneficial organisms, crop damage and excessive pesticide residues and environmental contamination.

Correct choice of equipment plays a vital role in efficient application. The results of a study done on the efficiency of different application methods showed that the proportion of applied dose taken up by biological target varied from 0.03% to 6% (Anon, 1992). The least effective was a knapsack applied foliar spray on the bean aphid while aerial application of lindane/ dieldrin on locusts was highest.

Current technology in application equipment may lead to efficient pest control with drastically reduced pesticide rates. The advantages of electrostatic pesticide application methods have been reported (Anon, 1992). The Imperial Chemical Industries' (ICI) Electrodyn, for example, a no-moving parts nozzle, is claimed to have various advantages over conventional spraying techniques particularly reduced drift, controlled droplet size and velocity, high recovery index (ability to land on the target plant), low rates per hectare, maintenance free, and low energy consumption (Anon, 1992). Field trials on the control of white flies on cotton showed that the Electrodyn sprayer was five times as effective as conventional spray techniques for the same active ingredients used. In addition, the amount of diluent needed was ten times less than in conventional sprayers.

Effective pesticide dosage rates have been declining over the years. Before the 1940s, the mean dosage rate per hectare was 10 kg of active ingredient.Today, dosage rates are as low as 0.01 kg active ingredient (Stephenson **et al**., 1993). There are two reasons for this. The first is a general departure from routine applications towards pest monitoring followed by timed applications. In addition, the efficacy of pesticides has increased with the discovery of new active ingredients which are effective at very low rates. For example, deltamethrin is effective against various insect pests at a rate of 50 g\ha active ingredient (Hoechst, 1994) while chlorsulfuron, an urea based herbicide is effective against broadleaved weeds and some annual weeds at 15-35 g\ha active ingredients

(Stephenson et al., 1993). If this trend continues, the possibility of adverse exposure to pesticides will continue to decline.

Education

Education is fundamental to safety (Edelman, 1991). This is true for pesticides as well for any other toxic chemicals. Jeiger (1964) noted that one reason for over-exposure of workers to pesticides was their lack of appreciation of the hazards associated with these compounds. It was later proposed by Davies et al. (1980c) that the transfer of use technology from place to place is not always equalled with corresponding transfer in safety technology. Davies and coworkers argued that this is the main reason why pesticide exposure has been common in some parts of the world. In contrast, Jeyarantnam (1982) attributed pesticide exposure to attitude and not to lack of knowledge on hazards of pesticides per se. This view was also expressed by Copplestone (1982). Regardless, education directed towards change in attitude and/or methods of increasing safety in handling pesticides has been found to be effective in reducing hazards from pesticide exposure.

Smith and Wiseman (1971) reported that after initiating a training programme on pesticide safety, the number of poisoning cases dropped from 118 in 1968 to 15 in 1969 in the Rio Grande Valley in Texas. Though the improvement was due to more than one factor, the workers attributed part of it to education. In Argentina, an education programme was initiated to curtail poisoning cases in Chaco Province, where it was reported that in 1966, 180 cases of poisoning occurred, out of which 38 were critical and 16 fatal (Lopez, 1982). An educational commission was set up to provide information on accident prevention but the results of this exercise were not reported.

In three countries in Africa, Asia and Latin America, the International Association of Manufacturers of Agrochemical Products initiated pilot projects to educate farmers on the safe and effective use of pesticides. Kenya, Thailand and Guatemala were chosen as target countries for the 'Safe Use Project'. GIFAP prepared two types of training courses for their member associations. There is a course for farmer trainers which includes one and three day courses for farmers (GIFAP, 1988b) and a course for agrochemical retailers (GIFAP, 1988a). In Kenya, in the three year period (1991-1993), 280,000 Kenyans were trained. The major benefit of the training realised was increased understanding of pesticides and their toxic effects (Njer, 1994). However, adoption of safe use practices is low. For example, in an audit to investigate the extent of adoption, it was found that less than 30% of the trained farmers were adapting to safety training (Njer, 1994). The main reasons given for this were inability to read and understand label instructions, high cost of protective clothing, lack of protective clothing in local business centres and the discomfort of wearing available protective clothing. The project also trained agricultural extension staff and retailers of pesticides. The results of these programmes are difficult to assess in terms of increased safety.

In Guatemala, in addition to farmer training, teachers in rural schools were trained and they in turn trained 70,000 children over a three year period. A special programme for children was developed called the 'Scarecrow' and was used to highlight the dangers of pesticides to children (GIFAP, 1994). However, the benefits of this approach appear not to have been assessed. This is also true in Thailand (GIFAP, 1994). Both farmers and students were trained on the importance of safety in pesticide handling, especially during application. While considerable reduction in exposure is said to have taken place, no data are presented (GIFAP, 1994).

Many organizations have developed training programmes for chemical safety. For example, the main emphasis of the Environmental Protection Agency (EPA) worker safety programme is education (ICF, 1985). The United States Agency for International Development (USAID, 1985) has also developed a training programme for pesticide users in its agricultural development projects. In Canada, pesticide applicators, operators and vendors are all required to be trained before they are licensed to operate their businesses (Franklin and Muir, 1982). There are slight differences between provinces but in seven out of ten, applicators must go through a course on safe handling of pesticides covering safety and health, protection while spraying, first aid, and poisoning (Franklin and Muir, 1982).

In Kenya, the Pest Control Products Board has the mandate to train farmers, traders and the general public on the safe and effective use of pesticides (Ministry of Agriculture, 1986). To this effect, the Board prepared a syllabus for training on pesticide management (PCPB, 1988). Good education must lead to understanding (Edelman, 1991). The first requirement is that it must lead to recognition of danger. The need for appropriate care then becomes an obvious matter (Edelman, 1991). Therefore for a programme to be effective, emphasis should be placed on those areas where hazard is highest (Copplestone, 1985). An unprioritized or blanket approach causes people to put much effort into preventing low risk exposures, therefore increasing the probability of negligence and accidents.

Certain information is considered to be mandatory in an exposure control programme. According to Edelman (1991), trainees should be able to determine when an exposure has occurred. The workers must also understand the physical and health hazards associated with pesticide contacts. The use of protective devices and practices, emergency procedures, containment systems and other ways of reducing contact should be understood. Any written information that may be used by the worker should be made available (Edelman, 1991). In addition to safety issues, it has been suggested that training on pesticides should be broader. Hayes (1971) and Murphy and Hayes (1972) suggested that toxicology should be part of biology, zoology, hygiene and general science studies from elementary grades through college. Information on dose-response relationship of chemicals to living organisms should be emphasized. Edelman (1991) concludes that if toxicology were part of the general education curriculum, within the next quarter century, the general public would be able to exercise improved judgement in handling toxic substances.

Non-conventional educational programmes may be used in training. Alstolfi and Londoni (1982) reported a programme in which large groups of pesticide workers were trained through the mail and awarded certificates accredited to a local university in Brazil. They found the system cheap, logistically easy to handle (people don't have to assemble in one venue for a specific period) and thus sustainable. The training of farmers in large groups can be both cheap and effective. Field days with different safety-topic stations manned by trainers have been found effective. Using this approach, it was found that it is possible to train 100,000 farmers in one year in Kenya (African Farming, 1994).

Education through a rapid publication journal was suggested by Oehme (1982). His proposal was to report on chemically induced problems and techniques for investigating them. Information would be available to all interested individuals as promptly as possible for immediate use in dealing with daily problems (Oehme, 1982). Regulatory authorities may also publish leaflets on pesticide recommendations, handling precautions and other information relevant to exposure reduction. These may be published at regular intervals and made available to farmers and the general public (OMAF, 1986).

Mandatory certification programmes have also been used as an education tool (Almeida, 1982). In this case, all new operators must be trained before licensing. Refresher courses on toxicological and use aspects can also be included in such programmes.

Exposures to chemicals and their hazards are a public health issue (Waltner-Toews and McEwen, 1994). Therefore the use of the mass media in educating the public on exposure reduction usually has a lot of impact. Radio and television programmes formed an important component of training programmes in Hungary (Bordas, 1982). The Safe Use Project in Kenya initiated 40 radio programmes on safety in pesticide handling in a period of one year (GIFAP, 1994). The programmes were organised as plays and competitions. From the responsiveness to the quizzes on knowledge, and drawings to represent the different safety practices, it was concluded that the programmes had a wide audience. The advantage of the radio over television is its widespread availability in rural areas.

Kishi **et al**. (1995) doubted the usefulness of training farmers on the dangers of pesticides and the practicality of advising them to use protective clothing. They argued that in the tropics it is too hot for farmers to use protective clothing and they are also too expensive. In addition, they argued that farmers respond to the short-term economics of farming at the expense of their own health. These conclusions were drawn from a study in Indonesia in which 62% of the farmers were reported to reduce pesticide usage when the government removed subsidies on pesticides between 1987 and 1990 (Kishi **et al**, 1995).

Protection

Protective devices and practices can play a big role in limiting exposure to pesticides. Devices are designed to reduce opportunities for human and environmental contamination by chemical agents (Edelman, 1991).

Devices may reduce exposure in industrial environments or can be for personal protection. Industrial protection is usually complex requiring construction of major safety devices for the protection of all workers in the work area. The choice of personal protective devices depends on the degree of hazard (Anon, 1992). Research has shown that all pesticide workers except those using closed worker systems are exposed to pesticides (Davies, 1980b). However, applicators using knapsacks are the most exposed as compared to ground applicators using other equipment and aerial spraymen (Lavy **et al**., 1980). Furthermore, a number of studies on the routes of pesticide exposure to workers have shown that the principal route is the skin while the respiratory route is much less important (Wolfe **et al**., 1967). Therefore the protection of the skin from contact with pesticides during handling and application would lead to significant reduction in exposure (Tordior and Van Heemstra, 1980).

The choice of protective devices depends on the work being done and the hazard likely to be associated with it. During mixing of the concentrate and while applying pesticides in enclosed areas or when using highly toxic pesticides, respirators are needed (GIFAP, 1989). To be effective, a respirator should have an air filter or cartridge. There are various systems available for dusts, organic vapours, acid vapours and various other chemicals (Edelman, 1991). However, in the absence of sophisticated equipment, a clean rag tied over the mouth and the nose will reduce exposure (Freed, undated).

Protective clothing are devices that have been found particularly useful in reducing exposure to the skin (Edelman, 1991). The aim is to reduce the surface area that might be contaminated with pesticides and which may be absorbed into the body. To be useful, clothing should not absorb the pesticide as this would lead to increased contact over time (Edelman, 1991). Conversely, impermeable clothing does not allow for ventilation and also decreases evaporation of perspiration. In the search for suitable alternatives, Davies **et al**. (1982) studied the efficacy of repellent treated fabrics. The workers found that significant protection was afforded to farmers who used cotton denim overalls and laundered them daily. When a repellent resin was sprayed or spilled onto the clothing, they absorbed less pesticide and were safer to use. It was recommended that protective clothing should be laundered daily and not together with the family washing.

Other workers have studied the usefulness of protective clothing in reducing exposure. Popendorf and Spear (1974) demonstrated that nylon-knit gloves and long-sleeved shirts minimised exposure of citrus harvesters. Popendorf **et al**. (1979) confirmed that gloves can prevent 90-95% of phasolone residues from reaching the hands of peach orchard workers.

Different fabrics afford different protection. Furthermore, different chemical agents behave differently depending on the fabric used. The choice of a proper fabric for each pesticide is important (Edelman, 1991). For example, Laughlin **et al**. (1986) reported that one of the factors that affect penetrability of clothing is the formulation of the pesticide. The Environmental Protection Agency evaluated the issues and problems of protective clothing. In a summary report, Bodden **et al**. (1983) reported more questions than answers. They resolved that factors such as permeability of clothing and the penetrability of pesticides through various treated and untreated materials should be investigated before decisions are made. Efficacy, work compliance, comfort and acceptance all need to be tested in the field.

Eye protective devices are necessary to protect the eyes from splashes of toxic or corrosive materials. Contact lenses are not recommended when working because they may trap the pesticide and increase contact to the eye (Edelman, 1991). Face shields are preferred to safety glasses. The latter are considered the best protection for both physical injury and bright light. Other protective devices that are being used today are suits providing a completely closed-system. Both field and factory systems are now in use. Knaak **et al**. (1980) used biological monitoring to evaluate the effectiveness of closed systems in reducing exposure. They found that in mixing-loading and application operations, the use of closed systems resulted in reduced depression of acetylcholinesterase activity in blood and reduced levels of alkylphosphates in urine. Edelman (1991) has reviewed the advantages and disadvantages of these systems and the structures that must be in place before they can be widely used. He felt that a proper training programme for workers who use the equipment is essential.

Protective devices such as soluble packages may also play a role in reducing exposure. Such packages are made in a way that the pesticide is measured and packaged to dissolve in water without having to open the pack in order to dissolve. The bag is then dropped into the correct volume of water (Du Pont, undated). In addition to protective devices, protective practices can also reduce exposure to pesticides. Their effectiveness is based on the ability of the user to observe hygiene practices. Avoidance of exposure may be achieved by using practices such as spraying downwind (GIFAP, 1989). Use of faulty equipment has led to high levels of exposure among applicators (Anon, 1992). Leaking pumps, valve springs and nozzles may lead to a lot contamination, therefore, maintenance of equipment can help to reduce exposure.

The removal of contamination after accidents such as the quick clean-up of spills is important (GIFAP, 1990). Water and other cleaning materials should be available in case of an emergency. First aid materials and measures should be posted in work areas.

Safety in storage ensures that unauthorized persons may not use or handle pesticides except in the presence of a trained and competent person. This is especially important for children. Pesticides intended for home and garden use may be supplied with tamper-proof caps that children would find difficult to open (Edelman, 1991). One cap was introduced in a contest where children were tested on their ability to open it. Among 300 children, those under three years could not open the cap even after being shown how, and few children under eight could open it without a demonstration (Stracener **et al**., 1967). The cap was for use in the pharmaceutical industry but the same principle may be applied for pesticides. Proper storage also takes into account the necessary procedures in case of fire outbreak. Edelman (1991) suggested that pesticides should be stored in tanks surrounded by dikes as in the case of fuel oil.

Lack of correct disposal of pesticides and pesticide containers has been reported to be a major cause of pesticide exposure (GIFAP, 1990). In many less developed countries, pesticide containers are used for household purposes. GIFAP (1990) recommended that pesticide containers should not be reused unless for refilling with the same pesticide. Methods for disposal of farm wastes, unwanted pesticides and containers are available (Harmer and Wolfe, 1983; GIFAP, 1990). Before disposal, containers must be cleaned thoroughly. In certain cases, it is necessary to clean them in organic solvents and detergents (Wolfe **et al**, 1961).

The use of pesticides around the home requires that special attention be paid to protective practices. Pesticides should not be stored in large amounts (Edelman, 1991). Children and even adults have been reported to have ingested pesticides due to poor storage or lack of labelling (Hayes, 1982a). In the home, all food and water containers and eating utensils should be protected from contamination. Farm animals should also be removed from areas where pesticides are being used or stored.

Old pesticides may pose a hazard in the home. Edelman (1991) has proposed a scheme to encourage the disposal of old pesticides around the home. These 'toxic roundups' can be carried out regularly to clear homes of toxic wastes. Health departments may organize this type of exercise in order to rid homes of unusable pesticides, old paints and any other toxic materials.

Regulations.

Legislation on pesticide production, use and storage have increased over time (McEwen and Stephenson, 1979). One of the earliest legislations was a State Law of New York enacted in 1898 to regulate the sale of Paris Green which was the most important pesticide at the time (Dewey, 1977). In 1910 the Federal Insecticide Act of the United States was enacted for the purpose of protecting consumers against misrepresentation of products. The need for comprehensive pesticide laws increased with the discovery of the synthetic organochlorine pesticides in the mid-20th century. Laws were needed to address the problems of safety to crops, to the users and to the environment (Glasser, 1976). In the United States, the Federal Insecticide Act was superseded by the Federal Insecticide, Fungicide and Rodenticide Act of 1947 (FIFRA, 1947). Many other countries enacted pesticide laws after this. Based on reports on exposure to pesticides (Barnes, 1953) it was recommended that legislation was needed to reduce the incidence of pesticide poisonings. The Food and Agricultural Organization of the United Nations published guidelines for legislation covering the registration of pesticides for sale and marketing (FAO, 1969). The following year, the World Health Organization published a review of the existing legislation on pesticides (WHO, 1970). A conclusion of the review was that the hazards from pesticides are preventable as long as appropriate legislation is actively enforced. The review found that while most countries in Europe and North America already had pesticide legislation, there was a large variation in definitions of pests and pesticides and in registration data requirements. The FAO subsequently published guidelines on data requirements for registration, good labelling practice and other areas related to the legislation of pesticides (FAO, 1985).

In designing a regulatory procedure, certain criteria must be addressed. Bruin (1983) has outlined the necessary steps in choosing and designing a pesticide law. Basically, the scope of the pesticides to be covered by the law and the target pests have to be defined. Generally, the wider the scope, the more comprehensive the law is likely to be. The objectives of the regulatory procedure depend on both the agricultural and economic structure and on legislative and political factors (Bruin, 1983). The basic goal is to control pesticides to enhance the safety of users, bystanders, consumers, non-target organisms and the environment (Glasser, 1976., Bruin, 1983).

A number of regulatory schemes have been described by Bruin (1983). The voluntary scheme is based on mutual trust and understanding. It requires that those concerned should be responsible without any legal actions being taken if there is non-compliance. The preventive scheme forbids the production, sale or use of pesticides except under the laws stipulated. Such a system, requires elaborate bureaucratic procedures and considerable resources. However, when enforced, it is very effective (Bruin, 1983). Other regulatory procedures that are not widely used are: retrospective, where the government does not intervene unless a problem occurs and, government, whereby the government handles all pesticides and regional schemes, which may cover many countries in a region. After the enactment of a specific regulatory procedure, accompanying regulations are needed to enforce the law (Whittemore **et al**., undated). Such regulations need to cover issues such as registration, licensing, trade, labelling, packaging and worker safety. A careful wording of these regulations is needed for the day-to-day enforcement of the regulations (Whittemore **et al**., undated). For the purpose of reducing pesticide hazards, WHO (1970) suggested that labels, containers and packages should have instructions on: safe usage and precautions, symptoms of poisoning, first aid measures and advice to physicians in case of poisoning. Other aspects that are likely to contribute to reduced exposure are regulations on protective clothing, registration of less toxic pesticides, control of contamination during transport and the periodic medical examination of workers.

A national organization is needed to implement pesticide law and regulations. A suitable person is usually the Minister for Agriculture (Bruin, 1983). Resources would then determine the size of the organization. According to the FAO (Whittermore **et al**., undated), a scheme may start with one person taking care of quality control and with time other aspects of efficacy, residue control, evaluation of user and bystander hazards as well as toxicological hazards can be added. In reducing exposure certain instruments of the law may be used. Registration is considered to be one of the best tools for this (Whittemore **et al**., undated). The WHO (1970) also recommended that registration can be a special tool in controlling pesticides. For a product to be registered for use, technical information on physical and chemical properties has to be supplied by the manufacturer.

Other information needed are biological efficacy, toxicological, environmental fate and effects, and residue data (Whittemore **et al**., undated). Based on this information, pesticides that are highly toxic, persistent or bioaccumulative are either not registered or their registration is cancelled or suspended. For example, a large number of the chlorinated hydrocarbon insecticides are either banned or severely restricted in both developed and developing countries (Whittemore **et al**., undated).

Licensing may also be used in the control of pesticides (WHO, 1970). Premises used in manufacture, storage and distribution of pesticides can be licensed. Licensing regulations stipulate the conditions which must be met before licensing. The emphasis is usually on worker safety and protection (Naef, 1983). According to Naef, the use of precautionary measures in pesticide premises can make it possible to manufacture even highly toxic pesticides without endangering the health of the workers. In addition to the licensing of workers, pesticide applicators can be licensed to operate. The licensing is subject to certain training. In Canada, for example, all applicators are required by provincial law to be licensed (Franklin and Muir, 1982).Other regulations to reduce exposure can control the destruction and disposal of wastes, storage requirements, protective clothing, monitoring of workers (Whittemore **et al**., undated), fumigation of premises and dressing of seeds (WHO, 1970).

In Kenya, the Pest Control Products Act of 1982 regulates the importation, exportation, manufacture, distribution and use of products for the control of pests (PCP Act, 1982). There are also regulations on licensing of premises, imports and exports, registration and labelling, advertising and packaging (PCPB Regulations, 1984). The Act also has provision for the Minister of Agriculture to make regulations pertaining to standards for efficacy and safety of any pest control product (PCP Act, 1982). Such regulations have, however, not been made. The existing regulations are not adequate to administer all aspects of pesticide exposure reduction. For example, there is no adequate legislation on worker safety, storage of pesticides, protective clothing and devices, monitoring of pesticide usage and health effects. Furthermore, there is no clear direction on whose responsibility it is to set residue tolerances on food. Exposure of agricultural workers who reenter treated fields is not mentioned in either the Act or the regulations. Regulations regarding emergency measures in case of pesticide fires and accidents, destruction and disposal of pesticides are needed.

CHAPTER TWO

A SURVEY OF PESTICIDE USAGE AND HANDLING PRACTICES AMONG SMALL-HOLDER FARMERS AT KIBIRIGWI IRRIGATION SCHEME.

ABSTRACT

Pesticide handling and usage were investigated among a group of three hundred horticultural farmers in an irrigation scheme in central Kenya. Sixty-five farmers were interviewed informally with the help of a questionnaire covering farm size, literacy level, cropping practices, crop and household pesticide use, animal husbandry, pesticide storage, handling and labelling, disposal, foods consumed and health history.

A wide range of crops were grown in the scheme and pest and disease problems were considered major constraints to production. Fifty-eight pesticide formulations (insecticides, fungicides, nematocides) were used in the scheme. Non-pesticide control methods were also but less commonly used to control pests.

Carbosulfan and endosulfan were applied on crops for which they were not recommended. Most farmers did not read labels although about 75% of the population could read either English or Swahili. Preharvest intervals were unknown and not observed for dimethoate, deltamethrin and mancozeb on kale and beans since farmers did not read labels but depended on extension officers and pesticide sellers to advise them on mixing and usage.

In the sample of 65 farmers surveyed, protective clothing was rarely used. No farmer was

found to have a full set of protective clothing and twenty-two did not have any item of protective clothing. Nineteen farmers stored pesticides inside the house and one farmer stored them inside his kitchen. Seven farmers reused pesticide containers, two for domestic purposes. Although 46 farmers did not reuse containers, they disposed them unsafely.

It was concluded that farmers in the scheme handle pesticides unsafely. Further phases of this study will investigate and quantify the levels of exposure due to spraying and other farming practices.

2.1 INTRODUCTION

Pesticides have been widely used to control pests and diseases of crops, animals and in public health programmes. Increased agricultural production and other benefits have been attributed to pesticide usage (Reynolds, 1985). However, a number of inherent environmental and health risks result from pesticide usage, particularly if these chemicals are mishandled. Excess pesticide exposure (both accidental and occupational) has resulted in a variety of documented adverse health effects (Almeida, 1966; WHO, 1977; Burmeister, 1981., Cantor, 1982; Restrepo **et al**; 1990; Kabalimu, 1990).

In Kenya, Obel (1983) attributed a large number of pesticide poisonings to occupational exposure in agricultural workers. However, he did not quantify the actual rates of exposure. A study in Kiambu District of Kenya showed that farmers used pesticides regularly (primarily on coffee) but frequently mishandled them (Mwanthi and Kimani, 1989). On large-scale estates in the same area, Partow (1995) reported recently that mishandling of pesticides was still common. These qualitative studies showed, what is commonly accepted in Kenya (IDRC, 1989), that actual pesticide handling and usage practices are poor and are likely to be causing exposure and adverse health effects.

In the high agricultural-potential areas of central Kenya, pests and diseases are major constraints to agricultural production. Farmers in this area frequently use pesticides on a variety of crops (primarily, coffee and horticultural crops) and animals. In order to establish practical methods for minimizing excess pesticide exposures among small-scale farms in this area, a multi-part study was established. This chapter reports on the first phase, to document current pesticide usage and handling practices and relate them to agricultural management practices. Subsequent phases will quantify pesticide levels in humans and the environment and relate high chemical levels to pesticide handling and usage practices and other risk factors. These findings will then provide the basis for programmes to advise farmers on more effective methods in safe-handling of pesticides in this area.

2.2 MATERIALS AND METHODS

2.2.1 Study area

Kibirigwi Irrigation Scheme of Kirinyaga District is situated 140 km north west of Nairobi. The scheme is on a flat open ridge between two valleys and measures approximately 9 km long by 1 km wide. It covers an area of about 482 ha of which 90 ha are irrigated. The area is divided into 3 administrative sections. Section one has 92 farms, section two has 104 farms and section three has 86 farms. The average farm size is 1.7 ha. All farms are privately owned by individual farmers. An irrigation scheme was inaugurated in 1980. Necessary infrastructure for water distribution was provided and each farmer was allocated two sprinklers with which to irrigate up to 0.4 ha of land.

The area has a bimodal rainfall pattern with long rains during March to June and short rains in October to December. The mean annual rainfall is about 1290 mm. The soils are fertile, well drained and very deep (Kenya Soil Survey, 1979). Plate 1 shows a crop of beans on one of the farms and Figure 1 shows a map of the study area.

Plate1 .A general view of Kibirigwi with a crop of beans in the foreground

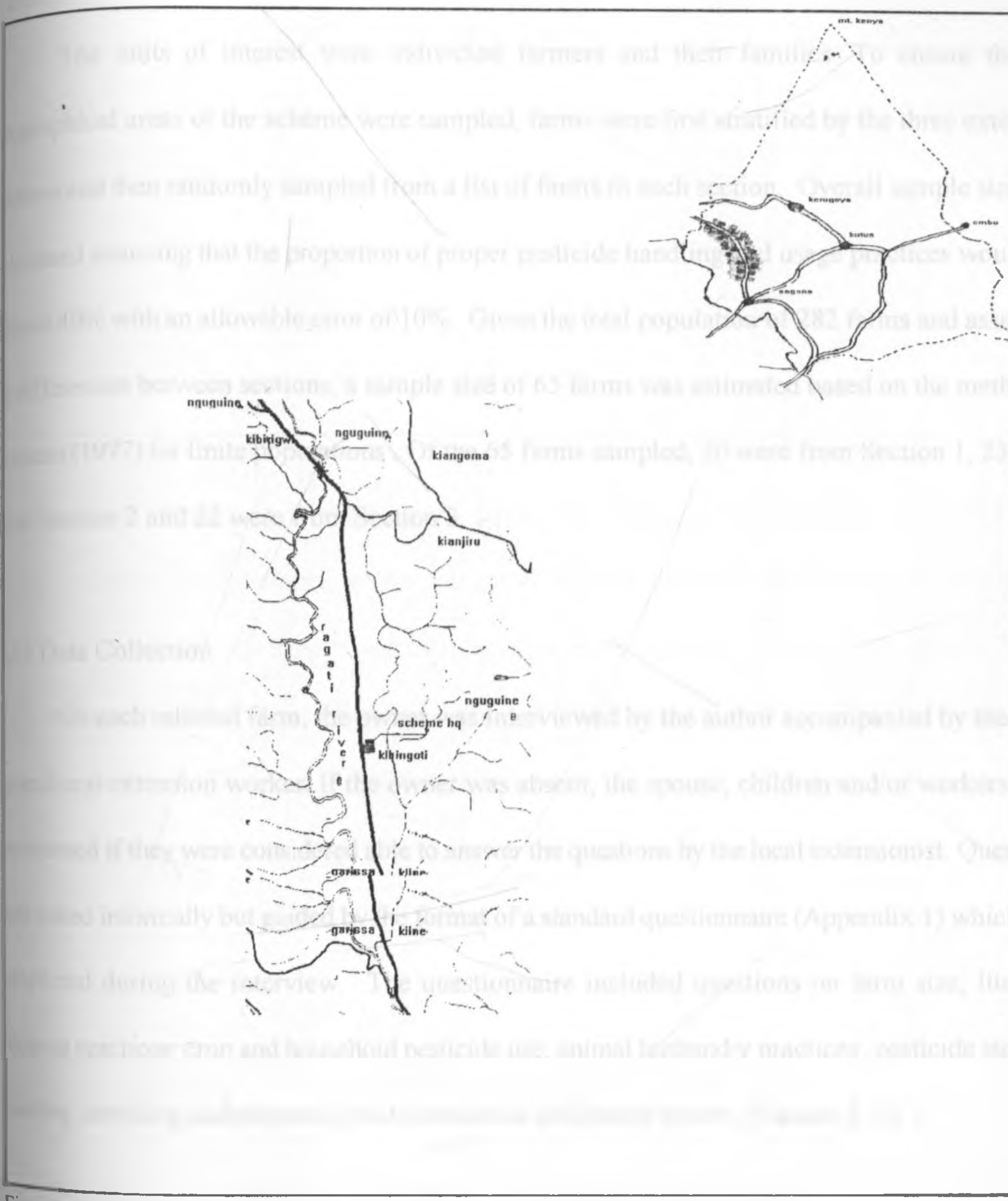


Figure 1:Map of Kibirigwi Irrigation Scheme and inset(Kirinyaga district)

2.2.2 Study design and sample selection

The units of interest were individual farmers and their families. To ensure that all geographical areas of the scheme were sampled, farms were first stratified by the three extension sections and then randomly sampled from a list of farms in each section. Overall sample size was calculated assuming that the proportion of proper pesticide handling and usage practices would not exceed 40% with an allowable error of 10%. Given the total population of 282 farms and assuming no differences between sections, a sample size of 65 farms was estimated based on the method of Cochran (1977) for finite populations . Of the 65 farms sampled, 20 were from Section 1, 23 were from Section 2 and 22 were from Section 3.

2.2.3 Data Collection

On each selected farm, the owner was interviewed by the author accompanied by the local agricultural extension worker. If the owner was absent, the spouse, children and/or workers were interviewed if they were considered able to answer the questions by the local extensionist. Questions were asked informally but guided by the format of a standard questionnaire (Appendix 1) which was completed during the interview. The questionnaire included questions on farm size; literacy; cropping practices; crop and household pesticide use; animal husbandry practices; pesticide storage, handling, labelling and disposal; foods consumed and health history (Section 3.4.4.).

2.3 DATA HANDLING AND ANALYSIS

All questionnaire data were entered into database files (DBase IV, Ashton-Tate,Torrance, CA, USA). After entry, data were checked for missing and out of range values. Descriptive statistics were then calculated using Statistix (Statistix Version 4.0, 1992 Analytical Software, 1958 Eldridge Avenue, MN 55113, USA). Categorical and continuous variables were tabulated and information as to farming practices; pesticides used; pesticide handling, storage and disposal practices; and intervals from pesticide application to harvesting was summarised.

2.4 RESULTS

2.4.1 Description of farms and farming practices

Most of the farms were small, intensive mixed farms raising subsistence crops, cash crops and livestock (Table 2.1). The median farm size was four acres with a range of 0.3-12.3 acres. Farmers were quite experienced, with a median of 14 years experience and a range of 10-28 years. The most important cash crop was french beans, grown for export. Other cash crops grown were kale, cabbage, tomatoes, green peppers, onions, coffee and sweet potatoes. The food crops grown were maize, beans, bananas, and potatoes. Napier grass was grown for livestock. Eighty-six percent of the farmers kept livestock, mostly dairy animals. Chickens (79%), goats (25%), beef cattle (6%), sheep (2%) and rabbits and pigs (3%) were also kept.

Table 2.1
Descriptive statistics for farming practices of 65 farms in Kibirigwi Irrigation Scheme, Kirinyaga District, Kenya, December,1992 - March,1993.

Contihuous variables	Mean	Median	Range
Farm size in acres	4.68	4	4.0-12.3
Number of years farming	13.12	14	10.0-28.0

Categorical variables	Number of farms	Percentage
Off-farm employment/full-time	5	8
part-time	4	6
On-farm	56	86
Subsistence crops		
Maize	50	77
Beans	24	37
Potatoes	6	9
Cash crops		
French beans	43	66
Tomatoes	19	29
Cucumbers	4	6
Onions	10	15
Coffee	13	20
Kales	31	48
Cabbage	19	29
Carrot	8	12
Green pepper	3	5
Others (sweet potatoes and bananas)	38	58
Livestock		
Dairy	56	86
Beef cattle	6	9
Goats	25	38
Sheep	2	3
Chickens	51	78
Other (rabbits and pigs)	3	4

2.4.2 Pest Control Methods

Pest and diseases were considered a major constraint with 85% of the farmers using chemical pesticides on either crops or animals. A total of 55 pesticide formulations were used or stored and included: organochlorines, organophosphates, permethrins, cypermethrins, dithiocarbamates and other groups. The ten most commonly used pesticides are shown in Table 2.2 and all pesticides reportedly used in the Scheme are listed in Appendix 2. Farmers obtained their pesticides from local shops (62/65), from the coffee cooperative society (15/65), the scheme's society (9/65), other farmers (3/65) and from salesmen (2/65).

Pesticides were often used in an unregistered manner. Carbosulfan was used on tomatoes though it is registered for use only on coffee, in nurseries and in orchards. Endosulfan is registered for cotton, maize, wheat, barley, coffee and for army-worm control. However, it was used on kale, cabbage, maize and french beans. The common formulations of dimethoate and benzimidazoles were unregistered by the Pest Control Products Board but were widely used.

Non-chemical pest control methods were also used. For example, crop rotation was widely practised (60/65). Non-pesticide pest control methods were used by 20/65 farmers. The most common one was applying ash to the soil at planting (8/20), followed by the use of soil to control maize stalkborer (5/20), manual removal of infected plants (4/20), not planting in infected or infested fields (4/20) and seed dressing (1/20). Other agronomic practices that could reduce pest problems were also used. For example, mulching was practised by one-fifth of the farmers (13/65) and intercropping by more than half (44/65). Maize/bean intercrop (37/44) was the most common. Other mixtures were sweet potatoes and maize (1/44), kale and cabbage (1/44), coffee and vegetables (1/44) and french beans and maize (1/44) and unspecified (3/44).

Table 2.2 The ten commonly used pesticides in Kibirigwi Irrigation Scheme, Kirinyaga District, December,1992-March, 1993

Pesticide	Ma	Be	Fb	To	Cu	On	Co	Ka	Ca	Car	Po	Gp	Ot	Recommended Crops
Dimethoate	+	+	+	+	+	+	-	+	+	-	-	+	+	unregistered
Mancozeb	-	+	+	+	-	+	-	+	+	-	+	-	-	potatoes,tomatoes tobacco,onions,cucumbers beans
Cypermethrin	+	-	+	+	-	-	-	+	+	-	-	+	+	beans,vegetables,fruits,armyworms, locusts
Triforine	-	-	+	+	-	-	-	-	+	-	-	-		horticultural crops,ornamentals
Benzimidazole	-	-	+	-	-	-	-	-	+	-	-	-		unregistered
Carbofuran	+	+	+	+	-	+	-	-	+		-	-		rice,bananas,fieldbeans,pyrethrum, pineapples,maize,coffee.
Mancozeb	-	-	+	-	-	-	-	+	+	-	-	-	-	horticultural crops, ornamentals
Carbosulfan	-	-	+	-	-	-	-	-	-	-	-		-	preplant on maize
Deltamethrin	-		-	+	-	-	-	-	+	+	-	-		cotton,coffee,horticultural crops.[illegible]trees.
Endosulfan	+	-	+	-	-	-	-	+	+	-	-	-	-	cotton,maize,wheat,barley tea,coffee,armyworms.

Key

Crops

Ma-Maize	Co - Coffee	+ used
Be-Beans	Ka- Kale	- not used
Fb-Frenchbeans	Ca- Cabbage	
To-Tomatoes	Car- Carrots	
Cu-Cucumbers	Po- Potatoes	
On-Onions	Gp- Green pepper	

2.4.3 Pesticide handling practices

Pesticide handling practices are listed in Table 2.3. All farmers used knapsack sprayers. Five farmers did not have their own sprayer but borrowed from neighbours within the scheme. Of the 60 sprayers examined, ten had no leaks, 40 had minor leaks and 10 major leaks. Forty-three farmers had protective clothing though no farmer had a full set of protective clothing.

Fifty-four farmers stored pesticides inside their houses. The total unlabelled and mislabelled pesticides exceeded the ones with intact manufacturers' labels (Table 2.3). Forty-two packages had complete manufacturers labels and 37 did not have labels. Fifteen had been repacked into containers which originally contained a different pesticide.

Table 2.4 shows the recommended and observed pre-harvest intervals for ten commonly used pesticides and the crops on which they were applied. In 9 of 10 crop-pesticide combinations, the observed pre-harvest interval was shorter than recommended. Preharvest intervals were not obeyed for mancozeb, cypermethrin, triforine, carbofuran and deltamethrin. Carbosulfan is only recommended as a soil treatment but the farmers sprayed it on beans and observed a pre-harvest interval of 7 days. Thiodan was also not used according to its recommendation (Table 2.4).

Table 2.3
Pesticide usage practices among 65 smallholder farmers in Kibirigwi Irrigation Scheme, December-March, 1993.

Practice	Number	Percentage
Sprayer status[a]		
secure	10	17
minor leaks	40	67
major leaks	10	17
Protective attire[b]		
none	22	34
some	43	66
- gloves	2	3
- head cover	4	6
- masks	4	6
- apron	18	28
- old clothes	14	22
- boots	5	8
Pesticide storage		
house - secure container	6	9
- loose	49	75
outside house	20	31
Pesticide containers[b]		
manufacturers package	42	65
unlabelled package	37	57
mislabelled	15	23
Container disposal		
disposed	46	71
reused - other chemicals	5	8
- water or food	1	1
Not disposed\not reused	13	20

[a] only 60 farmers owned sprayers
[b] more than one response per farm was possible

Table 2.4
Recommended and Observed Preharvest Intervals (days) for ten pesticides commonly used in Kibirigwi Irrigation Scheme, December, 1992-March, 1993.

Pesticide	Crop	Recommended Preharvest Interval(d)	Observed Preharvest Interval(d)
Dimethoate	Beans/kale	14	14
Mancozeb	Tomatoes	7	3
Cypermethrin	Beans	3	1
Triforine	Beans	14	3
Benzimidazole	Beans	7	3
Carbofuran	Beans	45	42
Propineb	Tomatoes	7	3
Carbosulfan	Beans	na[a]	7
Deltamethrin	Beans	7	3
Thiodan	Beans/kale	28	7

a- Not applicable. Pesticide recommended as a soil treatment only.

2.5 DISCUSSION

There is an overreliance on pesticides among the farmers. In most cases, pesticides were applied routinely even when pests were not observed. Most farmers had a supply of pesticides even when they were not using them. For example, during an inventory carried out to assess the pesticide storage methods and the types of pesticides stored, it was found that only five farmers out of 65 did not have a pesticide, while 39 had 3 or more types and 2 farmers had more than 10 types. Handling practices were poor and thus adverse health effects among the farmers were likely.

Fifty-eight formulations were found including some restricted pesticides such as dieldrin, aldrin and carbosulfan. The major chemicals used were dimethoate, an organophosphate and cypermethrin, a synthetic pyrethroid. However, many other organophosphates were used such as diazinon, omethoate, fenitrothion and ethion. Organophosphates are among the most toxic classes of pesticides in use. Most are classified as either moderately or highly hazardous according to the WHO Classification by Hazard (Copplestone, 1982). Most of these pesticides were stored in houses and therefore exposure could occur from contamination of indoor air.

The situation in Kibirigwi appears similar to that reported by Mwanthi and Kimani (1989) for Githunguri Division of Kiambu District. Though the number of different pesticides used were not reported, pesticides were used in all households of 6 villages visited, half of them all year round. In addition, 1368 of 1769 households had pesticides stored either in the sleeping area or the food store.

Procedures used for mixing of pesticides prior to application were also likely to lead to exposures among farmers. Pesticides were mixed inside the knapsack either by agitating the tank or stirring with a stick. Splashing could easily occur. When measuring concentrated chemicals, protective gloves were not worn. It has been shown that exposure to farmers occurs during handling, mixing and filling the concentrated formulation into the spray equipment and that this is a more serious exposure source than spraying, since during spraying , the pesticide mixture is already diluted (Coults, 1980). During mixing, hands are the most frequently exposed body part (Al Jaghbir **et al**, 1992). Given that farmers mixed pesticides with bare hands, they were likely to get exposed by that route.

The use of gloves and a daily change of clothing usually reduces exposure to pesticides considerably (Lamb, 1980). Furthermore, it has been shown that farmers working in the fields are exposed to pesticides through the dermal route than through either inhalation or ingestion (Coults, 1980). In Kibirigwi, farmers were found to spray pesticides while wearing their regular clothing. Only a small number removed their clothing after work. Therefore, they were likely to be exposed to pesticides even after the spray period was over. Davies **et al.** (1980) reported that pesticides penetrate clothing and that removal of contaminated clothing in the shortest possible time has a significant effect on penetration of the pesticide into the body.

During spraying, exposure would be mainly from leaking sprayers. Only 10 of 60 sprayers observed were secure. Baker **et al**. (1978) observed that the integrity of the sprayer used was an important risk factor for exposure among malaria sprayers in Pakistan. Leaking sprayers caused exposure to the hands, arms and chest. In this study , farmers were also likely to be exposed in the same way. Dimethoate, the most commonly used pesticide, is soluble in water (25,000 mg/l at 21C) (British Crop Protection Council, 1987) and easily penetrates skin. Tsuruta (1975) reported that the solubility of a chemical and its absorption rate into the skin are positively correlated. This view has been opposed by Dedek (1980), but the two workers agreed on one point; dimethoate is absorbed faster through the skin than trichlorphon which is more soluble in water than dimethoate.

Farmers did not read label instructions and therefore used pesticides indiscriminately.

Furthermore, more than half the pesticides were either mislabelled or unlabelled. Thus, pesticides were frequently misused. For example, carbosulfan was used as foliar spray on beans in disregard of government recommendation that it should be used as a preplant treatment for maize, nurseries and in orchards only. Endosulfan was used on kale and cabbage though it is only recommended on crops to be harvested more than 28 days after spraying (PCPB, 1993). After spraying their crops, farmers disregarded pre-harvest intervals for a number of crops. After application of endosulfan on kale and cabbage, harvesting occurred within 7 days. These leaf crops have a high surface/volume ratio and thus have a greater concentration of residues than crops with a lower ratio (Spear, 1991). Thus exposure from eating contaminated kale and cabbage was quite likely.

Carbosulfan is a toxic carbamate with a low ADI of 0.005 mg/kg body weight (BCPC, 1987). In the United States, registration has been pending since the 1970s. In many other countries it is only recommended as a soil treatment. Farmers and their families are likely to get exposed to carbosulfan on eating beans sprayed with the pesticide.

Farmers re-entered sprayed fields to harvest without regard for the pre-harvest interval. They were, therefore, likely to contaminate themselves with sprayed foliage. Women workers were found to re-enter treated fields at any time regardless of when the last spray was applied. Elsewhere, it has been found that harvesters may be exposed to pesticides in this way (Ritcey **et al**, 1987), and in some cases get sick (Milby **et al**, 1964).

Pesticides were stored in the houses and only a small proportion were securely stored. This would facilitate the spreading of fumes from the chemicals throughout the house. Exposure to contaminated indoor air can lead to illness. In a study in the United States of America, English **et al.** (1970) reported that three week old twins were treated for laboured breathing after being in a house neighbouring to one where diazinon had been applied the day before. A number of pesticides that are commonly used and stored in the scheme were emulsifiable concentrates. These include dimethoate, diazinon, various cypermethrin formulations and fenitrothion. These pesticides are usually dissolved in hydrocarbon solvents which are volatile at room temperature thus making contamination of indoor air likely and posing hazard to the occupants of these houses. Another common unsafe practice was the storage of pesticides in containers meant for food. Eight farmers had stored pesticides in soft drink bottles, 3 in whisky bottles, and one in a beer bottle. This practice is dangerous and could lead to serious poisoning.

A high proportion of farmers disposed of their empty containers (46 of 65), but the rest of the farmers reused them to buy pesticides and one reused them for domestic purposes. The use of pesticide containers for domestic purposes has led to death from poisoning in other parts of the world. For example,in Jamaica, a bag of pure methomyl powder that was left in a baking tin and mistakenly used to prepare a meal made six people severely ill out of which 3 died (Davidson **et al**., 1977). In addition, farmers often did not refill the container with the same pesticide that was contained in the package before. This may lead to wrongful usage of pesticides, especially in cases where the two pesticides are vastly different and have different uses. It was found that farmers frequently forgot what was in containers, especially if the label was lost or damaged due to handling with wet hands in the process of mixing the pesticide with water.

The farmers placed a lot of emphasis on chemical methods of pest control. The safer non-chemical methods were rarely used. There were, therefore major opportunities for exposure. Farmers reported various adverse health effects associated with pesticides usage. However, due to the large number of pesticides handled and poor definition of exposures, it is difficult to pinpoint actual pesticides associated with various adverse health effects. Subsequent phases of this study will investigate the specific exposure of sprayers and field workers to dimethoate and cypermethrin, the most frequently used pesticides, in order to determine what practices were associated with high exposure levels. The information obtained from these studies will help in advising farmers on sources of exposure and what safe use practices could reduce these exposures. If the farmers are to continue to benefit from pesticide usage, improved practices such as: choosing safer chemicals, using protective clothing when mixing and spraying and proper storage and disposal of pesticides are needed to reduce the risks of contamination and exposure to pesticides.

2.6 CONCLUSION

It was concluded that the farmers in Kibirigwi Irrigation Scheme were handling pesticides unsafely and may be adversely affected by pesticide exposure. Lack of sufficient information on labels and not reading the available information led to misuse of pesticides. Since most farmers did not wear protective clothing when mixing and spraying pesticides, they were likely to be exposed. Leaking sprayers would lead to exposure on both the hands and the rest of the body. Household exposure due to poor storage and eating contaminated food are expected to be sources of exposures for farmers and their families since pre-harvest intervals were unknown. Applicators and women workers may be exposed during normal farm operations such as weeding and harvesting.

CHAPTER THREE

STUDIES TO DETERMINE PESTICIDE EXPOSURE AND RELATED HEALTH EFFECTS IN KIBIRIGWI IRRIGATION SCHEME.

ABSTRACT

Studies to investigate the extent of household pesticide exposure among farmers in Kibirigwi Irrigation Scheme were carried out between September,1992 and August,1995. Forty table swab samples were collected from 40 randomly selected homes in the scheme to assess household pesticide contamination. Dimethoate, malathion, fenitrothion, diazinon, chloropyrifos and cypermethrin were detected in these samples. The range of organophosphate pesticides detected was 0.01-8.7 ug/cm^2 of table area and for cypermethrin the range was 0.0024 ng-5.8 ng/cm^2

Thirty-six nursing mothers in the scheme provided milk samples. These were all the breastfeeding mothers in the scheme between March and May, 1993. The milk was analyzed for organochlorine pesticide residues. A wide variety were detected: *p'p'*DDE (100%), β-BHC (69%), γ-BHC (31%), α-BHC(25%), heptachlor (17%), aldrin (8%), *p'p'*DDT (8%), dieldrin (8%), *o'p'*DDT(3%) and DDD(3%). Twenty eight of these samples were also analyzed for organophosphates pesticides. Nine had peaks which were not identified.

Eighty bean samples were collected from 40 farms on two dates and analyzed for dimethoate, omethoate and cypermethrin residues. Mean residues detected were 0.17 ppm, 0.02 ppm and 2.1 ppm for dimethoate, omethoate and cypermethrin respectively.

The health status of members of sixty-five randomly selected farms in the Scheme was investigated. Questions on health status of all family members were asked informally guided by the format of a questionnaire. Twenty farmers reported serious health problems in the year preceding the study period. The common ailments were backache, stomach upset, headaches, skin problems and diabetes. Twenty-six farmers had complaints which they associated with handling and spraying pesticides. These were coughing/sneezing/cold symptom (7), eye irritation (4),swellings (3), chest pain (3), stomach upset (2), fatigue (2), dizziness (1), diarrhoea (1) and uneasiness(1).

3.1 INTRODUCTION

Increased agricultural production has been attributed to pesticide usage in many parts of the world. However, undesirable environmental and health effects have resulted from pesticides particularly when mishandled (WHO, 1988). Both ordinary people and agricultural workers may be exposed. In Kenya, the few qualitative studies carried out reported that pesticides are frequently mishandled and storage practices are poor (Mwanthi and Kimani, 1989., Partow, 1995). The extent of household exposure has rarely been assessed.

Elsewhere, household pesticide exposures have been reported to occur. The most important source of exposure has been eating contaminated food (Spear, 1991). Reports abound of the fatal effects of eating food contaminated with pesticides (e.g. Mackerras **et al**., 1946; McGee **et al**., 1952; Baron and Merriam, 1988). In the incident reported by McGee and coworkers, four people ate collards that had been sprayed with toxaphene in the United States. One person died.

Contamination of indoor air has often had serious consequences for occupants. In some instances, contamination has resulted from a planned application to control indoor pests. This was the case in an episode reported by Taya **et al**. (1976) where interior surfaces of a house were sprayed with fensulfathion. Five inhabitants got sick and one died. In other cases, however, contamination may occur accidentally and residues of compounds may be absorbed dermally from contaminated surfaces (Spear, 1991).

In Kibirigwi, pesticides are used in agriculture and for domestic and veterinary purposes. In other areas where pesticides are widely used, it has been shown that the general population may also be affected by pesticides. For example, residues of pesticides have been detected in the general population both in other parts of the world (e.g. Frank **et al**., 1988) and in Kenya (Wasserman **et al**., 1972). Since pesticides are widely used in Kibirigwi Irrigation Scheme, the general population as well as sprayers are likely to be exposed. This study was carried out to assess the extent to which pesticide contamination occurs in homes and what are the likely sources of this contamination. Analysis of breastmilk samples was done to assess contamination of mothers with persistent pesticides. A survey of health status among occupants of farming households was carried out to assess the extent of pesticide related health effects among occupationally and non-occupationally exposed people in the scheme.

3.2 MATERIALS AND METHODS

3.2.1 Study Area and Population

The study area is described in Section 2.2.1. The study population involved in the health study were from the 65 randomly selected farms. For each farm selected, the head of the house was interviewed for information on all members of the household.

In the breastfeeding study, all mothers in the scheme who were breastfeeding between March and May, 1993 were recruited. There were thirty-six such mothers aged between 17 and 40 years. Their parity was between 1 and 7 children.

3.2.2 Sample Collection

Table swab samples

Table swab samples were collected from 40 randomly selected farms.The method was as follows: Fifty cotton cloth samples measuring 30 cm*30 cm were prepared in the laboratory and soaked in methanol two days before the date of sampling to ensure that they were completely saturated with the solvent. In each sampled homestead, the table used for meals was swabbed with a piece of cloth held with a pair of tongs by a person wearing gloves. The cloth was then placed in a wide-mouth glass jar. A piece of aluminium foil was placed below the cap to avoid any contamination from the plastic cap. The sample was placed in a coolbox with ice packs until stored in a deep freezer in the laboratory. A control cloth handled in the same way as the samples except for swabbing was also analyzed. Information on which pesticide (s) was recently handled in the home and when were also recorded.

Collection of Mothers Milk Samples

Milk samples were manually expressed by mothers into 40 ml Supelco'jars with Teflon-lined caps. The samples were placed in a cool box with ice packs, taken to the laboratory and stored at _18^{0}C until analysis. Information on age, parity and the general health of the mother was recorded.

Collection of bean samples

Bean samples were collected on two occasions from each of 40 randomly selected farms. Samples were harvested during a study to assess for pesticide contamination when harvesting sprayed plots. Each farmer was asked to harvest from his plot for five minutes and the sample placed in a plastic bag, labelled and placed in a cool box with icepacks and taken to the laboratory where they were stored at -18^{0}C until analysis.

Health Status Survey

The author was accompanied by the local extension officer on all farm visits. Sixty-five farmers were interviewed by the author informally, following the format of a questionnaire prepared beforehand (Appendix 1). As part of the larger questionnaire, farmers were asked to provide information on the health status of household members.

3.2.4. Laboratory Methods

Calibration of standards

Dilutions of dimethoate, omethoate, malathion, diazinon, fenthion and chloropyrifos standards (British Greyhound Chromatography and Allied Chemicals Birkenhead, England) were prepared from initial stock (concentration of 1000 ppm) to 1 ppm, 0.5 ppm, 0.25 ppm and 0.1 ppm of each standard. These were injected into the GLC using the conditions described below, and calibration curves prepared.

Extraction of table swab samples.

The extractions were carried out according to a procedure described in the Pesticide Analytical Manual (1973) and later used by Ritcey **et al** (1987). Immediately on arrival at the laboratory, each sample was soaked in 200 ml dichloromethane then placed in the deep freezer overnight. The following day, the cloth and dichloromethane were transferred into 500 ml conical flasks with small rinsings of dichloromethane. They were extracted in the same solvent by shaking on a Burrel wrist shaker for one hour at a setting of 3. The solvent was filtered into a Buchner flask through a sintered borosilicate funnel under vacuum. The contents were then transferred into a 500 ml round-bottomed flask together with small rinsings of the Buchner funnel. The dichloromethane was evaporated to just dryness on a rotary evaporator at 50 °C. The extract was dissolved in 5 ml hexane and the sample was transferred to a 7.4 ml Supelco[R] bottle with a Teflon[R] lined cap for analysis for organophosphate pesticides. A portion of each sample was later cleaned-up for analysis of cypermethrin as described below.

Extraction of bean samples

Samples were extracted according to a procedure described by Braun and Stanek (1982). A bean sample weighing 12.5 g was blended in 125 ml of 2:1 acetonitrile water for 5 minutes in a blender. This extract was placed in a separatory funnel and diluted with 500 ml distilled water and 25 ml saturated sodium chloride solution and partitioned twice into 50 ml of dichloromethane. The extract was dried by passage through anhydrous sodium sulphate into 500 ml round-bottomed flasks. The dichloromethane extract was dried on a rotary evaporator to just dryness and re-dissolved in 5 ml iso-octane. This was transferred to 7 ml Supelco[R] Teflon-lined tubes for analysis of dimethoate and omethoate. Samples were also later cleaned-up for analysis of cypermethrin residues.

Clean-up of bean and table swab samples

Clean-up was done using the microlitre method. One ml of sample was used for clean-up and a pasteur pipette was used as the column. A small piece of hexane washed cotton wool was inserted in the column and the column was packed with 0.2 g of preheated florisil (135° C overnight) and a small portion of anhydrous Na_2SO_4 added on top. The column was prewashed with 1 ml of hexane and 1 ml of the hexane extract introduced into the column. The column was then eluted with 5 ml acetonitrile:dichloromethane:hexane (0.35 : 50 : 50) at a small dropwise rate The eluate was collected in 10 ml boiling flasks and evaporated to just dryness on a rotary evaporator at 50 ^{0}C and redissolved in one ml of hexane. The final extract was placed in 7.4 ml Supelco^R tubes with Teflon lined caps. All samples were stored at -18^{0}C until analysis.

Extraction, Clean-up and Analysis of Mothers Milk Samples for organochlorine pesticide analysis.

Samples were extracted using a procedure described by Brevik (1978) and modified by Kanja **et al.** (1986). 10 ml samples of milk were extracted with acetone (15 ml) and n-hexane (20 ml) by ultrasonic disintegration. The extraction was repeated with 5 ml and 10 ml acetone and n-hexane respectively. The hexane was evaporated in a gentle stream of nitrogen in a sand bath and the fat content was determined. The fat was redissolved in n-hexane (0.05 g fat/ml hexane). Two aliquots, each 1 ml, were used in the clean-up. One aliquot was treated with 2 ml of concentrated sulphuric acid and the second one with 2 pellets of potassium hydroxide, 0.1 ml of distilled water and one ml of absolute alcohol. The aliquots were centrifuged at 300 r.p.m for 5 minutes. The clear hexane extracts were made up to 5 ml with hexane, evaporated on a rotary evaporator to just dryness and redissolved in 5 ml hexane. The final extract was collected into 7 ml Supelco tubes ready for analysis of organochlorine pesticides on the gas chromatograph. Detection was done on a ^{63}Ni electron capture detector on a gas chromatograph Packard model DX 12362 Series 428 with the following parameters and operating conditions: Detector temperature at 300^{0}C; Injector temperature at 240^{0}C; Glass column 1.5 m* 2 mm i.d packed with 1.5% SP-2250/1.95% SP-2401on Supelcort 100/120 mesh at 200^{0}C, carrier gas, nitrogen at a flow rate of 30 ml/min.

Analysis of bean, table swab and milk samples for organophosphate pesticides.

Bean samples were analyzed for dimethoate and omethoate residues. Table swab and milk samples were analyzed for a variety of organophosphate pesticides commonly used in the scheme. These included dimethoate, omethoate, malathion, diazinon, chloropyrifos, fenitrothion and fenthion.

All the analyses were done on a Flame Photometric Detector on the Gas Chromatograph Model Varian 3400 on a capillary column (Capillary Column J & W Scientific : Length 15 m, i.d. 0.54 mm and 1.5 microns thickness) and equipped with an integrator Model Varian 4400. The conditions were as follows: column temperature 150^{0}C to 250^{0}C at 20^{0}C per min; injector temperature 230^{0}C; detector temperature 250^{0}C; and gases used were nitrogen, hydrogen and air at flow rates of 40 ml/min, 60 ml/min and 250 ml\min. respectively. Milk samples were also analyzed on the Gas Chromatograph\Mass Spectrometer.

Analysis of bean and table swab samples for cypermethrin

Analysis was done on an ^{63}Ni Electron Capture Detector on the Gas Chromatograph Model Varian 3400 with a capillary column (Capillary Column J & W Scientific : 15*0.25 mm i.d., 0.25 microns film thickness) and equipped with an integrator Model Varian 4400. The conditions were as follows: column temperature 200^{0}C to 280^{0}C at 20^{0}C per min; injector temperature 230^{0}C;detector temperature 300^{0}C and gases used were Nitrogen and air at flow rates of 40 ml/min and 30 ml/min respectively.

Injections were done manually using a 5 µl Hamilton syringe (Microlitre^R 7105 ul syringe). Before the samples were injected, 2 µl of dimethoate and omethoate standards were injected several times to confirm stable peak area and retention time. Then the same volume of sample was injected. The same procedure was followed for cypermethrin standards and samples.

3.3 DATA HANDLING AND ANALYSIS

Data were entered into database files (DBase IV, Ashton-Tate, Torrance, CA, USA) and checked for out of range values. Statistical analysis were carried out in Statitix (Statistix Version 4.0, Analytical Software, 1958 Eldridge Avenue, MN 55113, USA) and BMDP(BMDP Statistical Software 1440 Supelveda Boulevard LA, CA 90025). For table swab data descriptive statistics for diazinon, malathion, dimethoate, chloropyrifos, fenitrothion and cypermethrin levels were calculated. An assessment of risk factors table area swabbed, pesticides said to have been handled and the number of days since a pesticide was handled for total pesticide detected was carried out using linear regression.

Descriptive statistics of variables in the breastmilk study (age, parity of the mothers and percent fat of the milk) were calculated and linear regression of sum DDT on the risk factors listed above was also carried out. In addition, the Estimated Daily Intake (EDI) of the different organochlorine pesticides detected in mothers milk were calculated and compared with the Acceptable Daily Intake (ADI) (FAO/WHO).

The descriptive statistics of variables in the bean residue study were calculated for dimethoate, omethoate and cypermethrin. Linear regression on risk factors associated with residues in beans (days between spraying and harvesting, area harvested, age and sex of the harvesters) was also done.

3.4 RESULTS

3.4.1 TABLE SWAB STUDY

Twenty-three of the 40 table swabs contained pesticides (Table 3.1). The range of concentrations was 0.08-8.7 ug/cm^2. Organophosphates detected were: malathion (9/40), diazinon (5/40), dimethoate (4/40), chloropyrifos (4/40) and fenitrothion (1/40). The highest amount of pesticide detected was fenitrothion, detected in one sample (45.1 ppm). Seventeen samples contained no detectable pesticides.

Comparisons of means for each pesticide showed that the means were significantly different from one another apart from dimethoate and malathion.

The results of the linear regression of total pesticide on three predictor variables (table area, days since pesticides were last sprayed and the pesticides that the farmers said they had handled) was done. None of these variables were significantly associated with level of pesticide detected.

Farmers had handled different formulations of cypermethrin (7/41), deltamethrin (2/41), fenvalerate (1/41) and lambdacyhalothrin (1/41). Table 3.2 shows descriptive statistics of the 40 homesteads sampled and the amount of cypermethrin detected in the samples. Nine samples contained residues. The mean was 1.36 ug/patch and the range was 0.06-36.66 ug/patch. No other pesticides were detected. Samples collected from those farmers who had handled pesticides less than 7 days before the sampling had more residues than those who had handled them later than that. Swabbing larger table areas also led to more residues. There was a general declining trend in mean residues as the days between handling and sampling increased (Figure 1). The highest point was censored in this figure.

An assessment of risk factors table area swabbed, days since the pesticide was last handled and the number of farmers who had handled cypermethrin before the study for total cypermethrin was carried out using linear regression. None of these factors was significant.

Table 3.1
Descriptive statistics for discrete and continuous variables associated with the amount of pesticides recovered by table swabs from 40 forty farmers' houses in Kibirigwi Irrigation Scheme, Kenya, July, 1995.

			ug/900cm^2 cloth	
Variable	Category	Number	Mean	S.e
Pesticide detected	Diazinon	5	3.91	3.23
	Dimethoate	4	9.72	9.29
	Malathion	9	7.25	5.66
	Chloropyrifos	4	0.30	0.08
	Fenitrothion	1	45.1	na
	None	17	na	na
Days since last handled	<7	18	2.40	2.07
	>7	22	5.77	3.07
Table area swabbed (cm^2)	<5580	12	0.70	0.48
	>5580	28	5.77	2.71

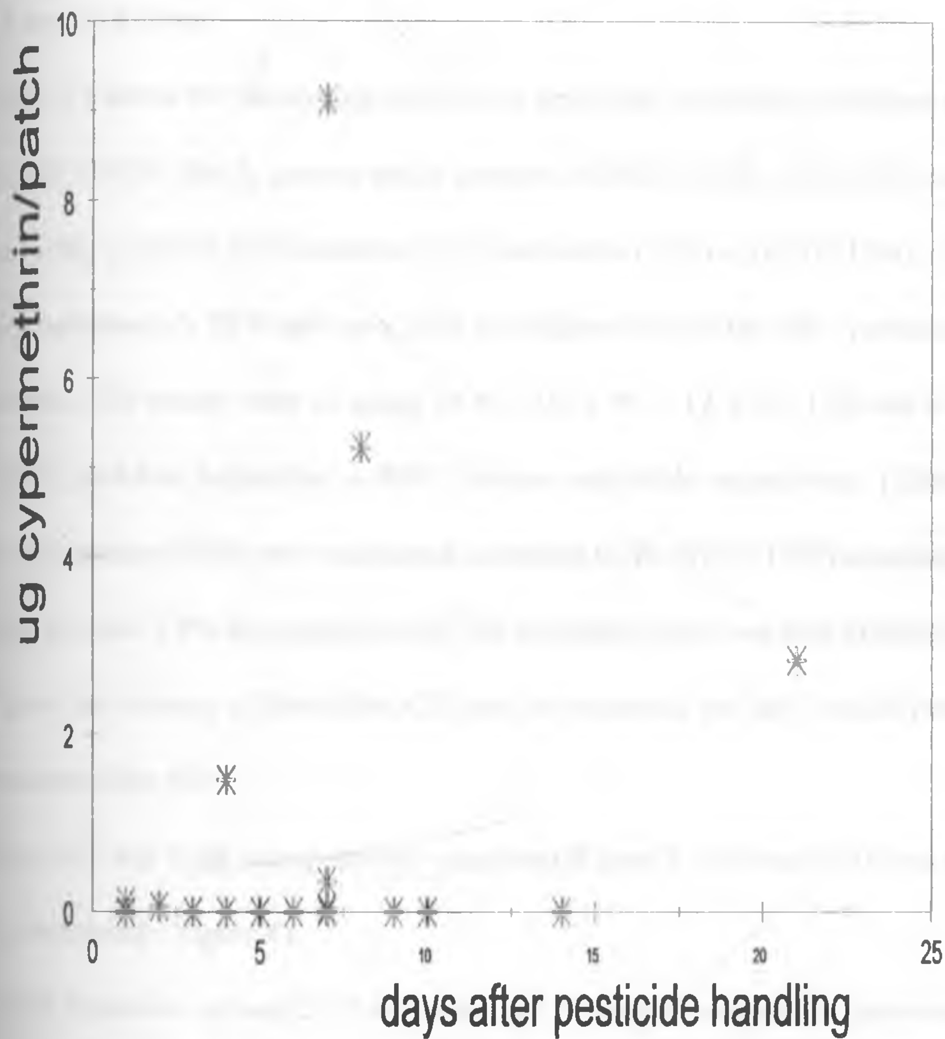
na- not applicable

Table 3.2
Descriptive statistics for variables associated with ug cypermethrin levels collected by table swabs from 40 houses in Kibirigwi Irrigation Scheme, Kirinyaga District, Kenya, July,1995.

			ug/900cm² cloth	
Variable	Category	Number	Mean	S.e
Pesticide detected	Cypermethrin	9	6.21	3.94
	None	32	na	na
Days since last handled	<7	19	2.02	1.93
	>7	22	0.80	0.48
Table area swabbed (cm^2)	<5400	12	0.76	0.76
	>5400	29	1.61	1.27

na-not applicable

Figure 2: Residues of cypermethrin in table swab samples and the number of days since the pesticide was last handled in Kibirigwi Irrigation Scheme, Kirinyaga District, July, 1995.



3 4 2 ORGANOCHLORINE AND ORGANOPHOSPHATES IN MOTHERS MILK.

The mean age of the mothers was 28 years with a range of 17-40 years and a median of 27 years. The mean % of fat in the milk was 4.6% with a range of 2.4-10.1%. Parity ranged between 1 and 7 children.

Table 3.5 shows the various organochlorine pesticides detected in mothers milk. These were *p'p*DDE (36/36), the β, gamma and α isomers of BHC (25/36, 11/36, 9/36 respectively) heptachlor (6/36), *p'p*DDT (3/36),dieldrin (3/36), and aldrin (3/36) *o'p* DDT(1/36), DDD (1/36). All samples contained *p'p*DDE and sum DDT was higher than all the other pesticides detected in the samples. The means were in ug/kg: 46.6, 19.0, 1.99, 1.17, 0.85, 1.40 and 0.41 for sum DDT, β-BHC, dieldrin, heptachlor, α-BHC lindane and aldrin respectively. (Table 3.3). The estimated daily intakes (EDIs) were calculated according to the WHO (1990) assuming an intake of 130 ml/kg b.w and 3.5% fat (Appendix III). The estimated intake was then divided by the ADI and this gave the number of times the ADI may be exceeded per day. For all pesticides, all samples exceeded the ADI.

Sum DDT and % fat were positively correlated (Figure 3) and sum DDT and parity were negatively correlated (Figure 4).

Linear regression of sum DDT on parity, age of the mothers and the percentage weight of fat was done. The proportion of fat in milk was found to be significant (Table 3.4).

Twenty-eight milk samples were extracted and analyzed for organophophates. Nine samples had unidentifiable peaks and 20 had no peaks.The retention time was 5.90min.

Table 3.3
Descriptive statistics of variables associated with ug/kg milk fat pesticide levels in 36 samples of mothers milk from Kibirigwi Irrigation Scheme, May,1993 (wet weight).

	Parity				Age(years)			
	<2.5 (n=18)		>2.5 (n=18)		<27 (n=16)		>27 (n=20)	
	Mean	s.e	Mean	s.e	Mean	s.e	Mean	s.e
Sum DDT	52.1	10.1	41.2	9.6	45.9	8.7	46.4	10.6
p'p'DDE	44.2	8.9	36.4	8.7	41.9	7.9	39.1	9.3
p'p'DDT	1.2	0.9	0.8	0.8	0.5	0.5	1.4	1.0
DDD	0.9	0.9	0.0	0.0	0.0	0.0	0.8	0.8
o'p'DDT	0.7	0.7	0.0	0.0	0.0	0.0	0.6	0.6
β-BHC	22.8	5.8	15.2	4.0	21.5	6.0	17.0	4.2
Dieldrin	0.8	0.8	3.2	2.2	0.9	0.9	2.8	2.0
Hepta-chlor	1.6	1.0	0.7	0.5	1.3	1.0	1.1	0.6
α-BHC	1.0	0.7	0.7	0.3	1.2	0.7	0.6	0.3
Lindane	1.1	0.5	1.7	0.8	1.2	0.5	1.5	0.3
Aldrin	0.4	0.4	0.5	0.4	0.1	0.1	0.7	0.4

Table 3.4
A linear regression model for risk factors associated with sum DDT (ug/kg) in 36 samples of mothers milk from Kibirigwi Irrigation Scl ›me, Kirinyaga District, Kenya, May,1993.

Variable	Coefficient[a]	S.e	P-value
Constant	4.8	17.5	0.79
% fat weight in milk	914.7	356.6	0.01
Parity			0.50
Age			0.57

[a] only coefficients for significant variables are listed

Figure 3: Sum DDT in mothers milk and parity of mothers in Kibirigwi Irrigation Scheme, Kirinyaga District, May, 1993.

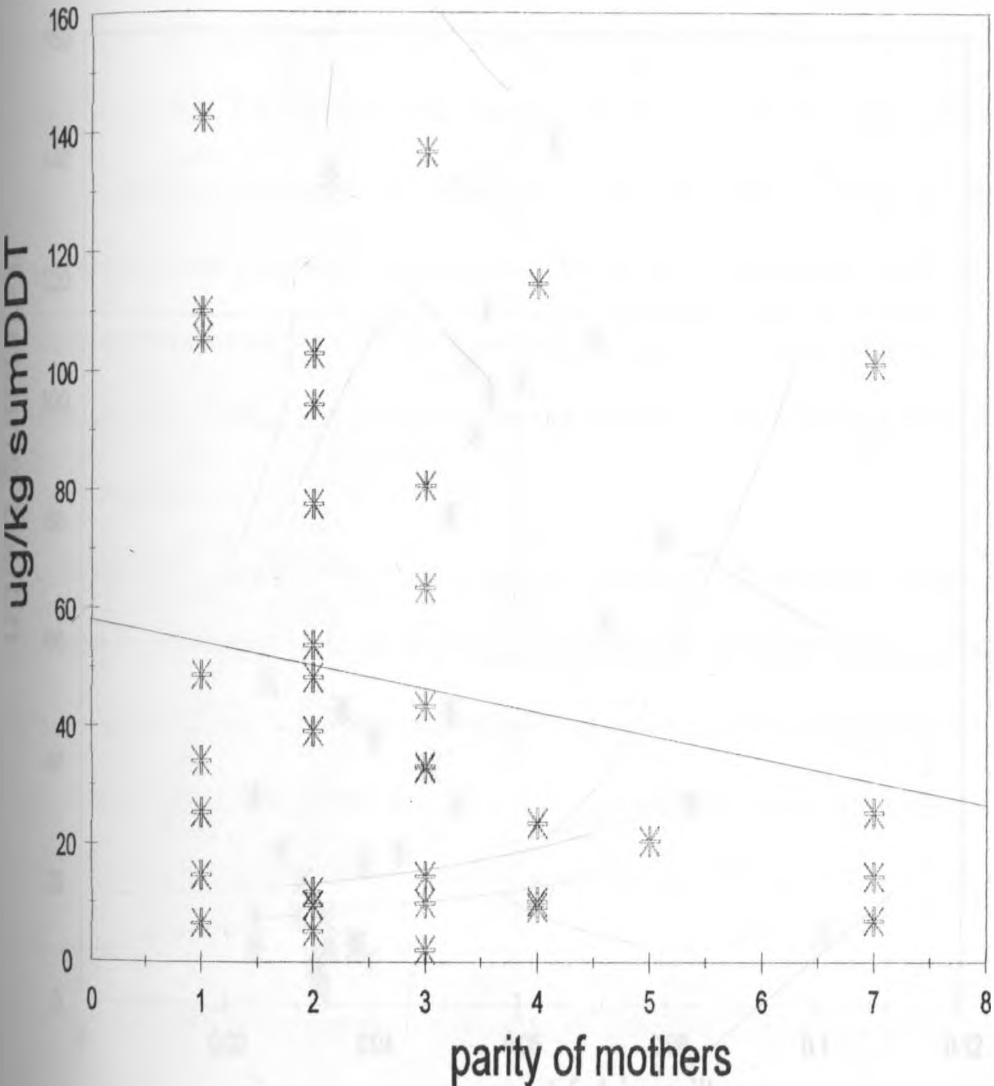
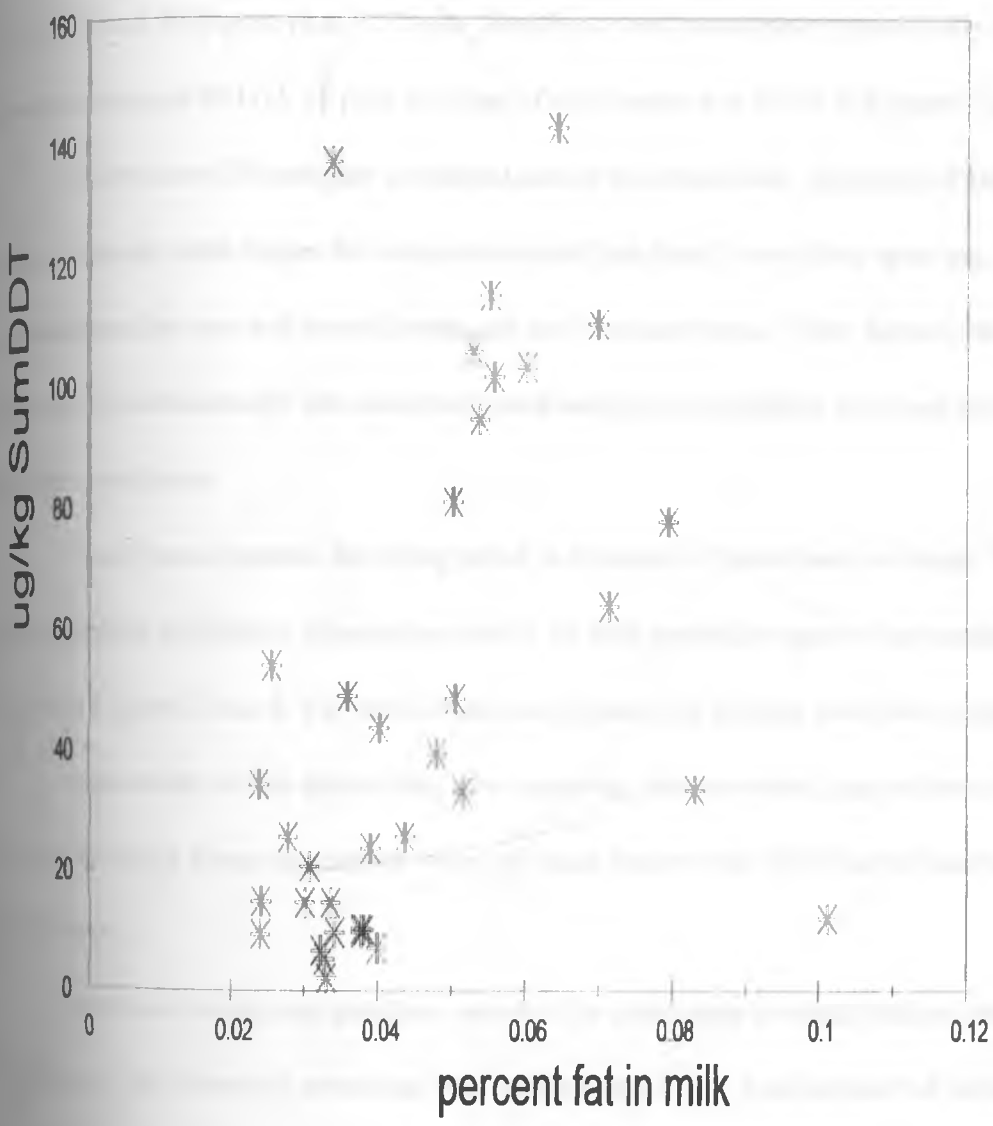


Figure 4: Sum DDT and % fat in mothers milk in Kibirigwi Irrigation Scheme, Kirinyaga District, May, 1993.



3.4.3 RESIDUES IN BEAN SAMPLES

Dimethoate and omethoate

Bean samples contained both dimethoate and omethoate. Mean levels were 0.17 ppm (s.e,0.14) and 0.02 ppm (s.e, 0.01) for dimethoate and omethoate respectively. The range for dimethoate was 0.001-11.25 ppm and that of omethoate was 0.001-0.46 ppm (Table 3.5).

Thirty-one of 80 samples contained one or two pesticides. Residues of both dimethoate and omethoate were higher for beans harvested less than 5 days after spraying. Farmers who harvested smaller area had more dimethoate but less omethoate. Older farmers harvested beans with more dimethoate and less omethoate and samples harvested by men had more dimethoate and less omethoate.

There was a general declining trend in residues of dimethoate in beans. The trend was less defined for omethoate. Dissipation curves for both pesticides against the number of days are shown in Figures 5 and 6. For each of the two figures, the highest point was censored.

Assessment of risk factors days after spraying, area harvested, age and sex of farmers was carried out using linear regression. None of these factors was found significant at 5% level of significance.

Age was a significant predictor variable for omethoate in beans and no other factor was significant. The amount of omethoate was independent of the total amount of dimethoate in the samples.

Cypermethrin

Residues of cypermethrin were detected in bean samples and are shown in Table 3.5. The range was 0.03 - 61.20 ppm and the overall mean was 2.09 ppm (s.e, 0.92). There was a significant difference between the amount of residues picked by older farmers and those picked by younger ones (p=0.1). For male and female farmers there was no significant difference though samples picked by men had numerically higher residues. There was no difference whether beans were picked before or after 6 days, the median number of days. There was slightly higher residues for larger areas picked though the difference was small.

Assessment of risk factors age of farmers involved in harvesting, days after spraying, area harvested and sex of the farmers for total cypermethrin in beans was carried out using linear regression. Age was the only significant variable. Figure 7 shows the residues of cypermethrin in beans and the number of days after spraying. In this graph, the highest level of 61.20 ppm was considered to be an outlier and was censored.

Table 3.5
Mean levels of pesticides detected in 80 bean samples harvested in Kibirigwi Irrigation Scheme, Kirinyaga District, Kenya, August-November,1994 (ppm).

Pesticide	Number	Mean	S.e	Range
Cypermethrin	80	2.09	0.92	0.001-61.20
Dimethoate	80	0.17	0.14	0.001-11.25
Omethoate	80	0.02	0.01	0.001-0.46

Figure 5 : Residues of dimethoate in bean samples and the number of days after spraying, Kibirigwi Irrigation Scheme, Kirinyaga District, August- November, 1994 (the highest point of 11.25 ppm was censored).

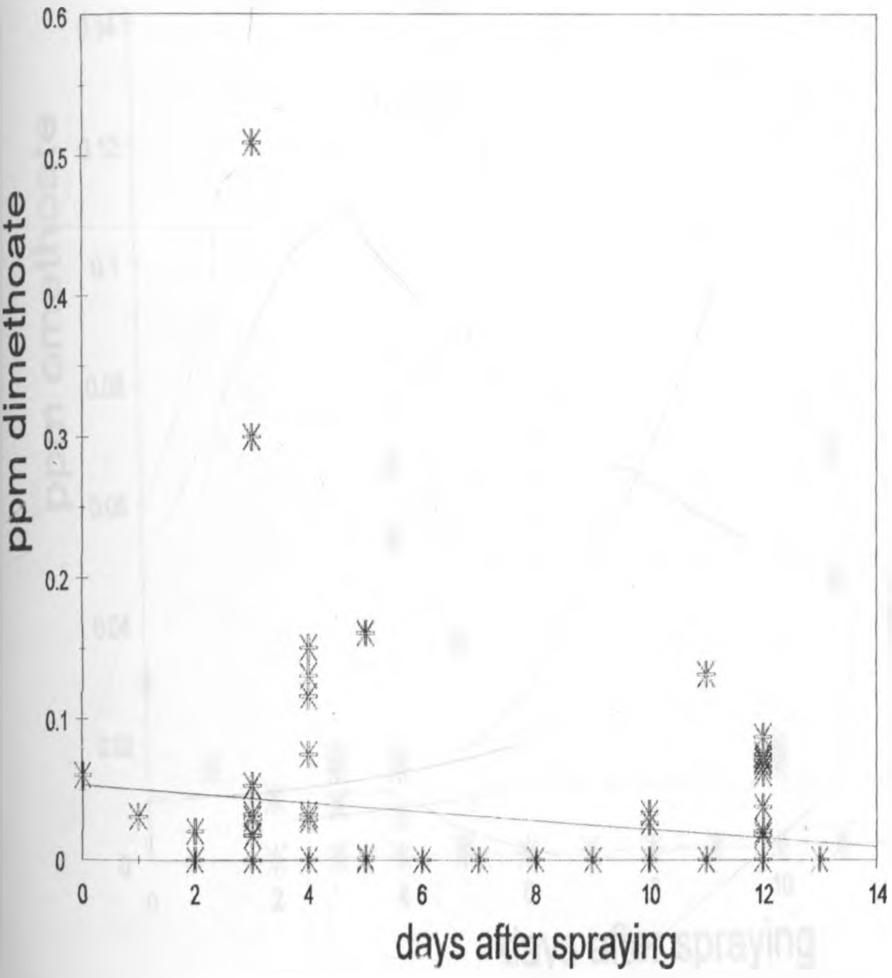


Figure 6: Residues of omethoate in bean samples and the number of days after spraying in Kibirigwi Irrigation Scheme, Kirinyaga District, August-November, 1994 (the highest point of 0.46 ppm was censored).

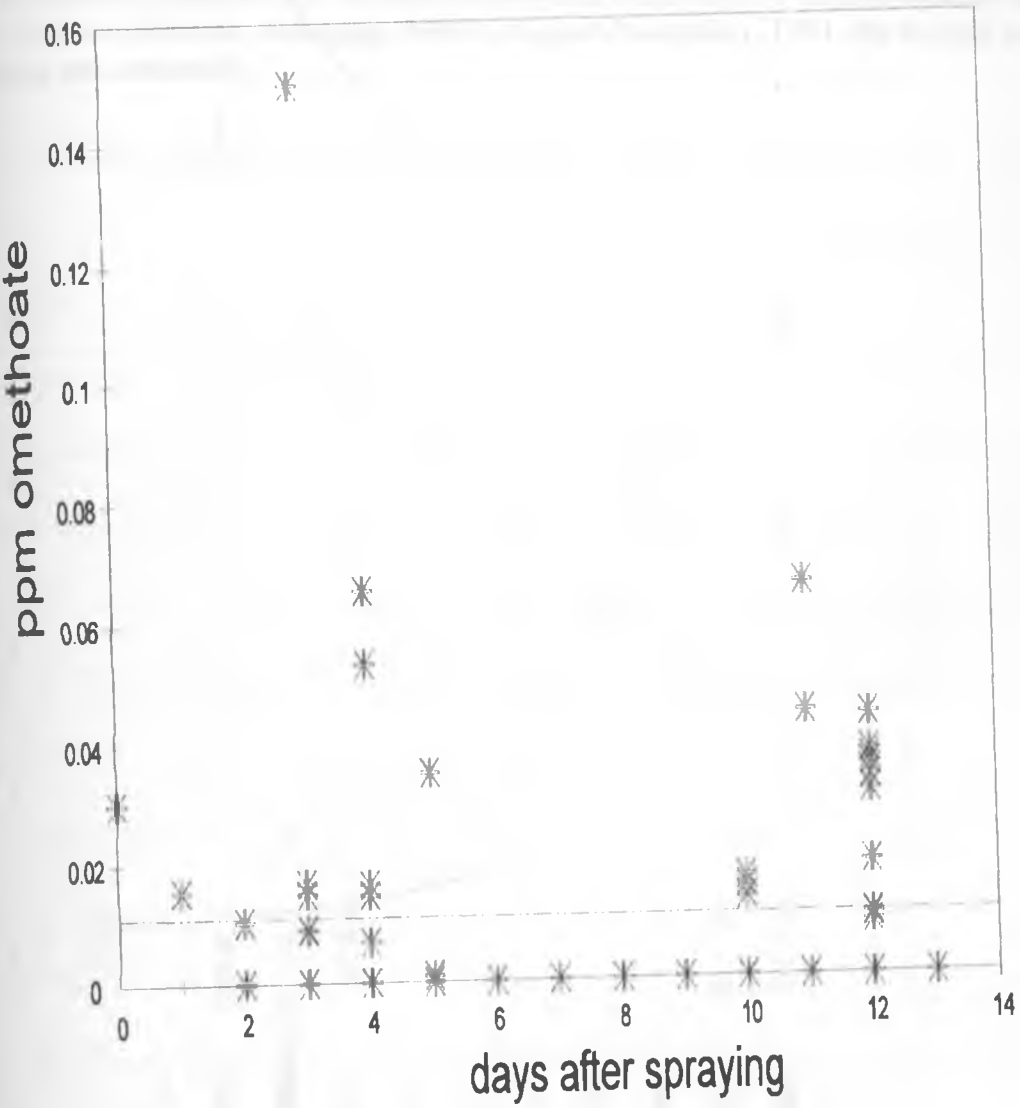
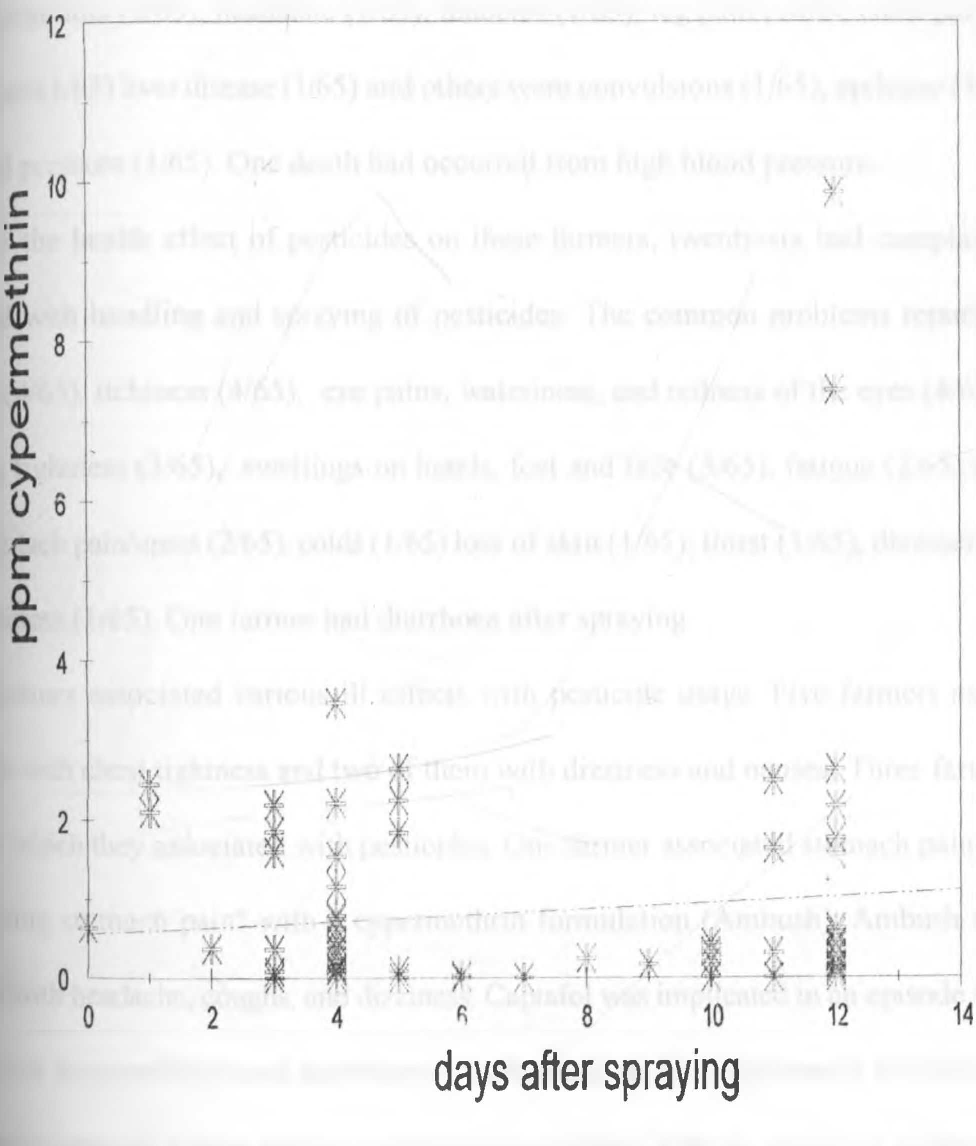


Figure 7: Residues of cypermethrin in bean samples and the number of days after spraying in Kibirigwi Irrigation Scheme, Kirinyaga District, August- November, 1994 (the highest point of 61.20 ppm was censored).



3.4.4 HEALTH STATUS OF FARMERS IN THE SCHEME

The general health of the 65 farmers and their families was recorded. Twenty farmers reported health problems for which they visited a doctor in the year preceding the study period. The common ailments were stomach pains (4/65), backache (3/65), skin problem/chronic wound (2/65), pneumonia (2/65), headache (1/65), diabetes (1/65), leg pain (1/65), chest pain (1/65), shoulder pain(1/65) liver disease (1/65) and others were convulsions (1/65), epilepsy (1/65) and high blood pressure (1/65). One death had occurred from high blood pressure.

On the health effect of pesticides on these farmers, twenty-six had complaints they associated with handling and spraying of pesticides. The common problems reported were coughing (4/65), itchiness (4/65), eye pains, wateriness, and redness of the eyes (4/65), chest pains and tightness (3/65), swellings on hands, feet and face (3/65), fatigue (2/65) sneezing (2/65), stomach pain/upset (2/65), colds (1/65) loss of skin (1/65), thirst (1/65), dizziness (1/65), and uneasiness (1/65). One farmer had diarrhoea after spraying.

Farmers associated various ill effects with pesticide usage. Five farmers associated dimethoate with chest tightness and two of them with dizziness and nausea. Three farmers had headaches which they associated with pesticides. One farmer associated stomach pain referred to as "cutting stomach pain" with a cypermethrin formulation (Ambush). Ambush was also associated with headache, coughs, and dizziness. Captafol was implicated in an episode in which a farmer had face swellings and carbofuran was blamed for skin irritation in two incidencies. One farmer claimed he had an allergic reaction to carbofuran after he applied it to the soil with bare hands. Hands were also observed to be swelling, peeling and sweaty in cold weather. One farmer claimed he had eye irritation after using a copper salt and another one had swelling, itchiness, and wounds inside the mouth after he sprayed a copper formulation. Another pesticide that was associated with adverse health effects was ethion (itchiness, eye irritation and chest pain). An unidentified grain storage dust was said to have induced sne ing.

3.5 DISCUSSION

Measurement of exposure to pesticides can be carried out by direct or indirect methods. Traditionally, exposure in the general population has been assessed by analyzing for pesticides in human tissues and fluids and in environmental samples. Exposure to chemical handlers has been assessed by monitoring their work environment and by measuring their dermal, inhalation and oral exposures. In this study, the extent of contamination of the general human population was assessed by analyzing for pesticides in mothers milk and beans commonly eaten in the scheme. General household exposure were assessed by swabbing tables commonly used for dining. It was found that tables were contaminated with pesticides and both bean and milk samples contained pesticide residues. Thus the general population of people in the scheme are exposed to pesticides.

Table swabs

The most likely explanation for contamination of tables is that farmers placed pesticides on them either as they prepared to spray or as they came back from spraying. Fifty-four out of 65 farmers that were visited in the scheme stored pesticides inside their homes and out of this number only six stored them securely. Elsewhere, spillage of pesticides has been reported to occur inside homes and to cause fatal accidents (Levine, 1991). It is also likely that farmers place their work clothes inside the house after work and these may be contaminated with pesticides either during spraying, weeding or harvesting pesticide treated fields. For example, out of 65 farmers visited in the scheme, 18 wore aprons and 14 wore old clothes when spraying. The latter were not washed after work. If such clothing was placed on the table as the farmer comes from the farm, contamination may occur.

In all homes only tables that are commonly used for dining were swabbed. From these results therefore, it is apparent that farmers and their families are likely to be contaminated by ingestion of food during meals, dermally by contact with contaminated tables, or by inhalation if the pesticides are volatile or dissolved in volatile solvents. Children are especially vulnerable to accidental ingestion of pesticides due to ignorance since they may place food directly on the tables. Such contaminated food would be direct sources of oral ingestion of pesticides.

Malathion was the most commonly detected pesticide. This is not surprising since it is widely used for treatment of cereals against insect pests in storage. Since it is normally mixed with grain, farmers may have the impression that it is safe and therefore handle it less carefully. Dimethoate was also a very commonly used insecticide in the scheme and contamination is likely from storage and poor handling of either contaminated clothing or the pesticide itself. Chloropyrifos, fenitrothion and cypermethrin were also frequently sprayed in the field and their presence on tables may also be due to careless handling and poor storage practices. Diazinon, however, is used as a household pesticide to control cockroaches and bedbugs and therefore its presence on the tables may be related to these usage practices.

The presence of these pesticides inside the houses is undesirable. There are reported incidencies of human intoxication with pesticides when people were exposed indoors. Three-week old twins got sick after being in a house neighbouring one previously sprayed with diazinon to control cockroaches the day before (English **et al**., 1970).

Cases of poisoning with fenitrothion have also been reported. For example, a thirty-three year old woman wiped the floor of her car with absorbent tissue after a 7.5% formulation of fenitrothion had leaked onto it. She was severely ill for one month and several months later, she still complained of fatigue and muscular weakness (Ecobichon **et al**., 1977).

Exposure to a mixture of chloropyrifos and dichlorvos occurred when a sixteen-year old man entered his house when it had been sprayed with the two chemicals and ate lunch. He had abdominal cramps and diarrhoea for two days and over the next 2 weeks he lost twenty pounds (Jablecki **et al.**, 1983).

Bean samples

The commonest source of household pesticide exposure is food. In this study, bean samples were found to contain residues of dimethoate, omethoate and cypermethrin. The mean level of cypermethrin (2.09 ppm) exceeded the maximum residue limit (MRL) of 0.5 ppm (FAO/WHO, 1982). Furthermore, persons who would consume these beans would also exceed the ADI of 0.006 mg/kg b.w equivalent to a total daily intake of 420 ug for a person who weighs 70 kg. A mean of 2.1 mg/kg is equivalent to 2100 ug/kg. If such a person consumes a quarter kilogram of beans he would have consumed more than 500 ug of cypermethrin per day and would exceed the ADI by more than 25%. From these results, it is apparent that farmers may be exposed to cypermethrin through the oral route. Children would be subjected to higher intake levels than adults given their lower body weight. The effects of oral ingestion of cypermethrin on man was reported by Poulos **et al.** (1982). They reported the death of one member of a family that ate a meal cooked in 10% cypermethrin concentrate used in error instead of oil. Symptoms were nausea, vomiting, stomach pain and diarrhoea. Other family members survived after intensive hospital treatment. The amount of cypermethrin consumed by any of the poisoned people was unknown and the effects of solvents and surfactants in the pesticides were unknown.

The amount of dimethoate in the beans did not exceed the MRL of 2 mg/kg. Beans had a mean dimethoate level of 0.17 mg/kg. However, the ADI of 0.002 mg/kg b.w. would be exceeded by persons who consume more than 0.8 kg beans with 0.17 mg/kg and above since a

70 kg man has an ADI of 140 ug/day. If dimethoate residues are present in other foods, such persons would be at higher risk. In addition, children and younger persons would obviously be more exposed. It should also be noted that the crop was sprayed with dimethoate more than two weeks before the sampling was done. Farmers were usually advised by the extensionists not to spray dimethoate on beans after the flowering stage so as to avoid residues in the pods. The fact that there was still some residues after 14 days confirms that if farmers were to spray dimethoate after flowering, they would be in danger of exceeding the MRL and eating such beans would exceed the ADI considerably.

Mean residues of 0.02 mg/kg of omethoate were found in beans. The ADI for omethoate is 0.0003 mg/kg b.w.(British Crop Protection Council, 1987) equivalent to 0.3 ug/kg. A 70 kg person would need only 21 ug total daily intake to exceed the ADI. The mean level of 20 ug\kg of beans found in these samples is therefore very close to the ADI and therefore may be unsafe especially for children. The presence of omethoate in beans in levels close to the ADI indicates that contrary to the view held by Spear (1991), the oxygen analogues of thiophosphate pesticides may be important as food borne residues in addition to their well-recognized role in crop-worker exposure.

Mothers milk

Pesticide residues in mothers milk samples indicate contamination with persistent pesticides. In this study, samples were found to contain a wide range of organochlorine pesticides. Levels were, however, lower than those reported earlier in Kenya. Analysis of organochlorine pesticides for various areas of Kenya was carried out by Kanja **et al**. (1986). Among the 8 districts sampled, the area most similar in farming activities to the present study area was Karatina (n=50). The mean level *p'p*'DDE for Karatina was 1.72 mg/kg between 1983-

1985 For Kibirigwi, the mean in the present study was 0.043 mg/kg. This mean was also lower than for all areas sampled by Kanja and coworkers in that study, including Loitokitok, a nomadic pastoral area. The results of this study could be used to draw a tentative conclusion that due to the decline in the use of DDT, the body burden of DDE of people in the general area may be declining. Such a trend has been reported in the United States (Levine, 1991) and in Sweden (Skaare and Polder, 1990). It is also widely accepted that a high DDT/DDE ratio indicates a relatively short time since exposure to DDT occurred (Smith, 1991). In this study, 36/36 samples contained *p'p*DDE and only 3/36 contained DDT. Kanja and co-workers reported a DDT/DDE ratio of 0.57-5.7. In this study, of the three samples that contained DDT, one sample had a ratio 1.73 and the other two had ratios of 0.33 and 0.87. With the exception of this one case, it is therefore likely that exposure to DDT has not occurred in the recent past among this study group. It is suspected that exposure to DDT would originate from the use of dicofol, a product frequently contaminated with DDT. This product is used occasionally in the scheme (Appendix II).

Sum DDT was found to be positively correlated with the percent fat of the milk. Percent fat is considered one of the important factors that influence storage and excretion of organochlorine pesticides in milk (Levine, 1991). Since DDT and its metabolites are fat soluble, the amount of chemical would be directly correlated with the amount of fat in the milk. This was found true for sum DDT and all other pesticides detected. Others factors that influence storage and excretion were reviewed by Levine (1991). Parity was found not to influence the level of sum DDT in agreement with a study reported by Dillon **et al**. (1981) but in contrast with other workers (Jensen, 1983., Rogan **et al**., 1986). The two workers reported a decline to constant levels at parity number four and higher levels of contamination in younger mothers respectively. Age was found not to be correlated with the amount of DDT in milk in this study.

The use of DDT in Kenya was restricted in 1986 and no imports have been approved since then (PCPB, 1993b). An inventory of the types of pesticides used or stored by farmers in the scheme was done and it was found that DDT was not stored or used by the farmers. However, dicofol, an insecticide often contaminated with DDT is used occasionally. In addition, it should be noted that organochlorine pesticides have been reported in foetal tissues giving an indication that babies may be contaminated in utero and born with pesticide residues (Levine, 1991).

With the exception of β-BHC, the levels of all pesticides were less than those reported by Kanja **et al**. (1986). The use of aldrin, dieldrin and heptachlor was restricted in 1986 and all isomers of hexachlorocyclohexane apart from the γ isomer, lindane were banned (PCPB, 1986). In the inventory carried out, aldrin, dieldrin, and lindane were found to be in use and at times were stored in homes in the scheme. Dieldrin and lindane were used on vegetables and aldrin around the home to control termites. It is therefore not surprising that these pesticides were detected in milk.

All pesticides detected exceeded the WHO Acceptable Daily Intake (ADI) when we assume an intake of 130 ml/kg b.w and 3.5% fat (the mean for the mothers in the present study was 4.57%). Dieldrin exceeded the ADI by a factor of over 1000 times in the 3 samples. Aldrin and heptachlor also exceeded by more than 200 times each, lindane by a range of 1-6 times for the 10 positive samples and all samples exceeded the ADI for *p'p'*DDE. Overall, however, there seems little risk to babies despite the presence of DDT in mothers milk (Smith, 1991). For example, Rogan **et al**. (1987) reported a study in which 858 children were followed from birth to one year. Ninety-three percent of mothers and children were followed for the whole year. A comparison of medical records between DDE exposed and non-exposed infants failed to demonstrate significant health effects.

The ADI for β-BHC is not known and thus daily intakes were not estimated. The residue level of β-BHC was higher than that of the γ and α isomers. This agrees with the findings of other workers elsewhere. In Japan, for example, the level of β-BHC was 0.23 ppı while the levels of γ isomer were much lower (Shimizu, 1972). β-BHC is slowly excreted from the body and although α and γ isomers can isomerise to the β isomer, the former are not usually the source of β-BHC (Smith, 1991). Mothers living in agricultural areas have lower β-BHC than urban ones according to studies by Matsuda and coworkers (1971) who attributed this to higher meat and dairy products consumption in urban areas. Shimizu (1972) reported that mothers could reduce the amount of β-BHC by eating less meat and milk. The presence of γ-BHC in milk indicates recent exposure to lindane. This may be the case for the mothers in this study since 11/36 samples contained the γ isomer with a mean of 0.0014 mg/kg. The integrity of the lindane in use may not be as expected and may be contaminated with β-BHC and α-BHC. This could therefore explain the higher levels of β-BHC than γ-BHC detected in mothers milk.

No case of chronic intoxication was reported from people who had high levels of the β-isomer, and mothers and their children showed no clinical signs of disease in Japan where the matter was widely investigated (Smith, 1991). Therefore, the presence of this isomer probably represents little risk to mothers and their children. However, as noted by Jensen (1983), there is an obvious lack of well-founded and comprehensive epidemiological studies on the effect of pesticides present in human milk on the health of infants. Furthermore, ADIs are not available for all the pesticides detected in human milk. Therefore, Jensen (1983) concludes that "the safe limit of these chemical agents in infant food is not known".

Analysis of mothers milk for organophosphates revealed peaks in nine of twenty-nine samples analyzed. These peaks could not be identified on the Gas Chromatograph\ Mass Spectrometer.

Health status

It is likely that some farmers have been poisoned with pesticides. Symptoms that farmers associated with pesticide poisoning correlated with common symptoms for poisoning with pesticides they were using. Five farmers associated dimethoate with chest tightness. One other farmer not involved in this survey but in other studies carried out in the scheme complained of dimethoate poisoning. He suffered the following symptoms after spraying without protective clothing; chest tightness, stomach pains, headache, double vision, disorientation, watery eyes, sluggishness and fatigue. Chest tightness is one of the symptoms of organophosphate poisoning (Gallo and Lawryk, 1991). Other symptoms include headache, lightheadedness, weakness, abdominal cramp, nausea, blurred vision, excessive salivation, perspiration and diarrhoea, (Morgan, 1980). Other symptoms which farmers associated with handling dimethoate were nausea and dizziness. In addition to dimethoate, various other organophosphates such as diazinon, malathion and ethion were also widely used in the scheme. One farmer reported that he felt uneasy after using pesticides. Levin (1976) investigated the health effects of continuous exposure to organophosphates and reported increased levels of anxiety in exposed persons.

One farmer reported that a formulation of cypermethrin caused a stomach pain which he referred to as "cutting pain". This correlates with the case reported by ı oulos **et al**. (1982) quoted earlier. Other effects of cypermethrins on humans were studied by Le Quesne **et al**. (1980) and Flannigan and Tucker (1985). These researchers reported that workers exposed to cypermethrin developed a transient facial sensation not accompanied with any inflammation. This was attributed to the continued firing at nerve endings characteristic of pyrethroid pesticides. No other symptoms were reported.

There were four cases of skin related illness. Two were associated with carbofuran and one with captafol. Carbofuran was found not to cause skin irritation in short-term studies (FMC,

1986) but captafol is widely recognised as a skin irritant (Groundwater, 1977., Brown, 1984). In Japan, for example, surveys revealed a high incidence of skin irritation among farmers using captafol in tangerine orchards (Edwards **et al**., 1991). It was also associated with swelling of the face and hypertension. Captafol was banned in Kenya in 1988 due to reports of causing irritation among coffee farmers (PCPB, 1993a).

Another group of pesticides associated with skin irritation are the dithiocarbamates. These products have been used for a long time and are generally regarded as harmless (Edwards **et al**., 1991). The LD_{50} exceeds 2,700 mg/kg b.w (British Crop Protection Council, 1987). However, maneb has been shown to cause contact dermatitis (Hearn, 1973). In addition, maneb and other EBDCs were shown to be skin sensitizers (Nater **et al**., 1979). Mancozeb and a mixture of mancozeb and metiram is popularly used in the scheme to control fungal diseases on vegetables (Chapter 2).

In addition to the commonly used pesticides quoted above, the farmers use at least another fifty different formulations (Appendix II). Due to the possibility of multiple exposures, it is difficult to isolate with certainty the real cause of reported adverse health effects. Different pesticides may cause similar effects. For example, skin irritations can be attributed to dithiocarbamates, pyrethroids and captafol while both carbamates and organophosphates have similar symptoms of poisoning due to cholinesterase inhibition (Tobin, 1970). Furthermore, farmers and other subjects used in epidemiological studies are subject to recall bias as reported by Blair and Zahm (1993).

3.6 CONCLUSION

It was concluded that farmers in the scheme experienced adverse health effects from exposure to pesticides. It is not easy to state the magnitude of the problem but it is apparent that a number of farmers have been poisoned with pesticides. It was not possible in this study to document all cases. A longitudinal study following farmers and their families is needed to assess over time the extent of poisoning that could be occurring. Regular clinical examinations and diagnostic tests (e.g. pulmonary function, etc.) of the residents of this area would be needed to investigate the extent to which their health may be affected by exposure to pesticides.

It is apparent that household exposure to pesticides is common. The farmer and his family are at risk from such exposure. Young children would be more at risk due to the possibility of multiple exposures from mothers milk, contaminated food as well as from pesticide contaminated surfaces.

CHAPTER FOUR

SPECIFIC AGRICULTURAL EXPOSURES : STUDIES TO DETERMINE EXPOSURE TO DIMETHOATE AND OMETHOATE DURING SPRAYING.

ABSTRACT

Dermal exposures to dimethoate and omethoate during spraying were investigated among 39 randomly selected farmers at Kibirigwi Irrigation Scheme. There was a large variation in the estimated amount of total dimethoate contamination on the farmers (25 ug-95000 ug/person) and among the various body parts (legs, hands, back, face) during spraying. The hands were the most contaminated (mean= 12.6 ug/cm^2) and the face the least (mean= 0.2 ug/cm^2). On almost all the farmers, one body part was the most contaminated; usually this was the right hand (21/39), followed by the left hand (10/39), the right leg (4/39), left leg (2/39) and the back (2/39).

Omethoate was found in 25% of the samples (range 0.01-228 ug/person). The highest mean omethoate was on the left hand (0.010 5 ug/cm^2) followed by the right hand. For both dimethoate and omethoate, women were more contaminated than the men ($p< 0001$). The larger the area sprayed per given time, the less contamination for both chemicals ($p<0.01$) was observed.

All farmers had blood samples taken 3 days before and 24 hours after spraying. There was variation in levels of acetylcholinesterase in whole blood before spraying (85-191 units) and after spraying (102-176 units). For 11 farmers, the enzyme level was lower after spraying, in two cases the depression was above 20% and in one of these cases, the level was depressed by 26%.

In a study to investigate whether residents of Kibirigwi have significantly lower levels of enzyme in blood compared to Kabete Campus residents, 47 persons from Kibirigwi and 15 from the campus were sampled for serum and plasma and enzyme measurements in the samples were done. It was found that the mean level of enzyme in residents of Kibirigwi Scheme (106, s.e= 3.27) was significantly lower than that of campus residents (124, s.e = 6.32).

4.1 INTRODUCTION

One of the earliest attempts to assess exposure to pesticides during spraying was by Batchelor and Walker (1954). They reported that applicators were exposed through the skin and by inhalation. Dermal and respiratory exposures were estimated at 77 mg/man/hr and 0.2 mg/man/hr respectively. Later studies to assess dermal exposure to farm sprayers were carried out by several workers (Copplestone **et al.**,1976., Wolfe **et al.**, 1972). They confirmed the findings of Batchelor and Walker (1954), that dermal exposures exceed respiratory exposures during application. Of lesser importance is oral exposure (Davies, 1980). Mixers, loaders and applicators have been reported to be exposed (Spear,1991). However, the workers are exposed to various degrees. In his review of pesticide exposure studies from 1955, Turnbull **et al.** (1985) concluded that mixers and loaders are more at risk than applicators. This has been attributed to the fact that mixers and loaders handle the concentrated material while applicators handle the dilute spray or dust (IARC,1992). A single worker may experience all three types of exposure. This is particularly the case for small sprayers who mix and spray pesticides on their farms (Kishi **et al.**, 1995).

There are various risk factors that contribute to exposure during spraying. In a study on dermal exposure to malathion in Pakistan, Baker **et al.** (1978) observed that there are work practices which increased dermal exposures. Spraymens'" clothing were often wet at the end of the working day and would be worn for several days without washing. Mixers and spraymen had extensive skin contact with the pesticide while filling and pressuring the spray tanks while some mixers mixed malathion suspension with their hands. In addition, many spray cans were leaking pesticide onto the arms, hands and chest of the spraymen and when nozzles became clogged, sometimes the spraymen blew into them to unclog them. In a different study, adjustment of spray nozzles during aerial pesticide application led to higher exposures on the hands of applicators (Maitlen **et al**., 1982). Different types of spray equipment lead to different levels of exposure. Dover (1985) reported that air blast spraying led to the highest average exposure (7.9 ug/cm^2) and portable mist blowers the least (1.5 ug/cm^2). Knapsack sprayers were estimated to lead to exposures of 3.2 ug/cm^2). Different formulations have different exposure potential (IARC, 1992) Wettable powders were found more hazardous than liquid concentrates during the mixing process (Hayes and Pearce, 1953). Conversely, Matthews (1985) investigated the efficacy of spraying different formulations and found that less than 0.1% of the applied dose of foliar sprays may reach the actual target, the insect. A large proportion is suspended in air and could be a source of contamination.

In Kenya, few studies have been done to assess occupational exposure from pesticides. Various qualitative studies (Mwanthi and Kimani., 1989; Kimani and McDermott, 1994; Partow, 1995) have confirmed what has commonly been accepted in Kenya, that actual pesticide usage and handling practices are poor (IDRC, 1989). Studies focusing on the analysis of organochlorine and dithiocarbamate residues in various environmental and food samples (Kahunyo, 1983., Kanja **et al**., 1986., Kimani, 1988) have been done. These have shown that there is environmental contamination from pesticides. However, no study has been done to quantify exposure during spraying and other agricultural practices.

This study was carried out in Central Kenya. The objective was to investigate whether farmers were exposed to pesticides during mixing and spraying. The study area was a small scale irrigation scheme with about 300 farmers growing horticultural crops particularly french beans. Farming and spraying goes on all year round. Dimethoate is the most commonly used pesticide. The area offers a consistent crop/spray combination for this kind of study. This study also investigated the effect of dimethoate and omethoate exposure on the activity of whole blood acetylcholinesterase in the farmers. Controls that were not exposed to pesticides were the comparison group. The information obtained from this study will provide a basis for a programme on better and more effective safe use practices in pesticide handling in this scheme and elsewhere in Kenya.

4.2 MATERIALS AND METHODS

4.2.1 Study area and Population

The study area is as described in section 2.2.1. Farmers had mixed farms growing subsistence and horticultural crops. Cash crops such as coffee and sweet potatoes are also grown. Most farmers also rear animals. The unit of interest was the farmer. Farms were stratified into three sections and an equal number of farms randomly selected from each strata to ensure that all geographical areas of the scheme were sampled. Overall sample size was 65. This was calculated based on the assumptions that the proportion of proper pesticide handlers do not exceed 40% with an allowable error of 10% and with confidence of 95 %. Given the total population of 282 farms and assuming no differences between sections, the following formula was used (Cochran, 1977).

$$n_1 = [\frac{Z^2_{1-\alpha}pq}{L^2}]\sqrt{\frac{n}{N}}$$

Z = is the standardised normal variable of a normal distribution in pesticide handling at 95 % confidence =1.96

α= the probability of error

pq= the variance given by pq where

p = proportion of farmers using proper handling procedures and q = 1-p

n =calculated sample size

n_1 = adjusted sample size

N= population size

L= allowable error

Thirteen farms were sub-sampled from each section to make a total of ??.

4 2 2 Measurement of Pesticide Exposures f Applicators

Prior to mixing the dimethoate with water each applicator was fitted with: (i) a pair of cotton leggings covering each leg from the knee to the ankle with a total area of 1862 cm^2 These were tied over the legs using two pairs of loops sewn onto the material on opposite ends. (ii) a pair of gloves to cover each hand from the arm to the elbow measuring 6 l0 cm^2; (iii) a cotton apron covering the middle part of the back (about where the spray tank rests) measuring 2760 cm^2 and secured with a pair of loops sewn on each end of the piece; and (iv) a dust mask covering the nose and mouth and with an area of 142 cm^2. This was secured on the face using elastic bands sewn onto each end of the mask and supported by the earlobes. The applicator mixed the pesticide in a 20 liter knapsack sprayer. The details on the mixing practice, the condition of the sprayer (any leaking points or not), the type and amount of protective clothing, and any spillage or splashing were recorded. The applicator sprayed the 20 litres of dimethoate: water mix (one spray cycle). All covers were then carefully removed. The back was removed by untying the loops while the gloves were removed by sliding them carefully off the hand. The back patch was untied while the mask was removed by disengaging the loops from the earlobes. Each of these samples were placed separately in a wide-mouthed glass jar with a screw cap lined with aluminium foil to avoid contamination. Jars were placed in a coolbox and transported to the laboratory for analysis within 24 hours of collection.

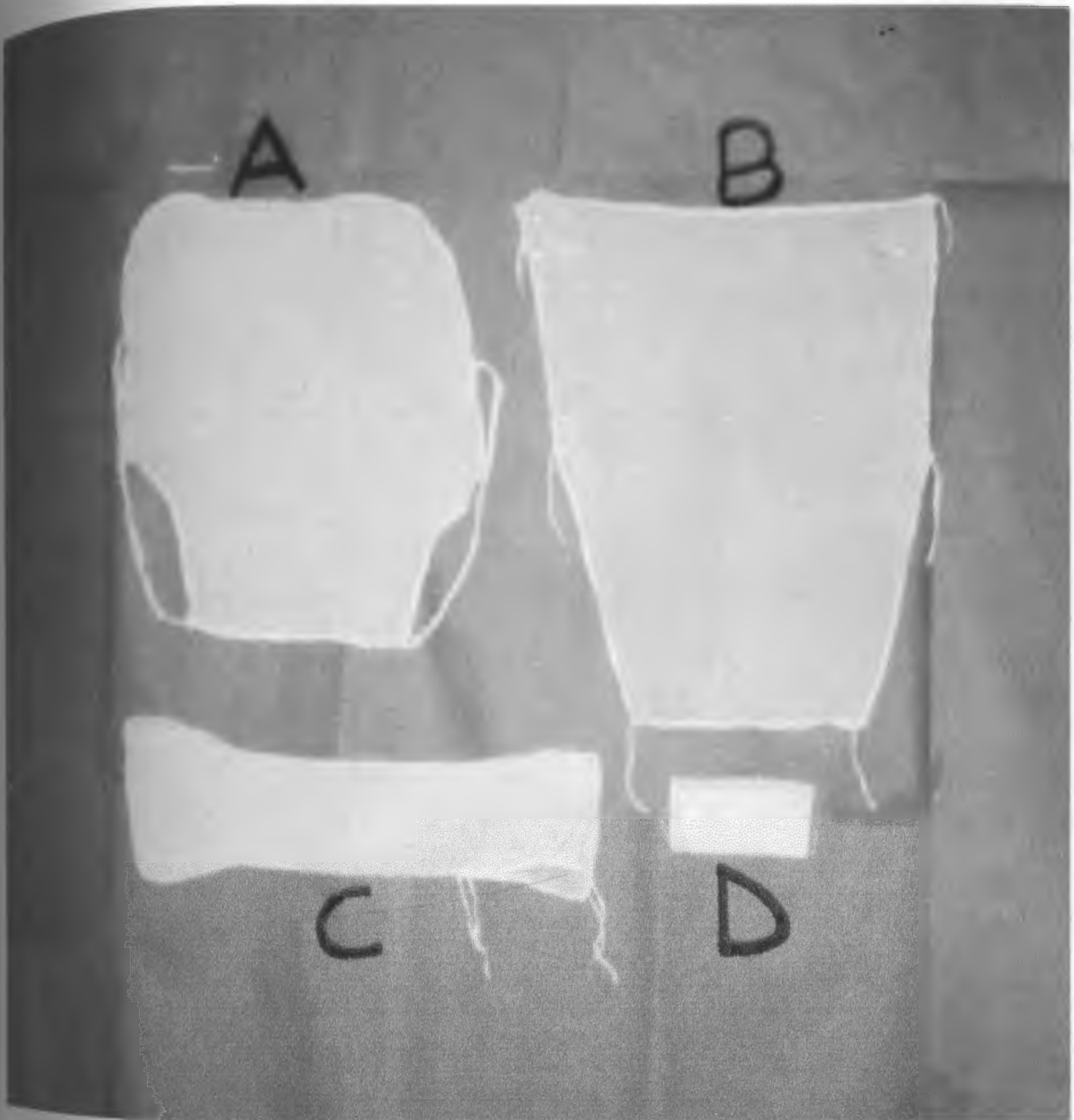


Plate 2. Back (A), leggings (B), sleeves (C) and mask (D) used in the spraying study.

Plate 3: A farmer mixing dimethoate in preparation for spraying.

4.2.3 Blood Sampling

Thirty-seven of the 39 farmers involved in the spraying study were sampled for blood before they sprayed. After spraying, 32 farmers were sampled. The remaining five were not sampled because of refusal to participate (3), and there was difficulty in sampling the other two. In addition, samples were collected from 47 persons from Kibirigwi and 14 from Kabete in order to compare enzyme levels among residents of Kibirigwi and those of Kabete Campus. For the farmers, blood samples were collected 72 hours prior to spraying (and at least two weeks after the last spray) and 24 hours after spraying into 10 ml heparinised vacutainer[R] tubes by a community nurse. Tubes were placed inside a coolbox and transported to the laboratory within 24 hours. For the 62 samples taken for comparison purposes, each sample taken was divided into two portions: one tube was 7 ml heparinised tube and the other was a 10 ml plain or serum tube.

4.2.4 Laboratory Methods

Calibration of standards and recovery studies.

The dimethoate analytical standard was obtained from the Pesticide Chemistry Laboratory of the Kenya Agricultural Research Institute and was purchased from British Greyhound Chromatography and Allied Chemicals (Birkenhead, England, Lot No 106-52A, PS-659, 98% purity. Omethoate standard was supplied by Bayer East Africa and was confirmed to be pure. Stock solutions were prepared in acetone to a concentration of 1000 ppm. From this stock, dilutions were prepared to 200 ppm and then to the following concentrations: 1 ppm, 0.5 ppm, 0.25 ppm, and 0.05 ppm for both standards. These were injected into the gas chromatograph (GC) and a standard curve was prepared as shown in Figures 8 and 9. The GC conditions outlined below were used. To determine the suitability of dichloromethane in extracting dimethoate and omethoate from the cloth samples, unused cloths measuring 30cm*30cm were spiked with 1 ppm, 0.5 ppm and 0.05 ppm dimethoate and omethoate. The cloths and a blank were extracted with the solvent using the method described below and the recoveries determined (Figures 8 and 9).

Extraction of Cloth samples

The extractions were carried out according to a procedure described in the Pesticide Analytical Manual (1973) and later used by Ritcey **et al.** (1987). Each cloth sample was soaked overnight in dichloromethane. The following day, the cloth and dichloromethane were transferred into 500 ml conical flasks and extracted in the same solvent by shaking on a Burrel wrist shaker for one hour at a setting of 3 on the scale. The solvent was filtered into a Buchner flask through a sintered borosilicate funnel under vacuum. The contents were transferred into a 500 ml round-bottomed flask. The Buchner funnel was rinsed with small portions of dichloromethane and these were added to the contents in the flask. The dichloromethane was evaporated to just dryness on a rotary evaporator at 50°C. The extract was dissolved in 5 ml hexane and the sample was transferred to a 7.4 ml Supelco(R) bottle with a Teflon[R] lined cap for analysis.

Analysis of cloth samples

Analysis was done on a Flame Photometric Detector on the Gas Chromatograph Varian 3400 equipped with an integrator Model Varian 4400. The conditions were as follows: Capillary column J & W Scientific : Length 15 m, i.d. 0.54 mm and 1.5 microns thickness ; Column temperature 150°C to 250°C at 20°C per min; Injector and detector temperature were 230°C and 250°C respectively. The carrier gas used was nitrogen at a flow rate of 30 ml\min. The hydrogen flow rates was 140 ml/ min and air at 80 ml/min and 170 ml\min for flames one and two respectively.

Injections were done manually using a 5µl Hamilton syringe (Microlitre[R] 7105) µl). Before the samples were injected, 2µl of dimethoate and omethoate standards were injected several times until the peak area and retention time were stable. Then the same volume of sample was injected.

Analysis for Acetylcholinesterase in blood samples

The 62 samples were analyzed for acetylcholinesterase using both the pH and the spectrophotometric method. The pH method is an electrometric method that measures the increasing acidity in solution resulting from the breakdown of acetylcholine substrate by the enzyme. The pH change is then measured accurately under carefully controlled conditions of temperature and pH. The spectrophotometric method measures the change in absorbance that results when the substrate is broken down by acid in the presence of an indicator, 5'5'bisnitrobenzoic acid.

The pre- and post- exposure samples obtained from the farmers were analyzed using the pH method described by Michel (1949). The buffer solution was prepared by dissolving 1.2371 g of Sodium barbitone, 0.1361 g of Potassium dihydrogen phosphate and 17.535 g of sodium chloride in 900 ml of water, made up to nearly one litre with water and the pH adjusted to 8.0 with 0.1N hydrochloric acid. The volume was then accurately made up to a litre. The substrate was prepared by dissolving 0.2 g acetylcholine bromide in 10 ml of water. All samples were analyzed in duplicate and a control was incooperated into each batch of 8. Clean stoppered test tubes were arranged on a metal rack suitable for placement in a water bath. To each tube was added 2.5 ml of buffer and 2.5 ml of water. The tubes were all incubated at 25^{0}C until equilibrium. 0.5 ml of substrate was then added to each and 0.05 ml of whole blood to 2 tubes only. The third tube acted as a control. The pH of all tubes was taken immediately and again after incubation at 25^{0}C for one hour with the Fisher pH/Temp Meter 119 with a resolution of 0.01pH and 0.1^{0}C.

In the spectrophotometric method, the dithiobisnitrobenzoic acid solution was prepared by dissolving 10 mg of 5,5, dithiobis-2- nitrobenzoic acid in 100 ml of phosphate buffer (pH = 7.4). A 5% acetylthiocholine iodide solution was prepared by dissolving 5 g of acetythiocholine iodide in 100ml of distilled water. The temperature of dithionitrobenzoic acid solution was adjusted to 25^{0}C. An aliquot of 3μl of this solution was added to 20 ul of the serum sample and 0.1 ml of 5% solution of acetylthiocholine iodide and all were mixed well. The absorbance of 1cm layer was recorded at 405 nm at 30 sec interval for a period of 2 minutes on the Beckman Model 25 Spectrophotometer.

The concentration of cholinesterase was calculated as follows: in the pH method, the difference in pH of the control and that of the incubated blood multiplied by 100 gives the cholinesterase activity in pH units (Michel, 1949); in the spectrophotometric method, Cholinesterase (milliunits/ml) = Change in absorbance in 30 sec x 23400.

4.3 DATA MANIPULATION AND HANDLING

4.3.1 Dermal Exposure Studies

All data were entered into dBASE (Ashton Tate, Torrance, CA, USA) and checked for out of range values. Analyses were done using statistical programmes: STATISTIX (Statistix Version IV, Analytical Software, 1958 Eldridge Avenue St. Paul MN 55113 USA) and BMDP (Statistical Software, 1440 Supelveda Boulevard, Los Angeles, CA 90025). The following statistical analyses and calculations were done: descriptive statistics including means, sums, variance, standard error and confidence limits were calculated for both dimethoate and omethoate levels on the clothing and for age of applicators, time taken to complete a spray cycle and area sprayed in each cycle. The total exposure per area of cloth and per hour were calculated for both dimethoate and omethoate. The percent toxic dose for total pesticide obtained from the clothing samples were also calculated using the method described by Durham and Wolfe (1962). Correlation coefficients of the variables time, area, protection, spillage, and leakage, for both dimethoate and omethoate were calculated and linear regression of total dimethoate/ and omethoate on age, time, sex, area, education, leakage, spillage and nozzle handling was also done.

Analysis of variance of a general mixed model with the amount of dimethoate/and omethoate per body part as the dependent variable and the farmer and error variables as random effects and all other variables as fixed effects was done.

4.3.2 Acetylcholinesterase Measurements

Descriptive statistics of acetylcholinesterase levels in serum and plasma samples from Kibirigwi and Kabete residents for both the pH and spectrophotometric methods were calculated. In addition, descriptive statistics for the acetylcholinesterase levels for blood samples of

Kibirigwi residents before and after spraying were calculated as well as correlation between age and levels of blood acetylcholinesterase.

A paired sample t-test between levels of the enzyme before and after spraying was done as well as a two sample t-test of the mean enzyme units of whole blood taken before spraying and the mean of non-exposed, non-spraying controls from the campus.

In addition, the analysis of variance of the mean enzyme units of whole blood taken after spraying and the mean of non-exposed, non-spraying controls from the campus was done.

Regression of acetylcholinesterase levels of farmers on the amount of chemical contamination on the clothing, time taken while spraying, area sprayed, age, sex and education level of the farmers was also done. In addition, linear regression of the cholinesterase levels in serum and plasma samples of Kibirigwi and Kabete residents on age, residence, education levels, last spray date, farmers/non-farmers, years of farming, years of spraying, sprayers/non- sprayers for the data from the pH and the spectrophotometric method was done.

4.4 RESULTS

4.4.1 Calibration of pesticide standards and recovery studies

The standard curves and the peak area for dimethoate and omethoate spikes in cloth samples are shown in Figure 8 and 9. There was high correlation between the peak area for the standards and the area for the spiked cloths for dimethoate ($r = 0.993$) and omethoate ($r = 1.00$). The percent recovery for the cloth samples was 94.0 -107 (mean = 98.1) for dimethoate and 93.9-99.4 (mean = 97.8) for omethoate.

Figure 8: Curves showing the peak areas of analytical dimethoate standard and the amount recovered from spiked cloth samples at various concentrations of dimethoate.

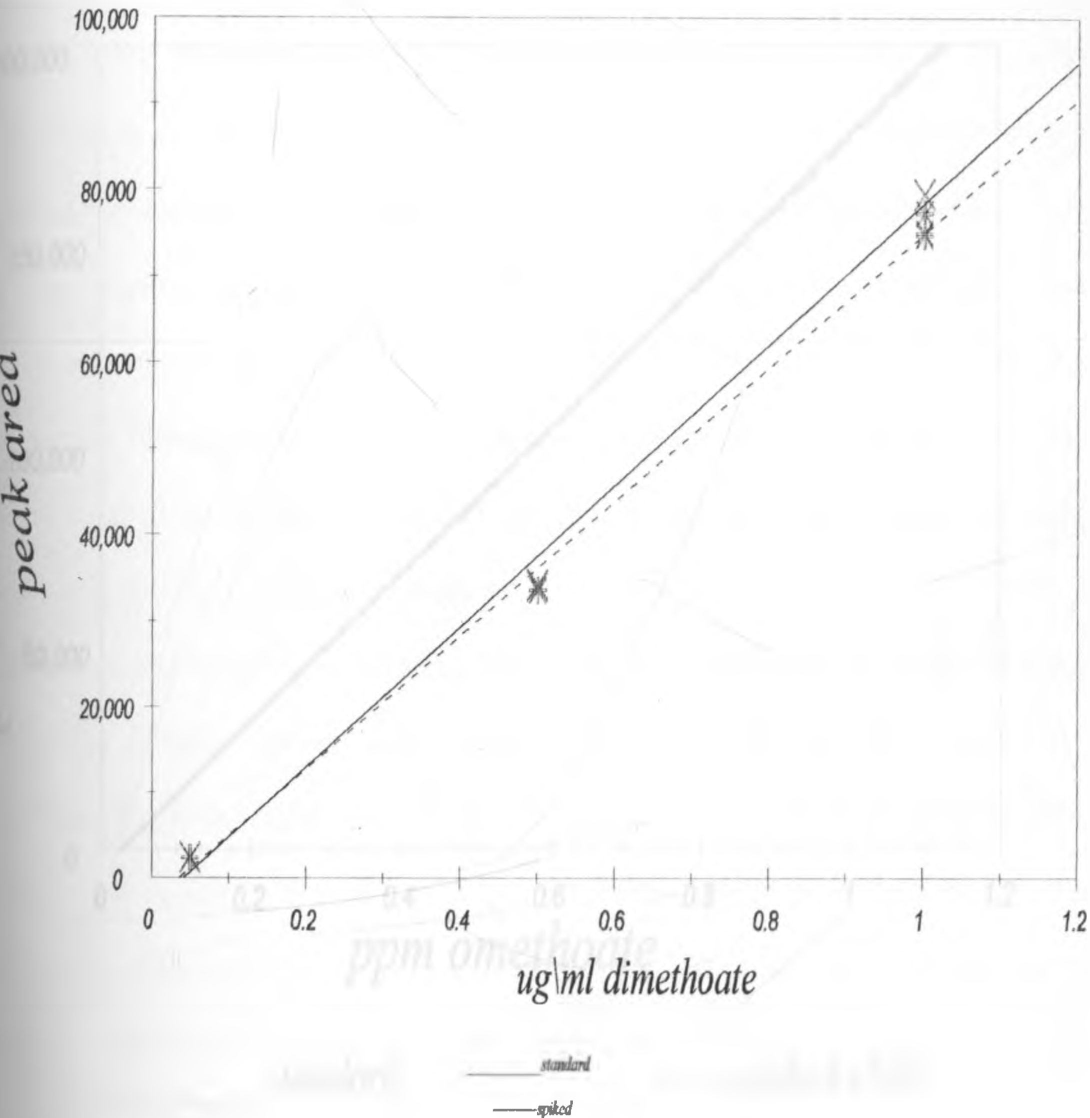
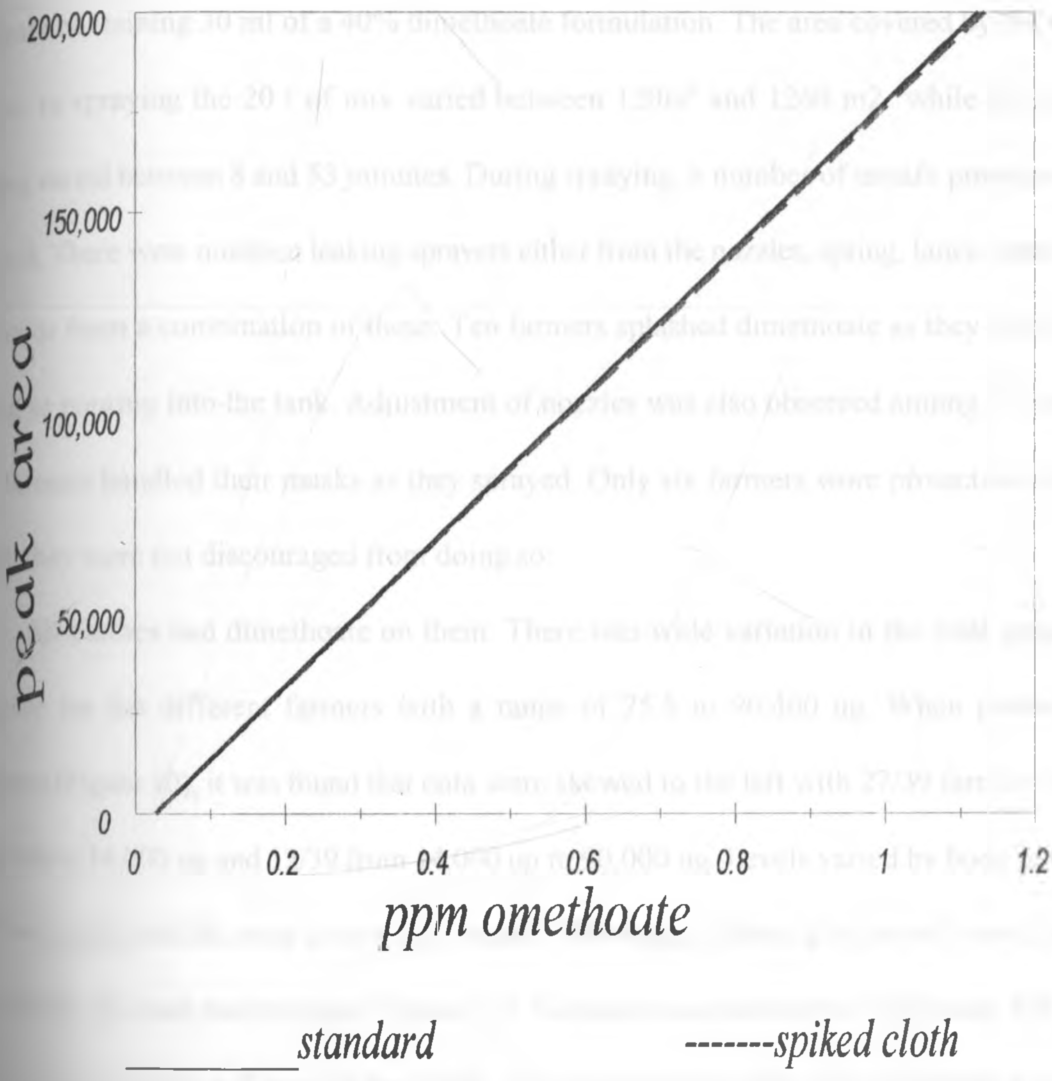


Figure 9: Curves showing peak areas of analytical standard omethoate and the amount recovered from spiked cloth samples at different concentrations of omethoate.



4.4.2 Residues of dimethoate and omethoate in cloth samples.

The descriptive statistics for the variables measured for associations to dermal exposure to dimethoate and omethoate are shown in Table 4.1. All farmers sprayed a standard 20 l of spray mix containing 30 ml of a 40% dimethoate formulation. The area covered by the thirty-farmers in spraying the 20 l of mix varied between 120m^2 and 1260 m2 while the time of spraying varied between 8 and 53 minutes. During spraying, a number of unsafe practices were observed. There were nineteen leaking sprayers either from the nozzles, spring, lance, main tank, the cap or from a combination of these. Ten farmers splashed dimethoate as they were either mixing or pouring into the tank. Adjustment of nozzles was also observed among 11 farmers. Two farmers handled their masks as they sprayed. Only six farmers wore protective clothing though they were not discouraged from doing so.

All clothes had dimethoate on them. There was wide variation in the total amount of pesticide for the different farmers with a range of 25.5 to 96,400 ug. When plotted as a histogram (Figure 10), it was found that data were skewed to the left with 27/39 farmers having levels below 14,000 ug and 12/39 from 14,000 up to 90,000 ug. Levels varied by body part. The right hand cloths had the most dimethoate (mean = 8068 ug), followed by the left hand, the left leg, right leg, the back and the mask (Figure 11). Variation was most on the right hand, left hand, right leg, left leg, back and mask in that order. The percent toxic dose was calculated according to the method of Durham and Wolfe (1962) (Appendix IV).

Fifty-eight samples contained omethoate, an oxidation product of dimethoate. The range of omethoate levels was from 0 to 228 ug (mean = 1.8 ug ($^{95\%}$CI) 0,3.8 ug). This data was also skewed with 37/39 having less than 30ug with the other 2 above this value. The ratio of omethoate with dimethoate was between 0 and 0.16 to 1. The correlation coefficient of omethoate over dimethoate was 0.38.. The percent toxic dose for omethoate was not calculated since it was expected to be less than 0.0003% (Appendix V).

Table 4.1
Descriptive statistics for discrete and continuous variables associated with log estimated total exposure of dimethoate and omethoate (ug) among 39 farmers in Kibirigwi Irrigation Scheme, Kenya, March-June,1994.

Variable	Category	Number	log total ug dimethoate		ug omethoate	
			Mean	s.e	Mean	s.e
Age (years)	<35	18	8.26	0.49	-0.23	0.35
	>35	21	8.18	0.45	-0.21	0.27
Sex	Female	4	10.10	0.64	0.79	0.19
	Male	35	8.11	0.34	0.34	0.23
Education	Illiterate	8	8.95	0.71	-0.24	0.47
	Literate	31	8.14	0.37	-0.22	0.24
Leak	No	20	8.38	0.44	-0.42	0.27
	Yes	19	8.23	0.49	-0.02	0.34
Spillage	No	29	8.46	0.38	-0.41	0.24
	Yes	10	7.88	0.64	0.33	0.46
Time (min)	<15	18	8.61	0.46	-0.15	0.35
	>15	21	8.06	0.47	-0.28	0.27
Area(m^2)	<380	20	8.71	0.42	-0.08	0.29
	>380	19	8.76	0.50	-0.35	0.32
Nozzle handling	No	28	8.39	0.35	-0.24	0.24
	Yes	11	8.08	0.78	-0.18	0.46

Figure 10: A histogram showing the frequency density of log(dimethoate) in cloth samples of 39 applicators in Kibirigwi Irrigation Scheme,February-June,.1994.

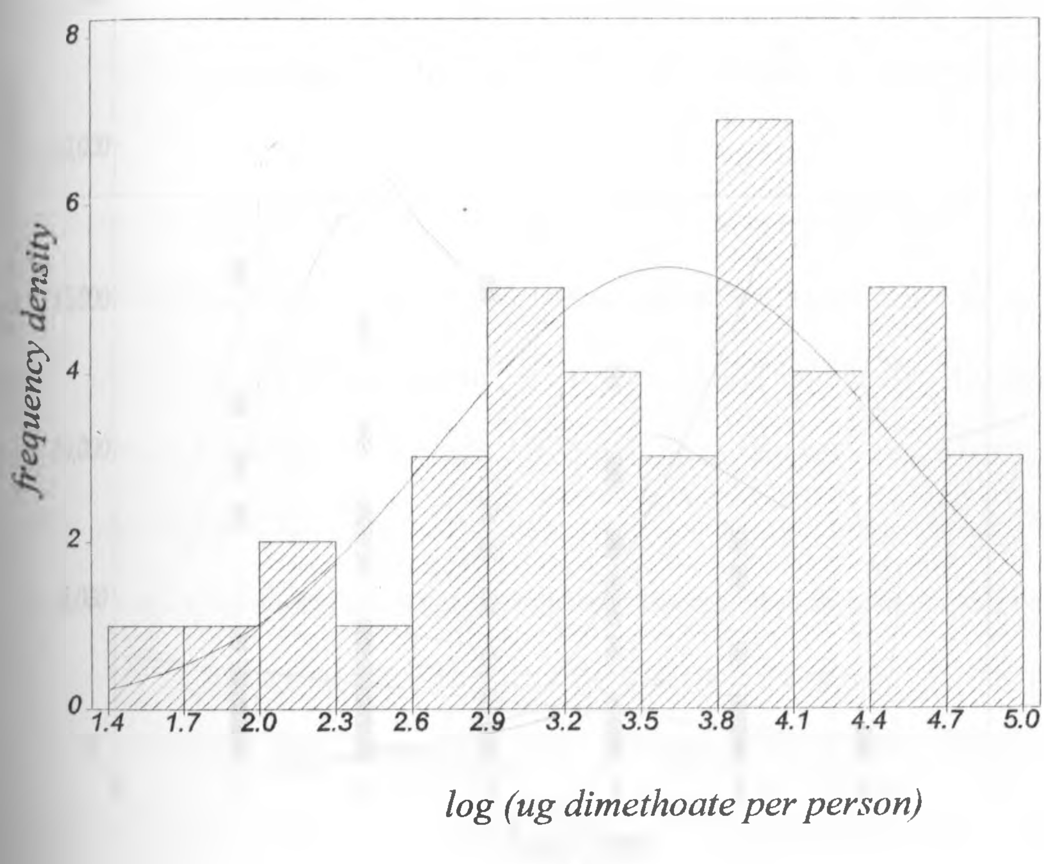
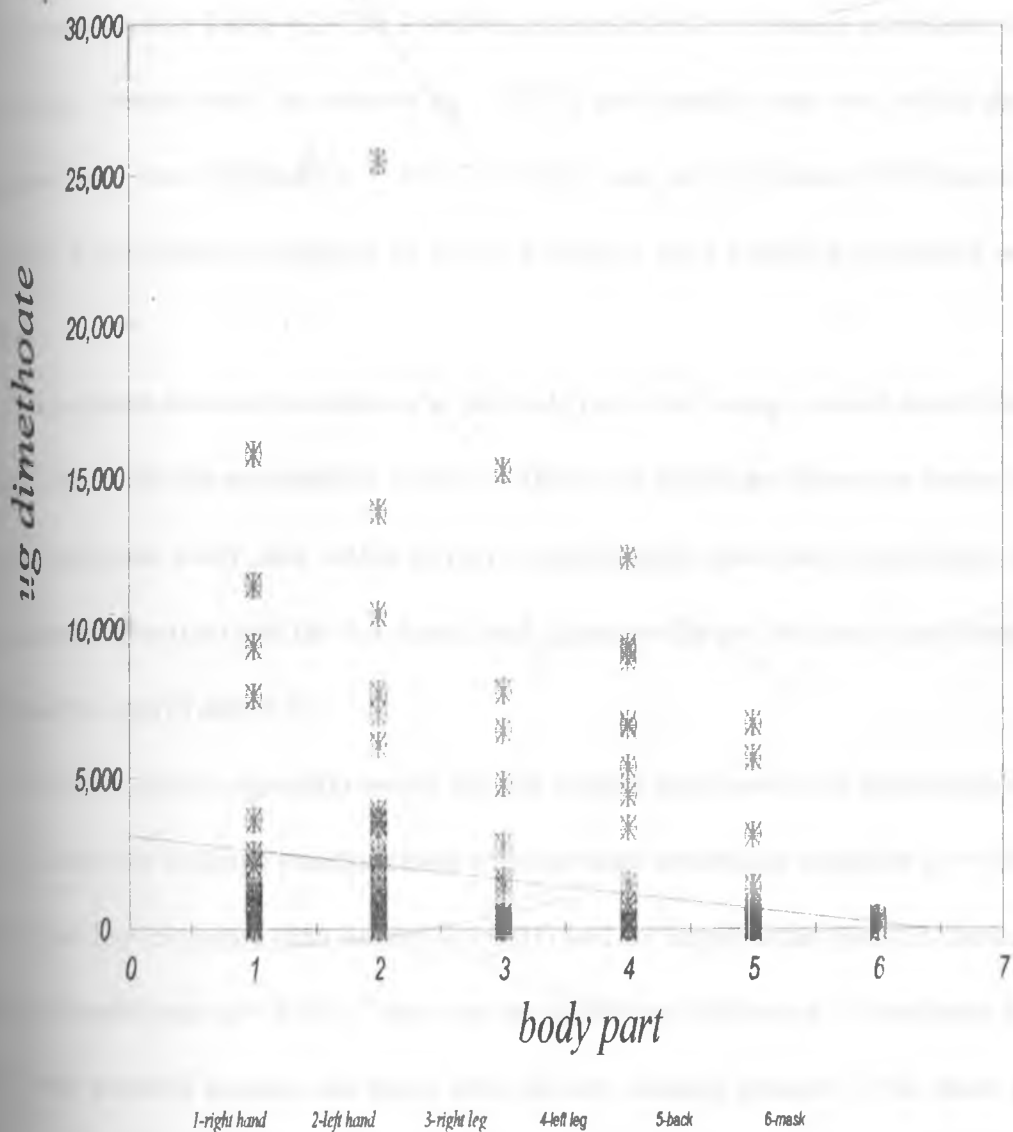


Figure 11: Distribution of dimethoate in various body parts of 39 applicators in Kibirigwi Irrigation Scheme, February - June, 1994.



4.4.4 Associations between risk factors and recovered pesticide levels.

The best sub-set linear regression model of risk factors associated with total dimethoate level are presented in Table 4.2. The 2 factors associated with increased dimethoate exposure were women (versus men) as sprayers (p = 0.007) and smaller area over which the 20 l of dimethoate mix was sprayed (p = 0.017). There was no significant differences in total dimethoate levels between sprayers by level of literacy, poor handling of nozzles or leaking sprayers.

Dimethoate levels were assessed at the body part level using a mixed model analysis of variance. The results are presented in Table 4.3. There was significant farmer to farmer variation in total dimethoate levels and within farmers, specific body parts had significantly different levels detected. The right and the left hands had higher levels and the back significantly lower levels than the legs (Table 4.3).

The best subset regression model for risk factors associated with omethoate levels are shown in Table 4.4. Spillage was associated with increased omethoate exposure (p = 0.04). Men sprayers had less exposure than women (p=0.01) and for larger areas sprayed, there was less exposure to omethoate (p= 0.01). There was no significant difference in omethoate levels for farmers who handled nozzles and those who did not, leaking sprayers, time taken to spray, education level and age of farmers (Table 4.4).

Omethoate levels were assessed at the body part level using general mixed model analysis of variance. The results are presented in Table 4.5. There was significant farmer to farmer variation. Within farmers, at the body part level, the left leg and both hands had significantly lower levels than the back and right leg. Men sprayers had significantly higher omethoate levels than women. In addition, for larger areas sprayed with dimethoate, there was less omethoate. All other variables were insignificant (Table 4.5).

Table 4.2

A linear regression model for risk factors associated with log(total dimethoate) levels from six cloth patch samples on 39 farmers spraying french beans in Kibirigwi Irrigation Scheme, Kenya, March- June,1994.

Variable	Coefficient[a]	S.e	P-value
Constant	12.35	1.29	0.00
Sex	-3.03	1.06	0.00
Area	0.00	0.01	0.01
Time			0.21
Education			0.55
Leak			0.57
Spillage			0.61
Age			0.68
Nozzle handling			0.83

[a]- only coefficients for significant variables are listed.

Table 4.3.
Results of analysis of variance of a general mixed model for risk factors associated with log(dimethoate) levels from six cloth patch samples on 39 farmers spraying french beans in Kibirigwi Irrigation Scheme, Kenya, March- June,1994.

Variable	Coefficient[a]	S.e	P-value
Fixed effects			
Constant	4.33	0.29	0.00
Source			0.00
Right hand	2.33	0.30	0.00
Left hand	1.73	0.30	0.00
Back	-0.76	0.30	0.01
Left leg	-0.53	0.30	0.08
Right leg			0.52
Spillage			0.15
Time			0.28
Area			0.34
Nozzle handling			0.43
Education			0.49
Age			0.62
Sex			0.79
Leak			0.92
Random effects			
Farmers	2.46	0.73	0.00
Error	4.24	0.43	0.00

[a] only coefficients for significant variables are listed.

Table 4.4
A linear regression model for risk factors associated with log(total omethoate) levels from six cloth patch samples on 39 farmers spraying french beans in Kibirigwi Irrigation Scheme, Kenya, March - June, 1994.

Variable	Coefficient[a]	S.e	P-value
Constant	2.12	0.83	0.01
Sex	-1.85	0.68	0.01
Area	-1.00	0.00	0.01
Spillage	0.89	0.68	0.04
Nozzle handling			0.46
Leak			0.50
Age			0.54
Time			0.59
Education			0.84

[a] - only coefficients for significant($p<0.05$) variables are listed

Table 4.5
Results of analysis of variance of a general mixed model of risk factors associated with log(omethoate) levels on six cloth patch samples on 39 farmers spraying french beans in Kibirigwi Irrigation Scheme, Kenya, March-June,1994.

Variable	Coefficient[a]	S.e	P-value
Fixed effects			
Constant	-1.48	0.08	0.00
Source		0.08	0.00
Left leg	-0.33	0.13	0.01
Left hand	0.31	0.13	0.01
Right hand			0.09
Back			0.46
Right leg			0.89
Sex	-0.33	0.12	0.00
Area	0.00	0.00	0.00
Spillage			0.16
Time			0.41
Education			0.58
Leak			0.64
Nozzle handling			0.87
Age			0.99
Random effects			
Farmers	0.11	0.06	0.00
Error	0.80	0.08	0.00

[a] - only coefficients for significant($p<0.05$) are listed

4.4.5 Comparisons of acetylcholinesterase activity estimates.

Two tests to estimate acetylcholinesterase activity in two groups of subjects were carried out. The pH and the spectrophotometric methods were used to compare 47 people from Kibirigwi with 14 from a non-agricultural population in Kabete as well as pre-spraying and post-spraying enzyme levels in farmers spraying dimethoate within the scheme.

The mean enzyme acetylcholinesterase level in serum for Kibirigwi residents was 121 pH units (s.e = 5.2) and the range was 84 - 190 pH units. In plasma, the mean was 91 (s.e = 2.5) with a range 57 -133 pH units. Using the spectrophotmetric method the mean enzyme level in serum for Kibirigwi residents was 3184 milliunits\ml (s.e = 205.8) with a range 1190 - 6728 milliunits\ml. In plasma, the mean was 3460 milliunits\ml (s.e = 167.7) with a range 1462 - 5850.

The results of analysis of 60 serum and 61 plasma samples from 47 residents of Kibirigwi and 14 from Kabete Campus for both the two methods are shown in Tables 4.6 and 4.7. The results for Kabete residents were higher than for Kibirigwi residents using the pH method but not the spectrophotometric method. In serum, the mean was 139.8 pH units (s.e = 10) with a range 86-224 pH units. In plasma, the mean was 109.9 pH units (s.s = 5.8) with a range 74-162 pH units. Using the spectrophotometric method, the mean in serum was 2525 milliunits\ml (s.e.= 339.6) with a range 1320 - 6728 milliunits\ml. In plasma, the mean was 3907 milliunits\ml (s.e. = 336.7) with a range 1755-7020 milliunits\ml.

Statistical analysis of the combined serum and plasma data showed that enzyme levels for Kibirigwi residents were significantly lower than those of the Kabete residents (p=0.0084). Analysis of variance was done for serum and plasma separately and the results are shown in Tables 4.8 and 4.9. For the serum samples, results for spectrophotometric analysis showed the residents of Kibirigwi had higher levels of enzyme and older people had less enzyme than younger people.The other risk factors were insignificant (Table 4.8). The model for the pH method showed that sprayers had lower enzyme levels (p=0.06) than non-sprayers (Table 4.9). The results of regression analysis of plasma samples are shown in Table 4.10 and 4.11. None of the risk factors were significant using the spectrophotometric method but with the pH method, Kibirigwi residents had lower enzyme levels, men had higher levels and those farmers who had sprayed recently had significantly lower enzyme levels than those who had not (Figure 12 and 13).

Table 4.6
Decriptive statistics for discrete and continous variables associated with Acetylcholinesterase levels in serum in 60 randomly selected subjects from Kibirigwi Irrigation Scheme and Kabete Campus, University of Nairobi, December, 1995.

Variable	Category	Number	Change in enzyme level			
			pH[a]		mU/ml[b]	
			Mean	s.e	Mean	s.e
Age (years)	<32	29	122.9	4.67	3373.9	279.5
	>32	31	128.5	8.07	2688.9	213.7
Sex	Female	17	119.7	4.11	2916.5	316.8
	Male	43	128.2	6.37	3060.9	217.5
Education	Illiterate	11	124.0	13.8	2446.2	237.5
	Literate	49	126.2	4.95	3148.8	208.6
Years Spraying	<1	24	135.4	7.41	2833.6	259.2
	>1	36	119.4	5.96	3144.2	243.1
Farmers	Yes	37	119.9	5.80	3090.8	235.7
	No	23	135.2	7.70	2906.0	275.8
Sprayers	Yes	38	119.1	5.65	3094.1	233.4
	No	22	137.3	7.90	2891.8	278.4
Time since last spraying (days)	<7	15	115.4	9.76	3217.3	424.3
	8-14	8	125.7	5.07	3290.4	576.4
	15-21	1	99.0	na	3510.0	na
	22-28	2	124.5	11.50	1778.5	146.5
	>28	14	122.5	11.10	2924.8	337.2
	Never	20	137.4	8.70	2830.1	296.7

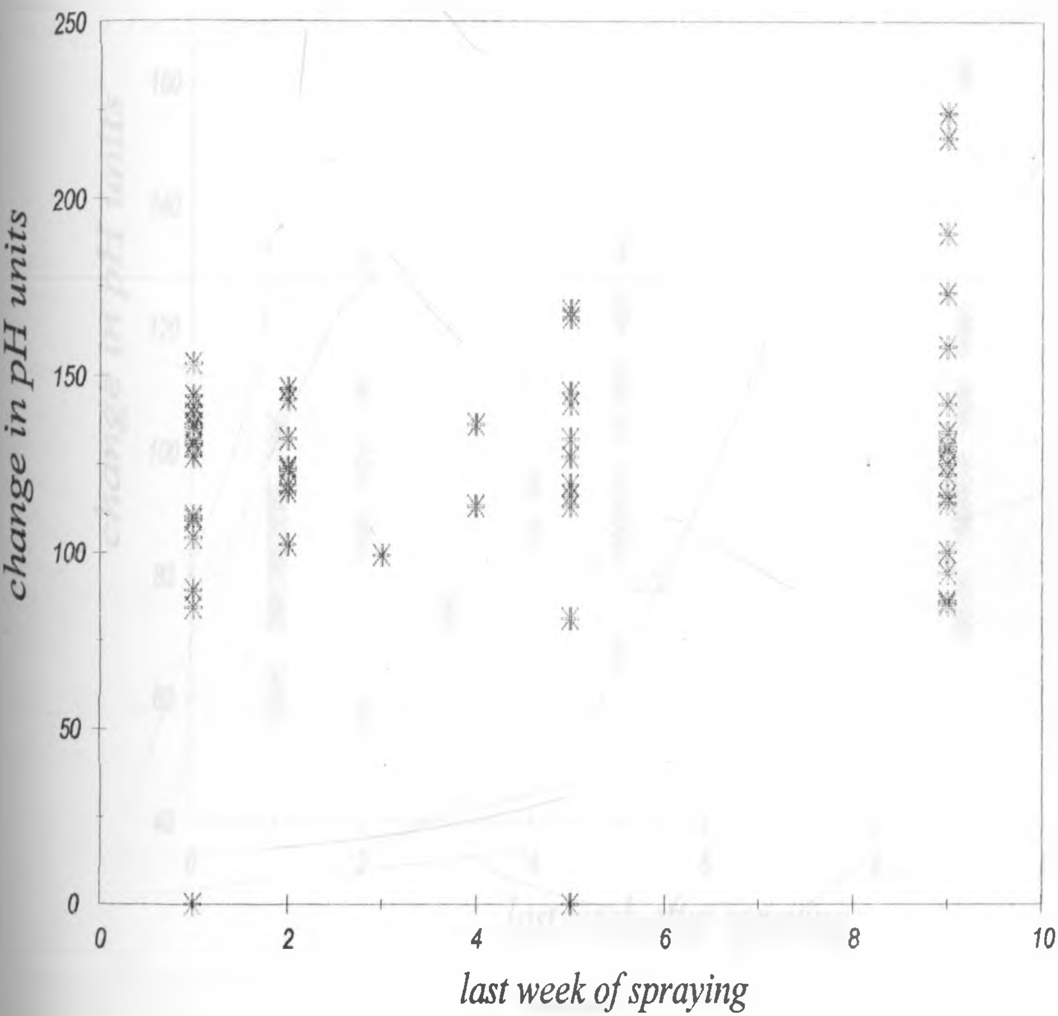
[a] - determined by Michels'method
[b] - detemined by Ellmans' method

Table 4.7
Descriptive statistics for discrete and continous variables associated with acetylcholinesterase levels in plasma among 61 farmers and non-farmers randomly selected from Kibirigwi Irrigation Scheme and Kabete Campus, University of Nairobi, December,1995.

Variable	Category	Number	change in enzyme level			
			pH[a]		mU/ml[b]	
			Mean	s.e	Mean	s.e
Age (years)	<32	31	89.4	3.24	3575.8	234.8
	>32	30	101.8	3.56	3548.9	192.6
Sex	Female	17	88.0	2.99	3595.9	293.3
	Male	44	98.4	3.20	3549.7	178.3
Education	Illiterate	11	88.0	4.30	3323.6	346.7
	Literate	50	97.1	2.80	3615.1	168.5
Years farming	<3	31	99.9	3.52	3481.6	212.9
	>3	30	90.9	3.45	3646.3	217.1
Years Spraying	<1	23	103.3	4.16	3611.7	237.3
	>1	38	90.7	2.93	3532.8	197.7
Farmers	Yes	39	91.1	2.87	3517.3	193.2
	No	22	103.3	4.36	3642.9	246.2
Sprayers	Yes	37	89.4	2.75	3525.5	197.3
	No	24	104.8	4.18	3619.7	239.3
Time since last spraying (days)	< 7	17	83.0	2.91	3182.8	312.1
	8-14	7	95.1	8.50	4178.4	521.4
	15-21	1	74.0	na	4387.0	na
	22-28	2	91	4.00	3217.0	1170.0
	>28	12	101.5	5.53	3582.9	257.4
	Never	22	103.3	4.36	3642.9	246.2

[a]- determined by Michels'method
[b]- detemined by Ellmans' method

Figure 12: Scatterplot of enzyme levels in serum of Kibirigwi and Kabete residents and the last day of applying pesticides.



9- non-sprayers *1,2,3,4,5.-weeks after spraying*

Figure 13: Scatterplot of enzyme levels in plasma of Kibirigwi and Kabete residents and the last day of spraying (Michels'method)..

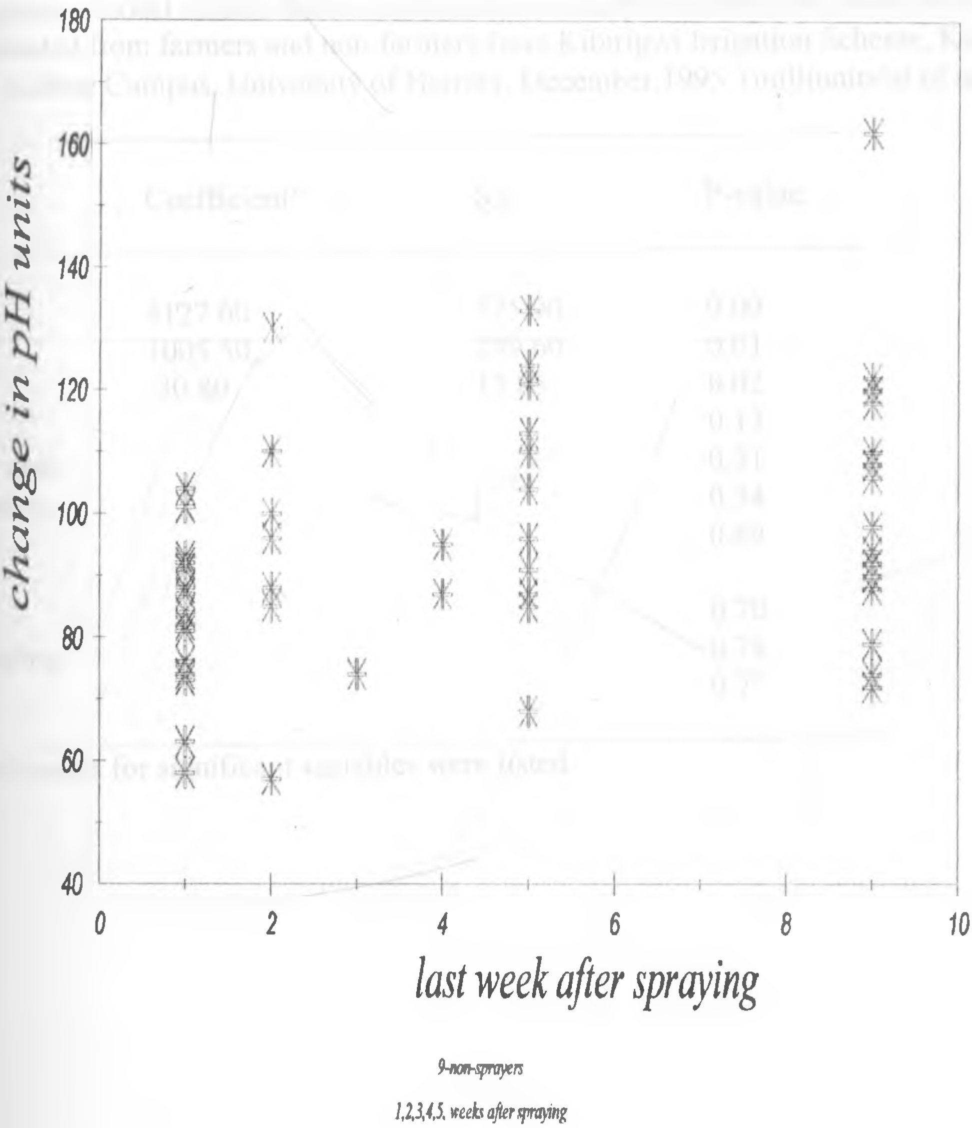


Table 4.8
A linear regression model for risk factors associated with acetycholinesterase levels in 60 serum samples collected from farmers and non-farmers from Kibirigwi Irrigation Scheme, Kirinyaga district and Kabete Campus, University of Nairobi, December,1995. (milliunits/ul of sample)

Variable	Coefficient[a]	S.e	P-value
Constant	4127.60	525.90	0.00
Residence	1005.50	399.60	0.01
Age	-30.80	13.85	0.02
Education			0.13
Last spray date			0.31
Years farming			0.34
Spraying			0.69
Sex			0.70
Years spraying			0.74
Farming			0.77

[a]- only coefficients for significant variables were listed

Table 4.9
A linear regression model for risk factors associated with acetycholinesterase levels in 60 serum samples collected from farmers and non-farmers from Kibirigwi Irrigation Scheme, Kirinyaga district and Kabete Campus, University of Nairobi, December,1995. (Δ in pH units/hr)

Variable	Coefficient[a]	S.e	P-value
Constant	137.30	7.63	0.00
Spraying	-18.10	9.59	0.06
Sex			0.27
Residence			0.53
Age			
Education			0.60
Years spraying			0.72
Farming			0.77
Years farming			0.79
Last spray date			0.85

[a]-Only coefficients for significant variables are listed.

Table 4.10
A linear regression model for risk factors associated with acetycholinesterase levels in 61 plasma samples collected from farmers and non-farmers from Kibirigwi Irrigation Scheme, Kirinyaga district and Kabete Campus, University of Nairobi, December,1995. (milliunits/ul)

Variable	Coefficient[a]	S.e	P-value
Constant	3907.00	314.00	0.00
Residence			0.22
last spray date			0.37
Farming			0.46
Spraying			0.47
Education			0.66
Years farming			0.76
Years spraying			0.87
Age			0.97
Sex			0.98

[a]Only coefficients for significant variables are listed.

Table 4.11
A linear regression model for risk factors associated with acetycholinesterase levels in 61 plasma samples collected from farmers and non-farmers from Kibirigwi Irrigation Scheme, Kirinyaga district and Kabete Campus, University of Nairobi, December,1995. (Δ in pH units/hr)

Variable	Coefficient[a]	S.e	P-value
Constant	109.80	4.85	0.00
Residence	-18.60	5.52	0.00
Sex	12.18	5.0	0.01
Last spray date	3.18	1.23	0.01
Age	0.46	0.18	0.01
Spraying			0.09
Education			0.22
Farming			0.68
Years farming			0.75
Years spraying			0.78

[a]Only coefficients for significant variables are listed.

Thirty-seven farmers were sampled for blood before spraying. However, five out of this group of farmers could not be sampled after spraying due to refusal to participate (3) and for two farmers, there was difficulty in sampling. For comparison, therefore, the results for thirty-two farmers were reported for whole blood both before and after spraying. The results of the enzyme levels for the 32 farmers are presented in Table 4.12. The mean age of the farmers who participated before spraying was 42 years (range, 22-70 years). The mean enzyme level was 138 pH units and the range was 85-191 pH units.

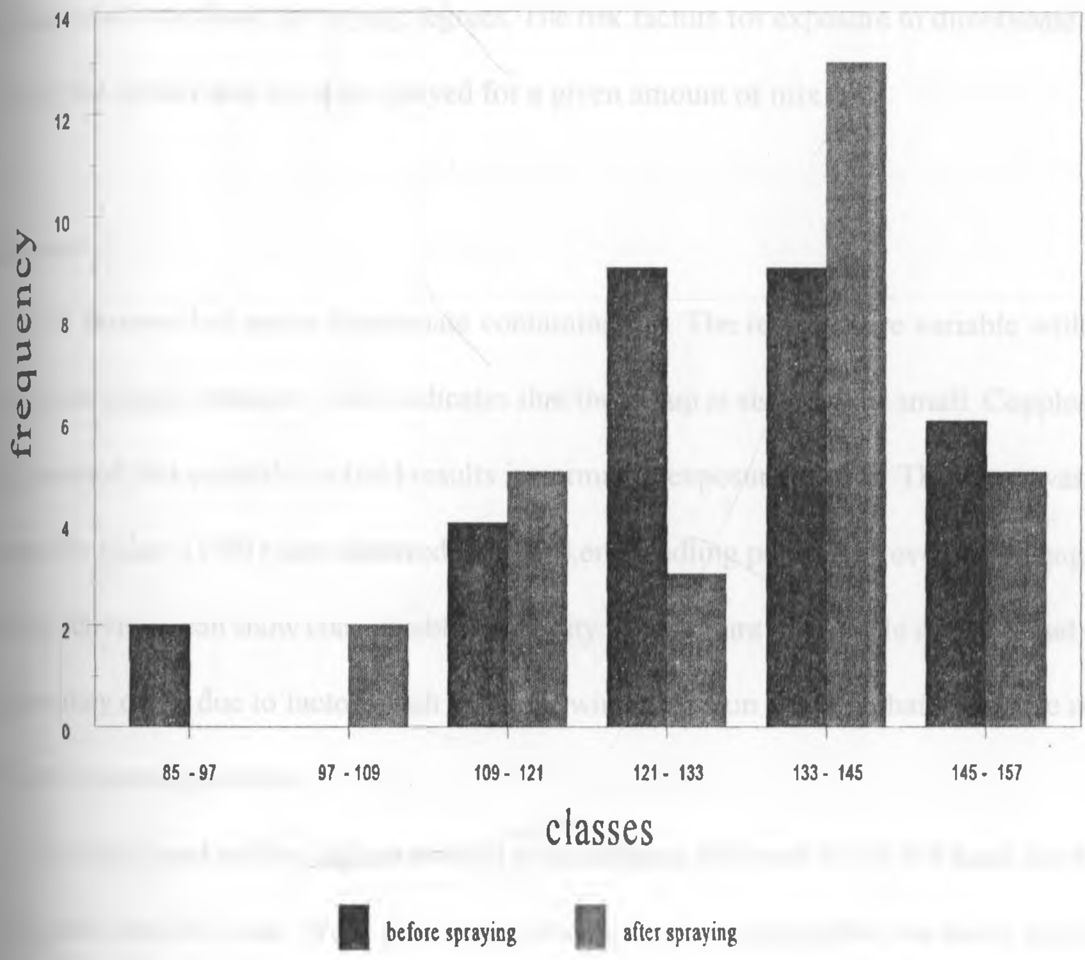
The mean age for the thirty-two farmers who participated after spraying was 40 years (range, 22-70 years). The mean enzyme level was 142 pH units and the range was 102-176 pH units. After spraying, there was decreased enzyme activity in eleven farmers, in two farmers, there was no change and in nineteen there was increased activity. Two farmers had more than 20% depression (one other had 19.4%). The mean change between the two categories was an increase of 2.94 units. The frequency distribution of the cholinesterase levels in whole blood of the farmers before and after spraying is shown in Figure 14.

Statistical analysis of the data showed that there was no significant difference between the enzyme levels before and after spraying. In a paired t-test, the difference was not significant at 95% confidence limit ($t = 0.80$). Analysis of variance showed that age, time taken while spraying, area sprayed, total dimethoate collected onto the clothings, education level and sex of the farmers did not affect the enzyme activity of the farmers significantly.

Table 4.12
Decriptive statistics for discrete and continous variables associated with acetylcholinesterase in whole blood collected from 32 farmers before and after spraying french bean fields in Kibirigwi Irrigation Scheme, March-June,1994. (Change in pH units).

Variable	Category	Number	change in enzyme level			
			Before spraying		After spraying	
			Mean	s.e	Mean	s.e
Age (years)	<35	13	138.0	7.5	136.8	5.7
	>35	19	139.9	4.0	145.7	3.6
Sex	Female	4	148.2	11.3	140.2	9.5
	Male	28	137.8	4.1	142.3	3.4
Education	Illiterate	7	153.5	5.0	154.8	4.7
	Literate	25	135.1	4.4	138.5	3.6
Dimethoate spillage (ug)	<5065	16	130.6	3.8	137.9	4.0
	>5065	16	147.6	5.9	146.3	4.9
Spraying time(min)	<16	15	142.0	7.3	146.8	5.1
	>16	17	136.7	3.2	137.9	3.8
Area sprayed (m^2)	<424	16	134.1	5.6	140.5	5.0
	>424	16	144.3	5.0	143.6	4.1

Figure 14: Frequency distribution of acetylcholinesterase levels in whole blood of farmers before and after spraying dimethoate in Kibirigwi Irrigation Scheme, Kirinyaga District, July-November, 1994.



4.5 DISCUSSION

4.5.1 EXPOSURE TO DIMETHOATE AND OMETHOATE WHILE SPRAYING

The results of this study show that during spraying, the farmers were exposed to both dimethoate and omethoate to varying degrees. The risk factors for exposure to dimethoate were the sex of the farmer and the area sprayed for a given amount of mix.

Dimethoate

All farmers had some dimethoate contamination. The results were variable with few farmers having high exposure. This indicates that the group at risk may be small. Copplestone (1980) reported that variabilty in field results is normal in exposure studies. This view was also expressed by Spear (1991) who observed that workers handling pesticides, even when engaged in similar activities, can show considerable variability in exposure levels. He asserted that such variations may occur due to factors such as minor wind direction changes that can cause major effects on exposure potential.

The right hand had the highest amount of dimethoate, followed by the left hand, right leg, left leg, back and the mask. From field observations, it was expected that the hands would be the most exposed. It was observed that farmers spilled the concentrated chemical on their hands during mixing and frequently touched the nozzles and other parts of the sprayer which were leaking during spraying. Maitlen **et al**. (1982) reported higher exposures for sprayers who had to pour out formulations during mixing prior to spraying. Similar observations were made by Baker **et al**. (1978). Among mosquito control spray teams in Pakistan, spraymen had most exposure on the hands due to extensive skin contact while filling the spray tanks.

All farmers except two were right-handed. They were therefore more likely to spill the chemical on the right hand (mean = 8068 ug, p = 0.000)) than on the left hand (mean = 2702 ug, p=0.000). The left handed farmers also sprayed with their right hand since all the sprayers had the pumping lever on the left and the lance and nozzles on the right. The left hand was consequently less contaminated than the right. This observation agrees with one made by Al Jaghbir **et al**. (1992). They observed that the highest level of exposure among six sprayers in Jordan was on the right arm sponges. Davies (1980) had earlier observed that in cases where a worker mixes his own pesticide before spraying, it is not uncommon for more than 90% of the total dermal exposure to occur on the hands.

Ten farmers had most contamination on their left hand. This may have occurred while mixing the concentrate with water since it involved the use of both hands. In addition, eleven farmers were trying to adjust their leaking nozzles (using both hands) and this may also have led to contamination on the left hand.

There was correlation between the condition of the sprayer and the amount of dimethoate on the cloths. For those farmers who had leaking nozzles or spring and nozzles combined, the mean amount of dimethoate for the former (2521 ug) and the latter (7464 ug) was higher than the overall mean (234 ug) and the difference was significant ($p=0.1$) for the combined cases. The overall mean of the leak group was, however, less than for the non-leak group.

Two farmers had most contamination on the back. This was not expected because the back is on the opposite side of the spray drift and not in contact with sprayed plants that may have pesticide on them. Exposure may occur, however, from a leaking pump, cap or from sprayers without a cap. One farmer had a leaking pump. However, his back exposure was low. It was observed that spray mix dripped from the pump to the leggings and did not land on the back. However, higher back exposures have been observed for backpack sprayers (Turnbull **et al.**, 1985). One farmer had a sprayer without a cap. He had higher (114 ug) than the median(41 ug) amount of dimethoate for the back. One other farmer had a leaking cap and he also recorded higher (193 ug) than median exposure for the back.

The left leggings had significantly more dimethoate than the right ones. It was observed that some farmers were spilling chemical onto their legs as they sprayed especially due to lack of control on the leaking nozzles. In general, leggings were expected to be contaminated because the workers were moving forward as they spray and are therefore likely to contaminate their leggings as they go along. This was reported to be the case in a study to assess exposure to dimethoate during tomato spraying in Hungary. Workers who moved forward through the crop were more exposed (mean=346 mg/hr) than those who moved backward (10.5 mg/hr) (Adamis et al., 1985).

The face masks had the least chemical compared with other cloths. However, the masks for three farmers had appreciable quantity of dimethoate. It is not clear what may have been the source of this contamination. It is likely that these people contaminated their masks by touching them with contaminated hands as well as through drift from air contaminated with the spray mix. In an exercise on exposure during spraying, Archibald **et al.,** (1993) found that sprayers often tried to adjust their masks as they spray. In this case, it was easy to tell that the farmers had handled their masks because the researchers used flourescent tracer methodology to identify the areas where contamination had occurred.

A number of farmers (10/39) splashed the concentrated chemical while mixing. The mean amount of dimethoate was higher for those who spilled than for those who did not, though the means were not significantly different in a two sample t-test.

Using the best-subset regression method, sex of the farmer and area sprayed with the same amount of spray mix (20 l) were the best explanatory variables for total dimethoate. It is not clear why women (n=4) collected more dimethoate on their clothing than the men (n=35). However, the women were less than the men and this may have resulted in less variability. The larger the area sprayed with the same spray mix, the less the exposure. This is possibly due to the fact that people who sprayed over large areas sprayed faster, and had less chance of contaminating themselves.

The results of the analysis of variance of the data as a mixed model showed that among the fixed effects, body part was important in determining the amount of total chemical for the workers. The hands were most significant (p=0.000), followed by the back (p=0.012) and the left leg (p=0.081). The right leg and the mask were insignificant. There was signifi ant farmer-farmer variation.

The results of this study indicate that the farmers are occupationally exposed to dimethoate. The dermal exposure on the right hand was calculated as 41.5 ug/cm ^{2}/hr dimethoate. The level was lower for the other body parts. This figure is considerably higher than that of Copplestone and coworkers (1976) who estimated dermal exposures using cellulose pads. He found levels of 1.0 ug/cm^2 for the lowe. leg and much lower levels for the other body parts. However, the workers reported variable data and for the lower leg, for example, a maximum of 236.7 ug/25 cm^2 was reported. In contrast, Al Jaghbir **et al.** (1992) estimated much higher levels. The highest exposure was for the right-arm sponges and was 62.2 ug/cm^2/hr and the lowest due to the back sponges. This latter result agrees with the data in this study where the back received the least mean exposure (mean= 0.6 ug/cm^2/hr).

For total exposures, the mean was 61.4 ug/cm^2/hr for dimethoate . Al Jaghbir **et al.** (1992) reported total mean exposure of 272 ug/cm^2/hr. However, his study was done under plastic house conditions where air-drift is less, the number of plants is double that in an open field and plants are much taller.

It is common practice to merge exposure data with toxicological information and report exposures in terms of percentage of toxic dose per person per hour (Spear, 1991). These were calculated based on the assumption that the workers have a two hour working day and the total exposed area was 5405.5cm^2 (total area for all the cloths used in the study). Dermal LD_{50} of animals are normally utilised (WHO, 1982) and for dimethoate it is 700 mg/kg b.w. (BCPC, 1987). The percent toxic dose calculated were less than 1%. (mean= 0.003% CI, 0.0017,0.0056). This level is considered to be the critical level of the acutely toxic dose in exposed individuals (WHO, 1971). The results obtained in this study therefore agree with usual reported values of dermal exposure, usually less than 1% of the acutely toxic dose per hour of exposure for a wide variety of chemicals and circumstances (Spear, 1991). Since the farmers do not wear protective clothing, these pesticides would come into contact with their skin when they spray. The amount of chemical absorbed on the skin would depend on the rate of penetration of pesticides through the skin. Jensen (1980) estimated that 10% of pesticides on skin may be absorbed. Though this author admits this value is based on little data and is not reliable, better estimates are unavailable. If we use Jensens' estimate therefore, the farmers would absorb about 234 ug (10% of the mean = 2338 ug) of dimethoate/hr which is also a daily rate since all calculations were based on a 2 hour day (the average time spent on spraying operations among these farmers). When compared with the Acceptable Daily Intake (ADI) of 0.02 mg/kg b.w (FAO/WHO, 1968), for a 70 kg person, the exposure for the farmers is less than the total ADI value of 1400 ug of dimethoate allowed per day. Sixteen farmers had exposures above 1400 ug/day. This is the number which can be considered at risk.

In the absence of protective clothing therefore, these farmers may be exposed to higher levels of dimethoate than the ADI.

Omethoate

Fifty - eight of 234 samples analysed contained omethoate. The risk factors were sex, area, body part and spillage. The distribution of omethoate was also variable with most of the farmers having less than 20 ug and a few cases between 20-40 ug and fewest cases with about 220-240 ug. The left hand had the highest amount followed by the right hand, right leg, the back, the left leg and the least was on the mask. This pattern is different from the one of dimethoate. The likely reason for this is that since omethoate is formed on oxidation of dimethoate, factors other than total amount of dimethoate would influence the oxidation reaction. The presence of omethoate in these samples is significant because it has been reported that the latter is at least four times as toxic as dimethoate (Santi and Pietri-Tonelli, 1959) and 75-100 times more potent than dimethoate as an inhibitor of acetylcholinesterase (Hassan **et al**., 1969). In another study, it was concluded that the oxygen analogues of dimethoate are at least 10 0 times more potent inhibitor of fly head and human plasma cholinesterase (Lucier and Menzer, 1970).

The results of a sub-set regression of omethoate and the risk factors showed that sex, area and spillage were the most important explanatory variables. The amounts of omethoate and dimethoate were positively correlated (r = 0.39). It is therefore not surprising that the same variables were significant. Variables that were found less significant were the condition of the sprayer (leak/non-leak). However, the mean for leak group was higher (19.3 ug) compared with the non-leak group (2.8 ug). Farmers who handled their nozzles during spraying also had a higher mean omethoate (23.9 ug) compared to those who did not (6.02ug) though the difference was not statistically significant. These differences may have arisen from leakage since when it occurs, the chemical on the clothing would be exposed and therefore subject to environmental change and therefore result in higher level of omethoate. The farmers who handled their nozzles were trying to adjust them because they were either leaking or blocked. In the process, the farmer would pick up some dimethoate onto the gloves and since leaking would start immediately after the pump is pressurized, the amount of dimethoate converted to omethoate would be high for farmers who tried to adjust their nozzles. There was no statistically significant difference between the mean for farmers below 35 years old (median age) and those above. However, the mean for the younger group was higher (16.9 ug, s.e. = 11.3) compared with that of the older group (5.70 ug, s.e. = 3.8). The likely reason was that the former are more energetic and less cautious compared with the latter. Education or lack of it caused no difference in total omethoate. The literate group had higher totals (mean = 12.6 ug, s.e. = 7.6) than the illiterate group (mean= 4.4 ug, s.e. = 2.2). The latter group were possibly more cautious due to fear of criticism while the former were more confident. A higher mean was recorded for longer spraying time possibly because workers exposed their dimethoate contaminated clothing longer in the fields. Farmers who spilled chemical when mixing had significantly higher total omethoate (32.9 ug) than those who did not (3.31ug). The likely reason for this was that after spillage, the dimethoate residues on the hands and other contaminated cloths would have had a higher chance for conversion to omethoate than the material inside the spray tank.

Analysis of variance of the general mixed model for omethoate revealed that the amount of omethoate on the different body parts were different. The model was based on the body part as the outcome (fixed) and farmer effects were assumed random. Other factors at the individual level were fixed (sex, age, area, time, education,leak, nozzle handling,spillage). Age, area and time were analysed as covariates. The left leg was the most significant (p=0.01). It was followed by the left hand(p=0.01) and the right hand (p=0.09). Other parts were insignificant. It is not clear why the difference exists. Sex and area were significant (p=0.05 and 0.08 respectively). This was expected because the same variables were significant for dimethoate.

This study had some limitations. Analysis of metabolites in urine to confirm the penetration of any pesticide into the body was not done. Dimethoate is known to have a very large number of metabolites (FAO/WHO, 1968) that are difficult to identify and separate. This would have made the study too complex for the sample size of farmers that were examined. In addition, the farmers were not questioned in detail on whether they had any ill-effects after spraying. Though none of them reported any illness soon after spraying, it may have been useful to do a follow-up in the few hours and days after spraying. In retrospect, also, it would have been more revealing to sample the hands separately from the rest of the arm. From observations, the farmers contaminated their hands as they were mixing and much less during spraying. Due to the fact that the exposure was assessed for the whole arm, it is difficult to separate hand exposures from arm exposures.

4.5.2 ACETYLCHOLINESTERASE STUDIES.

These studies were carried out to investigate whether the farmers who carry out the spraying with dimethoate are exposed to the anticholinesterase agent, dimethoate and its metabolite, omethoate and whether depression of the enzyme occurs due to exposure during spraying. Due to the wide range of enzyme activity in normal, unexposed individuals (Augustinsson, 1955), pre-exposure determinations are usually recommended. The proportionate reduction of the enzyme activity from the normal for the individual is more important than the numerical value of the test (Vandekar, 1980). Therefore the pre-exposure determinations were carried out.

Analyses were carried out for non-spraying, non-farming persons who were part of the farming community as well 14 non-farmers from Kabete campus, University of Nairobi. It was found that the acetylcholinesterase levels in plasma and serum were signicantly higher than the level for farmers (p = 0.008). Variations in enzyme activity were observed in the farmers before spraying (85 - 191 pH units). The mean for the 37 farmers before spraying (139 pH units) was found to be significantly different from the mean for controls (237) recruited from the university and confirmed to be non-spraying and non-exposed to anti-cholinesterase agents (p=0.000, 95%).

After spraying, the range was smaller (102-176) though the sample size was smaller. Three farmers were unwilling to partipate further in the study and for two subjects, we had difficulty in sampling the second time. The mean for this group was 142 pH units and was also significantly different from the mean of the control group from Kabete (p=0.00, 95%).

All farmers had activity levels which were significantly below the mean of the control group. This seems to indicate that the levels for these farmers were ordinarily lower than normal and this may be due to continuous exposure. A study by Lander **et al.** (1992) reported only small changes in plasma cholinesterase among a group of farmers working in greenhouses. The workers concluded that this may have been because application of anticholinesterase agents occurs almost throughout the year and subjects were already depressed before the baseline measurements were taken. The farmers in the scheme do irrigation farming and therefore are growing crops and spraying almost continuously. It is appparent that farmers are more at risk of exposure to anticholinesterase agents compared to non-farmers.

The difference in enzyme activity before and after spraying was calculated for each farmer. It was found that in two farmers, there was more than 20 % depression. The two exceeded the WHO exposure index (WHO, 1988) which lies between 20-25%. One farmer had 26% depression. Vandekar (1980) has observed that while depressions of more than 12.5% may represent normal fluctuations in activity or experimental error, if observed in several workers, it may represent actual exposure. In this case there were 3 cases with more than 12.5% depression (26%, 24%,19.4%).

In nineteen farmers, there was an increase in enzyme activity. In one case, the increase was 67%. This had also been observed by Burgess and Roberts (1980), who reported that in a group of workers packing pesticides, there was an increase in red blood cell acetylcholinesterase after a period of packing. The researchers suggested that a possible explanation to this trend was that a low level of exposure to an inhibiting agent caused an increase in the enzyme by enzyme induction and this would rise above the measured baseline. Roberts (1980) also emphasized that enzyme induction can occur for reasons not related to low- level exposure.

The means for enzyme levels before and after spraying were not significantly different. This agreed with the results of a similar study in the Sudan in which Copplestone **et al.** (1976) found that the mean cholinesterase level post-spraying with dimethoate (9 . %) was higher than pre-spraying. They explained that there was no difference between the exposed group and the controls and therefore this difference does no represent a difference in enzyme activity before and after spraying. It has also been reported that it requires high levels of intoxication with dimethoate for any depression in acetylcholinesterase to be observed. For example, in a study on human volunteers, a dose of 15 mg dimethoate daily showed no effect after administration for upto 57 days (British Crop Protection Council, 1987). In another study to assess the effects of organophosphates on acetycholinesterase levels of applicators, Peoples and Knaak (1982) found that there was no significant difference between workers and non-workers. In contrast, Al-Jaghbir **et al.** (1992) reported mean depressions of 37% for blood sampled 15 minutes after exposure and 26 % for blood sampled 24 hours after. However, they had a small sample of 6 sprayers.

Blood samples were collected 24 hours after spraying. It is possible that enzyme levels in the farmers had already started recovering. In the study by Al Jaghbir **et al.** (1992) mentioned above, there was more depression if samples were drawn 15 minutes versus 24 hours postspraying. Cases of spontaneous enzyme reactivation have also been reported (Reiner, 1971., Edson, 1958). Other reports indicate that recovery is gradual and may take more than two weeks due to the natural consequences of the aging of the enzyme (Vandekar, 1980). Despite the obvious advantages of repeated sampling, however, it was not possible to draw samples more than once due to the reluctance of repeated blood samples by the farmers.

The reported levels are for exposure periods less than one hour long (8 min-53 min). When the change in levels were calculated per hour, it was found that the theoretical levels gave more than 50% depression of the pre-exposure levels. However, under field conditions, exposures are not predictable and the trend observed during the spray period may not have continued. Recovery also occurs at different rates in different people (Vandekar, 1980). Serial sampling would provide more insights into these patterns but compliance is difficult to achieve for multiple samples under field conditions.

4.6. CONCLUSIONS

It was concluded that farmers were exposed to more than the ADI of dimethoate but not omethoate during spraying. The exposure was, however, less than 1% of the toxic dose of dimethoate as measured by the amount of dimethoate and omethoate on the cloth samples. Since the cloths acted as protective clothing for the farmers, this study confirms that protective clothing would be useful in reducing exposure to dimethoate and omethoate during spraying. Most of the contamination was on the hands. Therefore protection of the hands is the most important measure the farmers can make to reduce total exposure. Careful handling during mixing to reduce splashing to the hands is also likely to be an important way of reducing total exposure.

The results of this study suggest that the farmers in the Scheme are continually exposed to anticholinesterase agents and therefore have abnormally low levels of acetylcholinesterase when compared to non-spraying, non-exposed controls. A longitudinal study is needed to measure acetylcholinesterase levels in their blood several times over a period of a year. The results of such a study would help to confirm whether the levels are low continuously or there are fluctuations coinciding with spray periods.

CHAPTER FIVE

SPECIFIC AGRICULTURAL EXPOSURES 11: STUDIES TO DETERMINE EXPOSURE TO DIMETHOATE, OMETHOATE AND CYPERMETHRIN DURING WEEDING AND HARVESTING.

ABSTRACT

Exposures during weeding sprayed french bean fields were investigated among six farmers at Kibirigwi Irrigation Scheme. Farmers sprayed dimethoate to their fields and then weeded one, three,four, ten and eleven days later. It was found that the overall mean levels of dimethoate and omethoate on their clothing declined from 0.33 ug on day 1 to nearly zero (0.0025 ug) by the 11 th day and from 0.27 ug on day 1 to 0.009 ug for the two pesticides respectively. Significantly more dimethoate was extracted from clothing if reentry was 1 day versus all other days after spraying.

Exposure from harvesting sprayed bean fields were investigated among forty farmers. Farmers harvested beans daily from day one to thirteen days after they were sprayed with cypermethrin only. The results of the harvesting study showed that farmers were exposed to cypermethrin as well as to dimethoate and omethoate which had been sprayed more than 2 weeks before sampling. The mean levels declined from 0.029 ug on day 1 to 0.001 ug on day 13 for dimethoate and 0.001 ug on day 1 to 0.303 ug on day 13 for omethoate. Cypermethrin residues declined from 12.21 ug on day 1 to 4.31 ug by day 13. It was concluded that these farmers receive measurable pesticide exposure during weeding and harvesting.

5.1 INTRODUCTION

Agricultural workers may be exposed to pesticides during different farm operations such as weeding and harvesting crops treated with pesticides (Milby **et al.**, 1964). Exposure may lead to poisoning. Re-entry poisoning was reported to be an important source of poisoning among farm workers more than forty years ago (Carman, 1952). It was observed that workers would fall ill if they entered treated fields after application. In California, for example, workers were poisoned after re-entering a field one month after the last spray (Milby **et al.**, 1964). A comparable incident also occurred when 142 students reentered a field and detaselled maize which was mistakenly treated with carbofuran a few hours earlier. Seventy-four were mildly poisoned, twenty-nine were sent to hospital and one was held overnight (USEPA, 1978).

Poisoning due to re-entry has been reported from sulphur pesticides, carbamates, chlorinated hydrocarbons and organophosphates (Wicker **et al.**, 1979). Organophosphates that have been implicated are parathion (Milby **et al**. 1964, Spear **et al.**, 1977), azinphos-methyl, ethion, dioxathion, malathion (McEwen, 1977) and dimethoate (Wicker **et al.**, 1979). Poisoning due to organophosphates has been attributed to their inherent toxicity and the relative ease with which the oxon metabolites are formed under field conditions. They are also easily absorbed through the skin (Hayes, 1982b).

Poisoning cases that have resulted after re-entering fields treated with dimethoate have been reported. Hayes (1982) reviewed a case in which a 16 year old boy developed weakness, nausea, headache and severe depression after picking hops previously treated with dimethoate. Wicker **et al.**, (1979) also reported three incidencies in which dimethoate was implicated in re-entry poisoning. In another study, Leisivuori **et al**. (1988) reported dermal exposures of 1.1 mg/cm^2 for dimethoxon and 0.48 mg/cm^2 dimethoate. However, the latter workers did not report any illness due to the exposure and the exposure time was also not reported.

Re-entry exposures to cypermethrin have not been widely investigated. One of the few studies is reported by Dover (1985) who investigated exposure to applicators in-Tanzania. He reported dermal exposures of 3 - 27 mg/hr. He also reported about the same levels in a study in Paraguay (29 mg/hr). Few studies have been done to assess contamination with cypermethrin during harvesting. The results of a study to investigate the amount of dislodgable foliar residues on cotton can give some idea of levels that may be expected (Estesen **et al**., 1982). It was reported that residues may persist beyond 12 days after spraying. The residue level by the 16th day was 0.077 ug/cm^2 of leaf surface.

Cypermethrin is a slight skin irritant, a mild eye irritant and has a weak skin sensitizing potential (BCPC, 1987). It may also cause allergy (Bayer, 1993). Other adverse effects noted include : immunosuppression (EHC, 1989), possible carcinogenicity (Anonymous, 1989) and mutagenicity (NIOH, 1989).

Studies on dermal exposure during harvesting are useful in establishing re-entry periods for agricultural workers. This study was carried out to assess the risk from cypermethrin exposure associated with harvesting among farmers growing beans in Kibirigwi Irrigation Scheme. Cypermethrin is widely recommended for use in the scheme for control of pests on beans after flowering while dimethoate is recommended to be used before flowering. However, it had been observed that due to the low cost of dimethoate compared with cypermethrin, the former is used even after flowering. After spraying, farmers re-enter treated bean fields to weed and harvest During the harvesting period, beans are harvested every day regardless of when they were last sprayed. The study investigated whether farmers' clothes would be contaminated with dimethoate and omethoate during weeding and with dimethoate, omethoate and cypermethrin during harvesting. The information obtained from this study will help in suggesting re-entry periods to be observed by farmers after spraying their fields with dimethoate and cypermethrin.

5.2 MATERIALS AND METHODS

5.2.1 Study area and design

The study area was Kibirigwi Irrigation Scheme as described in Section 2.2. Farms were stratified into three sections and an equal number of farms randomly selected from each strata to ensure that all geographical areas of the scheme were sampled. The design was as described in Section 4.2.2. (Chapter 4). Thirteen farms were sub-sampled from two sections and 14 from one section for more detailed quantitative studies.

5.2.2 Study subjects

Six farmers were randomly selected from the 40 above and requested to participate in the weeding study. These were four men and two women. In the harvesting study, there were forty farmers who included seventeen women and twenty-three men.

5.2.3 Field Methods

Farm visits

The weeding study was undertaken in July and August, 1994. All farmers who were recruited for the study were visited before the sampling to ensure that they had planted beans so that the study would be undertaken when the bean crop was about one month old. Within this waiting time another visit was made one week before the sampling date. During the visit, a farmer was provided with 30 ml of a 40% formulation of dimethoate. He was then advised on the date to spray and the sampling was done either on a 3rd or the 4th day and then one week later on the 10th and 11 th day after the spray date.

The harvesting study was done after the beans had flowered. This is normally the period when the farmers spray with synthetic pyrethroids. Just before the sampling time, farmers were visited again, about one week before they were scheduled to spray and during this visit were supplied with 40 ml of a 5% formulation of cypermethrin. Sampling was done either on the 3rd or the 4th day and one week later on the 10th or the 11 th day after the spray date.

Sampling weeders and harvesters

For one weeder, sampling was done on the first day after spraying. For the other five farmers, one weeded on the third and the fifth day, one weeded on the fc th and the eleventh and the last three weeded on the fourth and tenth day after spraying. Prior to weeding, each applicator was fitted with:

(i) a pair of cotton leggings for each leg measuring 1862 cm^2 and covering the leg from the knees to the ankle.

(ii) a pair of gloves to cover each hand and the arm up to the elbow and measured 640 cm^2 (see plates 4,5, and 6.

The weeder then weeded for 5 minutes while the researcher kept time and measured the area covered in 5 minutes. The cloth covers were then removed carefully and each item placed separately in a glass jar with a wide mouth with a screw cap lined with aluminium foil to avoid contamination. Jars were placed in a cool box ready for transportation to the laboratory. The same procedure was repeated for the second sampling. Blank cloths were incorporated on each sampling day. A total of 44 samples were collected for the weeding study. All samples were transported to the laboratory in glass jars in cool boxes packed with ice, within twenty-four hours of collection. The procedure for harvesters was the same as the one for the weeders. All farmers harvested twice. The largest group harvested on the fourth and twelfth day (13/40), followed by the fourth and eleventh (5/40), third and tenth, and fifth and twelfth (4/40 each), third and eleventh, and third and twelfth (3/40 each) and the remaining nine farmers in various other combinations of dates. Before sampling, the harvesters were fitted with the same type of clothing as described for the weeders above and samples were treated in the same way. In total 320 samples were collected for the harvesting study.

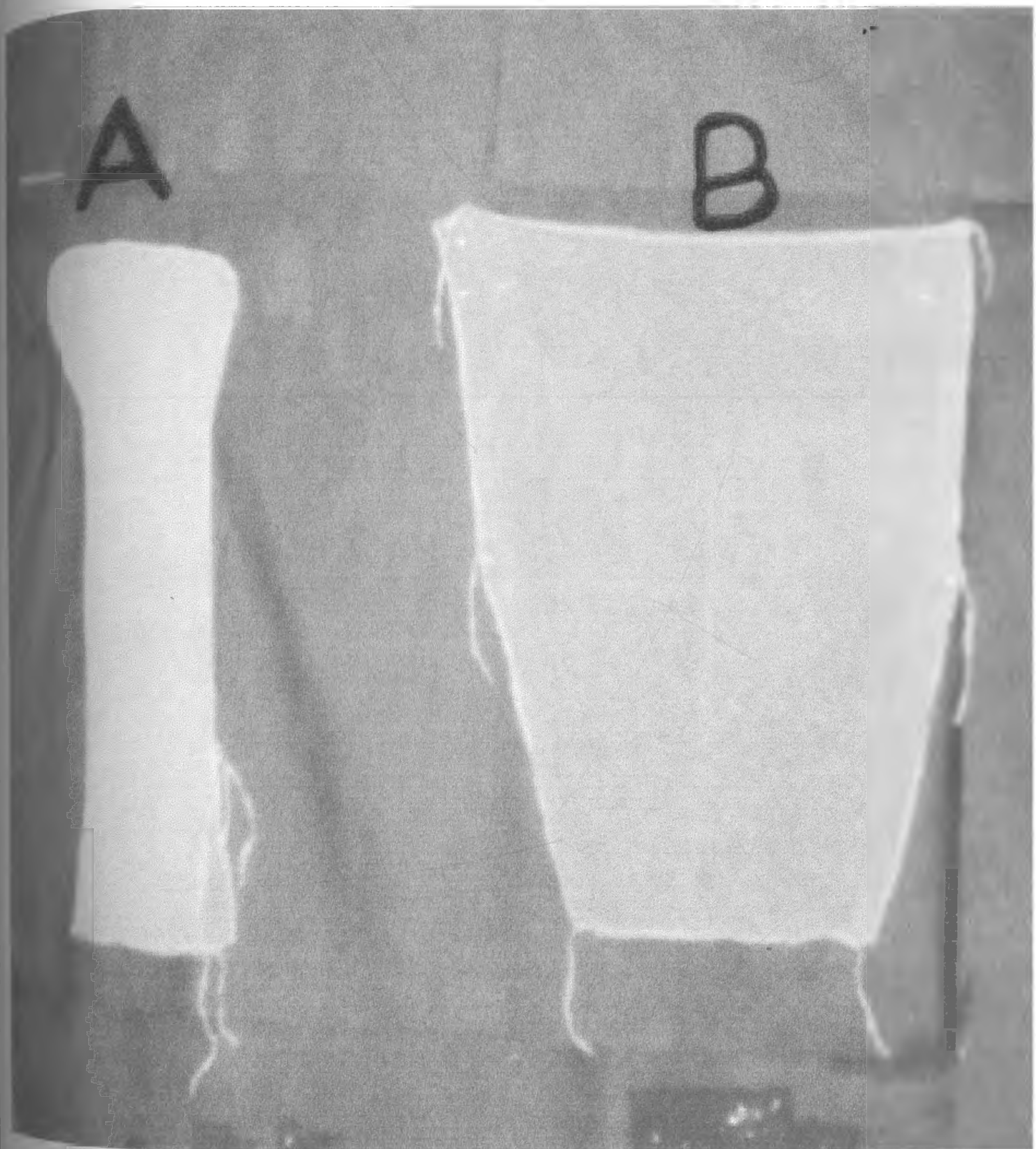


Plate 4: Sleeves (A) and leggings (B) used in the weeding and harvesting study.

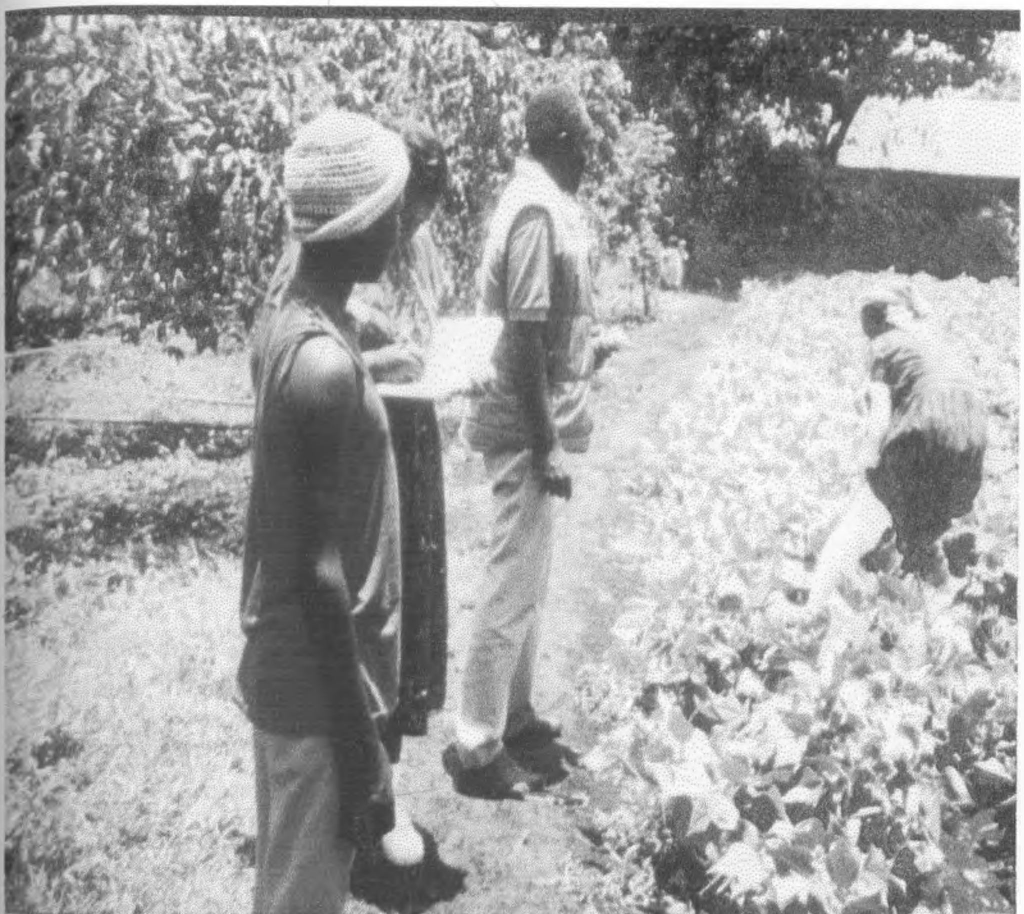


Plate 5: A farmer weeding a french bean plot (extreme right) during the weeding study.

Plate 6: A farmer harvesting beans during the harvesting study

5.2.4 Laboratory Methods

Calibration of standards and recovery studies.

The dimethoate analytical standard was obtained from the Pesticide Chemistry Laboratory of the Kenya Agricultural Research Institute and was purchased from British Greyhound Chromatography and Allied Chemicals (Birkenhead, England, Lot No 106-52A, PS-659, 98% purity). Omethoate standard was supplied by Bayer East Africa and was confirmed to be pure. Stock solutions were prepared in acetone to a concentration of 1000 ppm. From this stock, dilutions were prepared to 200 ppm and then to the following concentrations: 1 ppm, 0.5 ppm, 0.25 ppm, and 0.05 ppm for both standards. These were injected into the gas chromatograph (GC) and standard curves were prepared. The GC conditions are outlined below.

To determine the suitability of dichloromethane in extracting these pesticides from the cloth samples, unused cloths measuring 30 cm*30 cm were spiked with 1 ppm, 0.5 ppm and 0.05 ppm dimethoate and omethoate. The cloths and a blank were extracted with the solvent using the method described below and the recoveries determined.

The cypermethrin analytical standard was also provided by the Pesticide Chemistry Laboratory of the Kenya Agricultural Research Institute earlier purchased from British Greyhound Chromatography and Allied Chemicals (Birkenhead, England Lot No 102-150A, PS-1068). The stock solution was prepared by dissolving 0.1155 g in 100 ml acetone to make 1000 ppm. This was diluted to a concentration of 200 ppm and this stock was used to prepare serial dilutions of 1 ppm, 0.5 ppm, 0.25 ppm and 0.05 ppm. These were injected into the Gas Chromatograph fitted with a ^{63}Ni Electron Capture Detector(ECD). The conditions used are described below. To determine recoveries from cloth samples, the cloths and a blank were spiked and extracted with dichloromethane solvent as described above for dimethoate and omethoate. The extracts were then cleaned up and the recoveries determined.

Extraction of cloth samples

The extractions were carried out according to a procedure described in the Pesticide Analytical Manual (1973) and later used by Ritcey **et al.** (1987). Each cloth sample was soaked overnight in dichloromethane. The following day, the cloth and dichloromethane were transferred into 500 ml conical flasks and extracted in the same solvent by shaking on a Burrel wrist shaker for one hour at a setting of 3. The solvent was filtered into a Buchner flask through a sintered borosilicate funnel under vacuum. The contents were then transferred into a 500 ml round-bottomed flask. The Buchner flask was rinsed with small portions of dichloromethane and these were added to the contents in the flask. The dichloromethane was evaporated to just dryness on a rotary evaporator at 50^{0}C. The extract was dissolved in 5 ml hexane and the sample was transferred to a 7.4 ml Supelco^{R} bottle with a Teflon^{R} lined cap for analysis on the GC with the Flame Photometric Detector (FPD). Samples from the harvesting study were divided into two portions: 0.5 ml for injection into the FPD and 4.5 ml for clean-up for analysis of cypermethrin residues.

Clean-up of samples for cypermethrin analysis.

A Mills column was first used for clean-up and later the microliter method was adapted due to the high cost of reagents. The column was prepared with chromatographic tubes 22 mm id*40 cm long. 25 g of deactivated florisil (heated overnight at 135^{0}C) was introduced into the column and an even packing was obtained by tapping the sides with a glass rod. A 1 cm layer of anhydrous Na_2SO_4 was introduced on top of the florisil. The column was prewashed with 50 ml of hexane and the hexane extract transferred into the column with 2-3 rinsings of the sample bottle. The column was then eluted sequentially with (A) 200 ml of dichloromethane: hexane (20:80) at 5 ml/min and (B) 200 ml acetonitrile:dichloromethane:hexane (0.35:50:50) at the same rate. The eluates were collected in 300 ml boiling flasks, evaporated to just dryness at 50°C and redissolved in 5 ml of hexane. In recovery studies it was found that only the second fraction contained the cypermethrin and therefore, in the microlitre method the first elution was not carried out.

The microlitre method has been used at the Pesticide Chemistry Laboratory of the Kenya Agricultural Research Institute (Namu, 1994). In this method, 1 ml of sample was used for clean-up and a pasteur pipette was used as the column. The column was packed with 0.2 g of preheated florisil and a small portion of anhydrous Na_2SO_4 added on top. The column was prewashed with 1 ml of hexane and 1 ml of the hexane extract was introduced into the column. The column was eluated with 5 ml of eluant B described above at a small dropwise rate. The eluate was collected in 10 ml boiling flasks, evaporated to just dryness on a rotary evaporator at 50°C and redissolved in 1 ml of hexane. The final extract was placed in 7.4 ml Supelco® tubes with Teflon lined caps. All samples were stored at -18°C until analysis.

Analysis of cloth samples for dimethoate and omethoate

Analysis was done on a Flame Photometric Detector on the Gas Chromatograph Varian 3400 on a capillary column (Capillary Column J & W Scientific : Length 15 m, i.d. 0.54 mm and 1.5 microns film thickness) and equipped with an integrator Model Varian 4400. The conditions were as follows: the column temperature was 150°C to 250°C at 20°C per min; the injector and detector temperatures were 230° C and 250° C respectively. The gases used were nitrogen, at a flow rate of 30 ml\min, hydrogen at 140 ml\min and air at flow rates of 80 ml/min and 170 ml/min for flames one and two respectively.

Analysis of cloth samples for cypermethrin

Analysis was done on an ^{63}Ni Electron Capture Detector on the Gas Chromatograph Varian 3400 with a capillary column (Capillary Column J & W Scientific : 15 m*0.25 mm i.d., 0.25 microns film thickness) and equipped with an integrator Model Varian 4400. The conditions were as follows: the column temperature was 200^{0}C to 280^{0}C at 20^{0}C per min.; injector and detector temperatures were 230℃ and 300℃ respectively. The gases were nitrogen and air at flow rates of 40 ml/min and 30 ml/min respectively.

All injections were done manually using a 5 µl Hamilton syringe (Microlitre^R 7105 µl syringe). Before the samples were injected, 2 µl of dimethoate and omethoate standards were injected several times until the peak area and retention time were stable. Then the same volume of sample was injected. The same procedure was followed for cypermethrin standards and samples.

5.3 DATA MANIPULATION AND HANDLING

Data were entered in database files (D-Base 1V, Ashton Tate, Torrance, CA, USA) and checked for out of range values. For both weeding and harvesting, descriptive statistics and linear regression models were done in Statistix (Statistix Version 1V, Analytical Software, 1958 Eldridge Avenue, MN 55113, USA). To incorporate correlations of body parts within farmers, general mixed model analysis of variance was done in BMDP (BMDP Statistical Software, 1440 Supelveda Boulevard, Los Angeles CA 90025). The following statistical procedures were carried out: calculations of descriptive statistics for discrete and continous variables age, sex, education, area weeded, number of days after spraying, levels of dimethoate and omethoate in different body parts, total dimethoate and total omethoate were done. The best subset regression and analysis of variance of total dimethoate and omethoate on the risk factors age, sex, education, area weeded, body part, time taken and number of days after spraying were also done.

Linear regression of total dimethoate and omethoate on age, sex, education, area weeded, body part, time taken and days after spraying for the weeding and harvesting studies as well as a general mixed model analysis of variance of level of dimethoate and omethoate on each body part and the risk factors above was done.

The descriptive statistics of the variables age, sex, education, area harvested and number of days between spraying and harvesting were done as well as linear regression of total dimethoate and omethoate on the risk factors above was also done. A general mixed model analysis of variance of the total dimethoate and omethoate per cloth on the same risk factors was done.

The descriptive statistics of variables during harvesting age, sex, education, area harvested, days between spraying and harvesting and cypermethrin residues was done and linear regression of total cypermethrin on the risk factors above and the total (cypermethrin)in beans harvested during the study was also done. A general mixed model analysis of variance for cypermethrin per cloth sample on the risk factors above was also done.

5.4 RESULTS

5.4.1 Calibration of standards and recoveries of dimethoate and omethoate from spiked cloth samples.

The calibration curves and recoveries for dimethoate and omethoate are shown in Figures 15 and 16. There was a high correlation between the chromatogram area for the standards and the area for the cloths spiked with dimethoate ($r= 0.993$) and omethoate ($r =1.00$). The percent recovery for the cloth samples was 94.0 - 99.0 (mean = 97.1) for dimethoate and 93.8 -99.0 (mean = 96.9) for omethoate.

5 4.2 Dimethoate and omethoate in cloth samples from the weeding study.

The descriptive statistics of the variables measured for association with dimethoate and omethoate in the ,weeding study are shown in Table 5.1. Out of forty-four samples analysed, twenty-nine samples contained dimethoate above the limit of detection (0.001ug\patch) and twenty-six contained omethoate above it. The mean dimethoate was 0.016 ug and for omethoate was 0.007 ug\patch. The amount of dimethoate in decreasing order was found on the left leg; right hand; left hand; right leg. For omethoate it was left leg; left hand; right leg; right hand. Dimethoate residues declined with time and the least was found on day 11. Omethoate residues decreased the first 5 days and increased slightly by the 10th day. The ratio of omethoate to dimethoate was 0.4 on the 4th day and 38 by the 12th day.

5.4 3 Association between risk factors and recovered pesticide levels in the weeding study.

Dimethoate levels were assessed at the body part level using a general mixed model analyis of variance. The results are presented in Table 5.2. There was less dimethoate exposure as the number of days after spraying increased and more dimethoate exposure for larger areas weeded. Farmer to farmer variation was not significant and as well as all other risk factors.

For omethoate, the general mixed model showed that only the number of days after spraying was significant in determining exposure levels. The longer the time after spraying, the lower the amount of omethoate that was detected (p = 0.07, Table 5.3).

Figure15: Curves showing peak areas of analytical standard dimethoate and the amount recovered from spiked cloth samples at different concentrations of dimethoate.

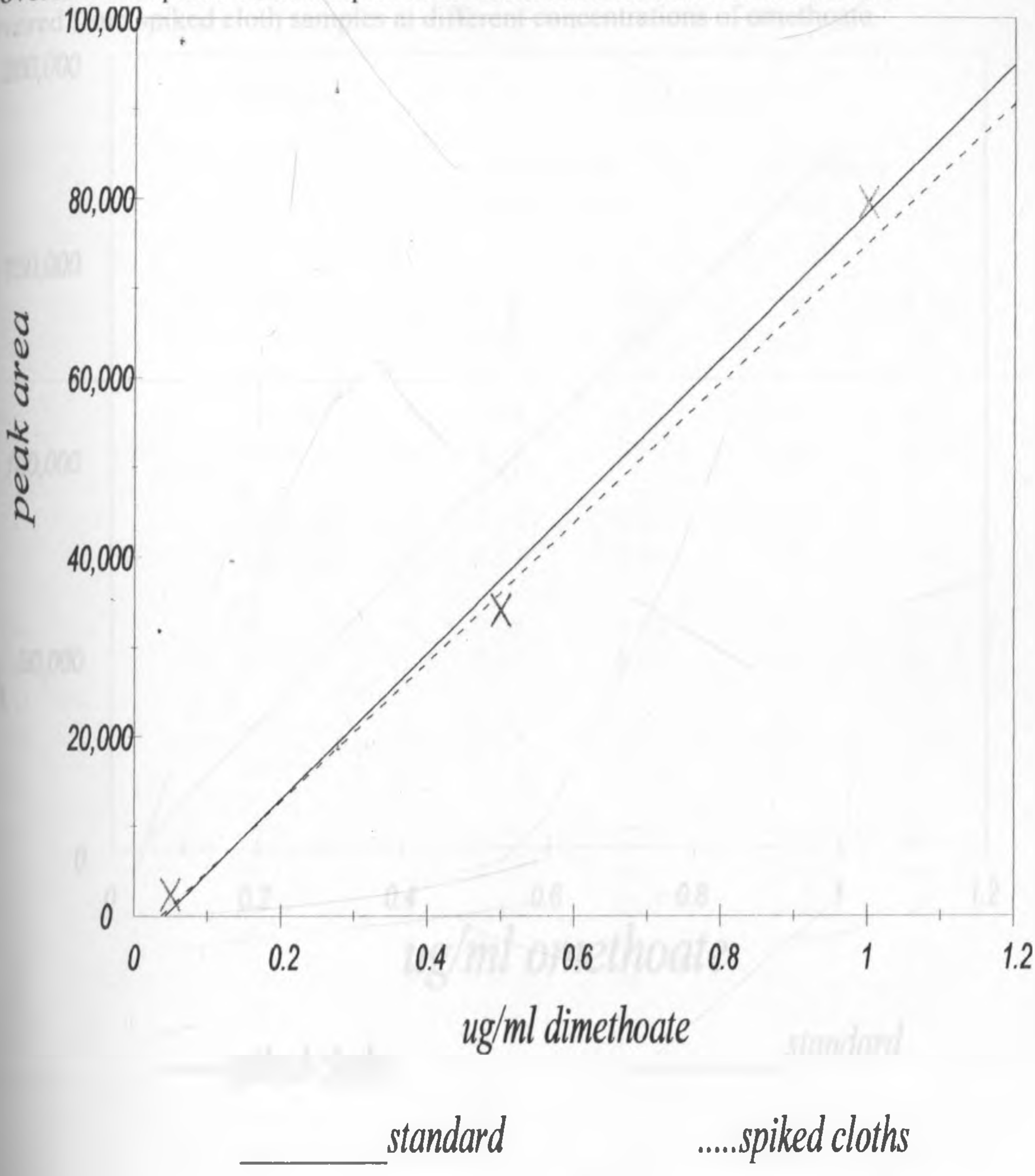


Figure 16: Curves showing peak areas of analytical standard omethoate and amount recovered from spiked cloth samples at different concentrations of omethoate.

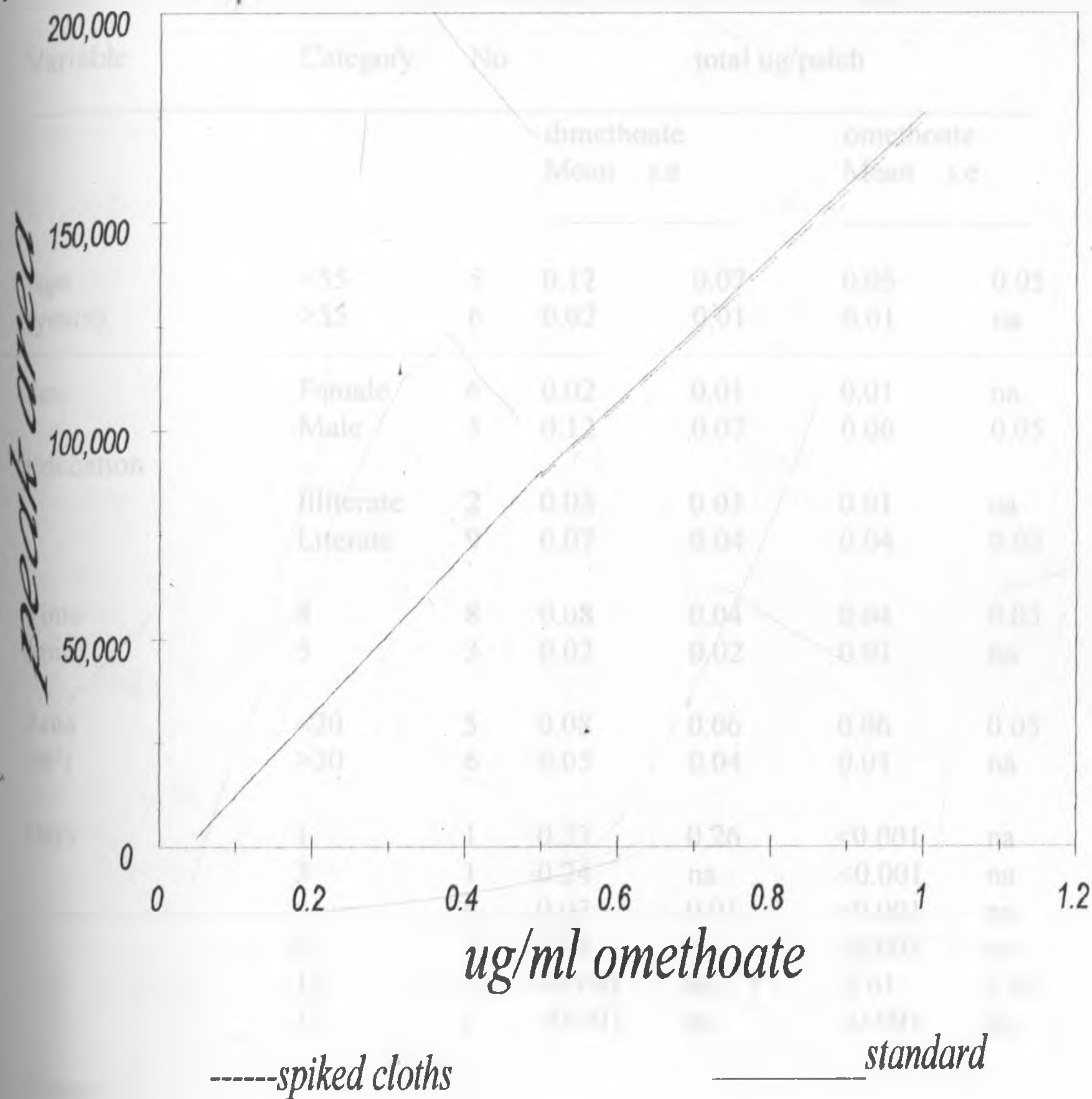


Table 5.1
Descriptive statistics for discrete and continous variables associated with ug dimethoate and omethoate in cloth patch samples worn by farmers during weeding in Kibirigwi Irrigation Scheme, Kenya, July-August, 1994.

Variable	Category	No	total ug/patch			
			dimethoate		omethoate	
			Mean	s.e	Mean	s.e
Age (years)	<55	5	0.12	0.07	0.06	0.05
	>55	6	0.02	0.01	0.01	na
Sex	Female	6	0.02	0.01	0.01	na
	Male	5	0.12	0.07	0.06	0.05
Education						
	Illiterate	2	0.03	0.03	0.01	na
	Literate	9	0.07	0.04	0.04	0.03
Time (min)	4	8	0.08	0.04	0.04	0.03
	5	3	0.02	0.02	0.01	na
Area (m^2)	<20	5	0.08	0.06	0.06	0.05
	>20	6	0.05	0.04	0.01	na
Days	1	1	0.33	0.26	<0.001	na
	3	1	0.24	na	<0.001	na
	4	4	0.03	0.01	<0.001	na
	5	1	0.02	na	<0.001	na
	10	3	<0.001	na	0.01	0.01
	11	1	<0.001	na	<0.001	na
Source						
	Right hand	11	0.02	0.02	<0.001	na
	Left hand	11	0.01	na	<0.001	na
	Right leg	11	<0.001	na	<0.001	na
	Left leg	11	0.03	0.03	0.02	0.02

na- not applicable.

Table 5.2
Results of analysis of variance of a general mixed model for risk factors associated with log(dimethoate) levels from four cloth patch samples on 6 farmers weeding french beans plots sprayed with dimethoate in Kibirigwi Irrigation Scheme, Kenya, July- August,1994.

Variable	Coefficient[a]	S.e	P-value
Fixed effects			
Constant	-0.95	0.15	0.00
Daysafter spraying	-0.13	0.04	0.00
Area	0.04	0.02	0.02
Sex			0.42
Time			0.54
Age			0.68
Education			0.90
Source			0.64
Left hand			0.61
Right leg			0.63
Right hand			0.76
Random effects			
Farmers	0.000	0.000	
Error	0.943	0.211	

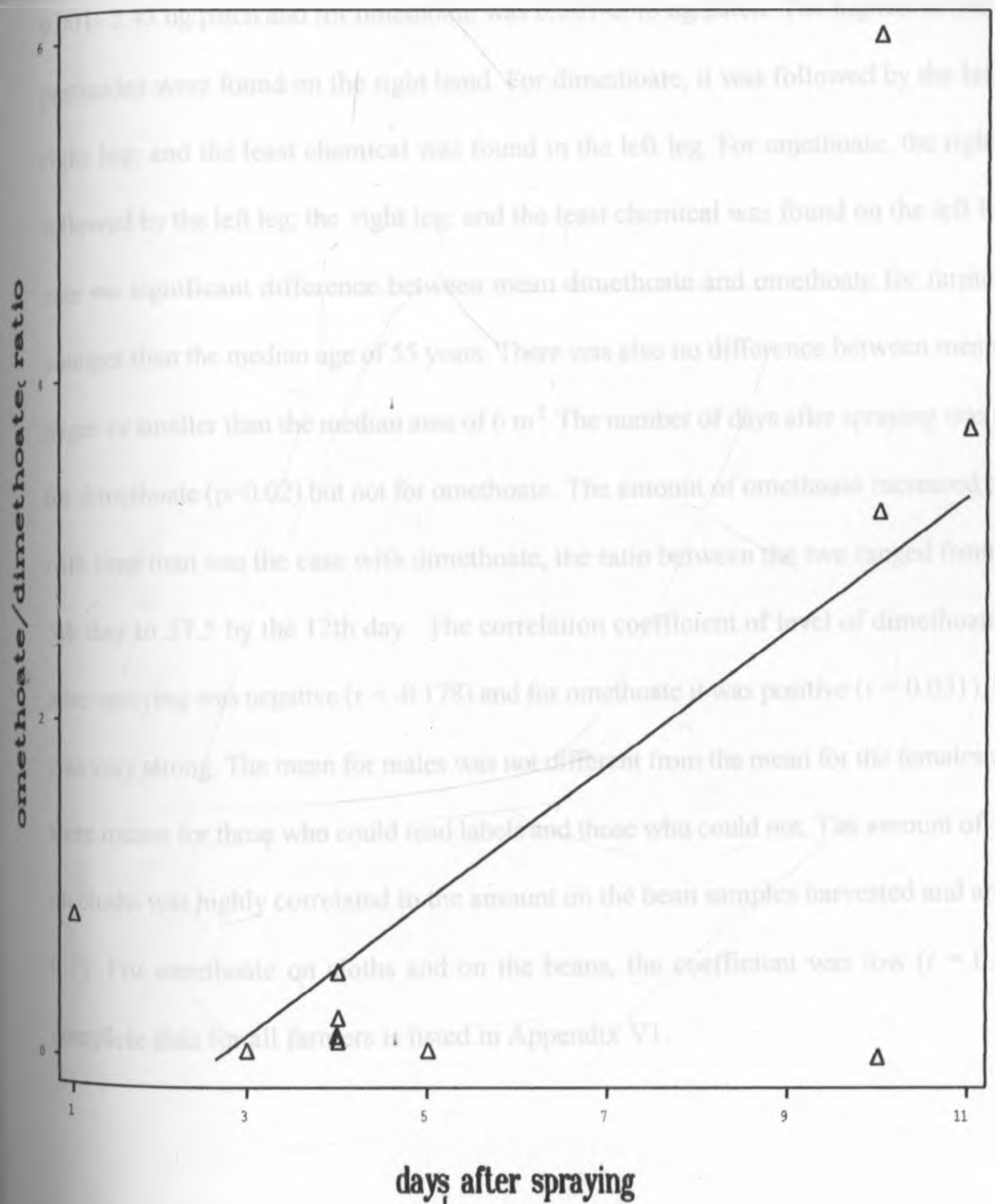
[a]- only coefficients for significant variables are listed.

Table 5.3
Results of analysis of variance of a general mixed model for risk factors associated with log(omethoate) levels from four cloth patch samples on 6 farmers weeding french bean plots sprayed with dimethoate in Kibirigwi Irrigation Scheme, Kenya, July- August,1994.

Variable	Coefficient[a]	S.e	P-value
Fixed effects			
Constant	-1.02	0.25	0.00
Days after spraying	-0.06	0.04	0.07
Source			0.23
Right hand			0.16
Right leg			0.40
Left hand			0.63
Time			0.60
Education			0.66
Sex			0.79
Age			0.83
Area			0.89
Random effects			
Farmers	0.55	0.09	
Error	0.53	0.44	

a - only coefficients for significant variables are listed.

gure 17. Omethoate/ dimethoate ratio with time in cloth samples worn during weeding in birigwi Irrigation Scheme, Kirinyaga District, July-August, 1994.



5.4.4 Dimethoate and omethoate residues in cloth samples after harvesting.

The descriptive statistics for variables asssessed for association with dimethoate and omethoate in the study on harvesting are shown in Table 5.4. The range for dimethoate was 0.001- 2.43 ug/patch and for omethoate was 0.001-2.48 ug/patch. The highest levels of the two pesticides were found on the right hand. For dimethoate, it was followed by the left hand; the right leg; and the least chemical was found in the left leg. For omethoate, the right hand was followed by the left leg; the right leg; and the least chemical was found on the left hand. There was no significant difference between mean dimethoate and omethoate for farmers older or younger than the median age of 55 years. There was also no difference between means for areas larger or smaller than the median area of 6 m^2. The number of days after spraying was significant for dimethoate ($p=0.02$) but not for omethoate. The amount of omethoate increased much more with time than was the case with dimethoate, the ratio between the two ranged from 0.4 on the 5th day to 37.5 by the 12th day. The correlation coefficient of level of dimethoate with days after spraying was negative ($r = -0.178$) and for omethoate it was positive ($r = 0.031$), but neither was very strong. The mean for males was not different from the mean for the females and neither were means for those who could read labels and those who could not. The amount of dimethoate on cloths was highly correlated to the amount on the bean samples harvested and analysed ($r = 0.7$). For omethoate on cloths and on the beans, the coefficient was low ($r = 0.053$). The complete data for all farmers is listed in Appendix VI.

5.4.5 Association between risk factors and recovered pesticides levels.

Dimethoate and omethoate levels were analysed at the body part level using general mixed model analysis of variance. The data are presented in Tables 5.5 and 5.6. respectively. The presence of residues in the beans was significant for dimethoate but not for omethoate. No other variables were significant.

Table 5.4
Descriptive statistics for discrete and continous variables associated with ug dimethoate and omethoate in 4 cloth patch samples worn by farmers in a study to determine dermal exposure during harvesting in Kibirigwi Irrigation Scheme, Kenya, August-November, 1994.

Variable	Category	Number[a]	total ug/person			
			dimethoate		omethoate	
			Mean	s.e	Mean	s.e
Age (years)	<55	36	0.19	0.06	0.14	0.04
	>55	44	0.19	0.08	0.26	0.08
Area (m^2)	<6	37	0.17	0.06	0.15	0.04
	>6	43	0.21	0.08	0.25	0.08
Days[b]	<5	35	0.32	0.11	0.23	0.09
	>5	45	0.09	0.02	0.19	0.05
Education	Illiterate	21	0.24	0.14	0.33	0.15
	Literate	59	0.17	0.05	0.16	0.04
Sex	Female	35	0.11	0.04	0.26	0.09
	Male	45	0.25	0.08	0.16	0.05
Source	Right hand	80	0.09	0.04	0.08	0.03
	Left hand	80	0.05	0.02	0.02	0.00
	Right leg	80	0.03	0.01	0.03	0.01
	Left leg	80	0.02	0.00	0.07	0.03

a - each farmer was sampled twice.
[b] - the last known date for dimethoate spraying was at least 14 days before.

Table 5.5
Results of analysis of variance of a general mixed model for risk factors associated with log(dimethoate) levels from four cloth patch samples on 40 farmers harvesting french beans in Kibirigwi Irrigation Scheme, Kenya, August- November,1994.

Variable	Coefficient[a]	S.e	P-value
Fixed effects			
Constant	-4.04	0.09	0.00
Log(total beans)	0.18	0.04	0.00
Source			0.16
Right leg			0.17
Right hand			0.20
Left hand			0.21
Area			0.14
Days[b]			0.15
Age			0.16
Sex			0.24
Education			0.86
Random effects			
Farmers	0.19	0.07	
Error	0.92	0.08	

[a] - only coefficients for significant variables are listed.
[b] - last known date that farmers sprayed dimethoate at least 14 days before

Table 5.6
Results of analysis of variance of a general mixed model of risk factors associated with log(omethoate) levels on four cloth patch samples on 40 farmers harvesting french beans in Kibirigwi Irrigation Scheme, Kenya, August-November,1994.

Variable	Coefficient[a]	S.e	P-value
Fixed effects			
Constant	-3.94	0.10	0.00
Log(total beans)			0.13
Source			0.16
Right leg			0.17
Right hand			0.20
Left hand			0.21
Area			0.27
Sex			0.37
Education			0.60
Age			0.79
Days[b]			0.94
Random effects			
Farmers	0.92	0.08	
Error	0.32	0.99	

[a] - only coefficents for significant variables were included (p<0 05)
[b] last known date that farmers sprayed dimethoate was at least 14 days before.

5.4.6 Cypermethrin residues in cloth samples after harvesting.

Calibration of standard and recovery studies.

Figure 18 presents the area curves for the standard and recovery from the spiked cloth samples. There was high correlation between the area for the standard and that of the spikes (r =0.95).

Residues of cypermethrin in cloth samples

Samples analysed for cypermethrin were found to contain residues to varying degrees (0.2-414 ug/person) with mean 35.6 ug/person (s.e, 7.4620). Two percent of the samples contained no cypermethrin (7/328). The most residues were on the right hand followed by the left hand, the right leg and the left leg in that order (Table 5.7). Younger farmers, women farmers and farmers who could read labels had higher residues in each category. Samples taken within 5 days of spraying had more residues than those taken later. Harvesting larger areas also led to more residues on the clothing. The distribution of residues on different body parts is shown in Figure 19 and residues on different days after spraying in Figure 20. The complete data for all the farmers in the study is listed in Appendix VII.

Figure 18: Curves showing peak areas of analytical standard cypermethrin and the amount recoverd from spiked cloth samples at different concentrations of cypermethrin.

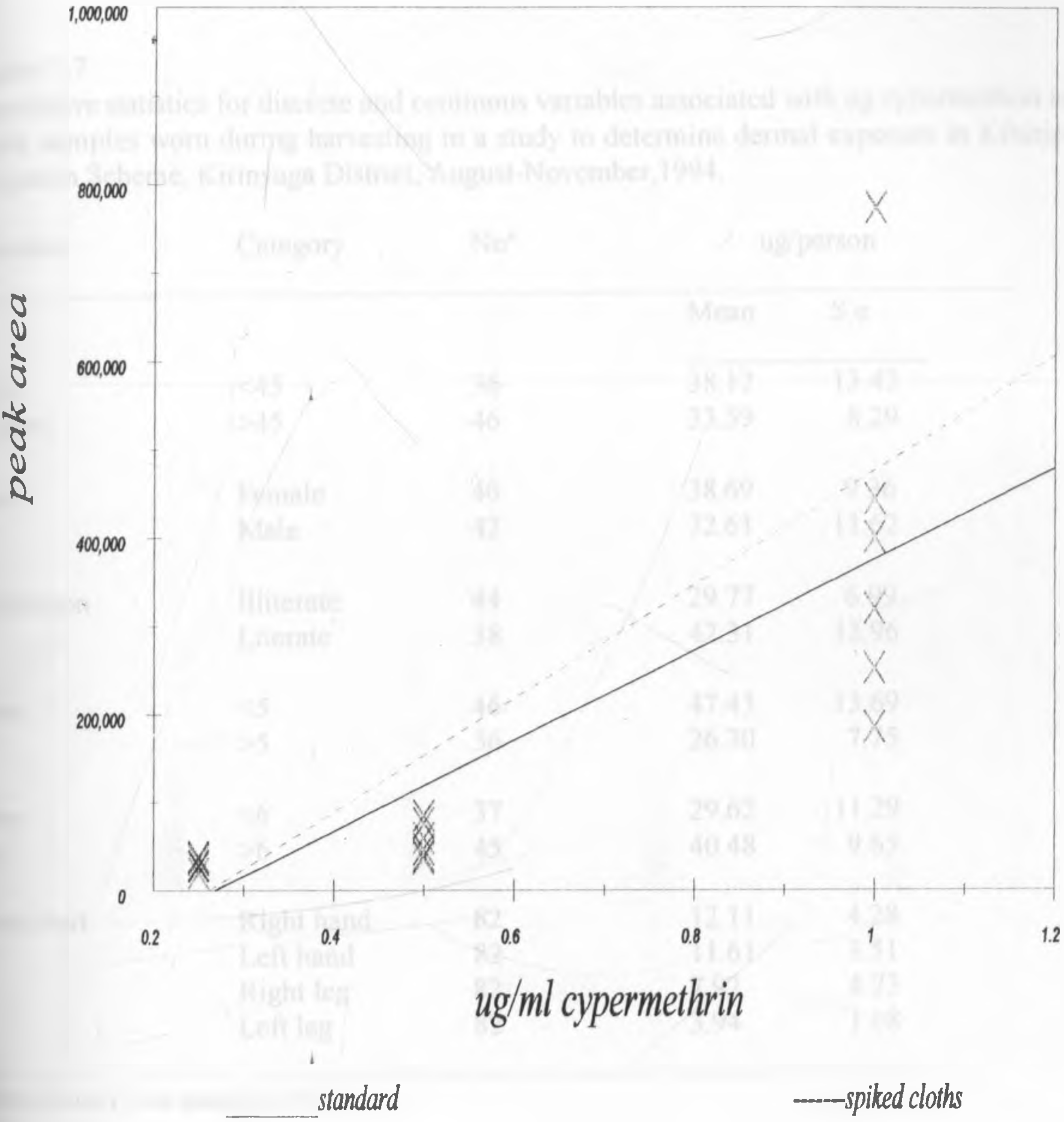


Table 5.7
Descriptive statistics for discrete and continous variables associated with ug cypermethrin in 4 cloth samples worn during harvesting in a study to determine dermal exposure in Kibirigwi Irrigation Scheme, Kirinyaga District, August-November,1994.

Variable	Category	No[a]	ug/person	
			Mean	S.e
Age (years)	<45	36	38.12	13.42
	>45	46	33.59	8.29
Sex	Female	40	38.69	9.36
	Male	42	32.61	11.62
Education	Illiterate	44	29.77	6.99
	Literate	38	42.31	13.96
Days	<5	46	47.43	13.69
	>5	36	26.30	7.75
Area (m^2)	<6	37	29.62	11.29
	>6	45	40.48	9.65
Body Part	Right hand	82	12.11	4.28
	Left hand	82	11.61	3.51
	Right leg	82	7.92	4.73
	Left leg	82	3.94	1.08

[a]each farmer was sampled twice.

Figure 19: Distribution of cypermethrin in cloth samples of 40 farmers after harvesting beans in Kibirigwi Irrigation Scheme, Kirinyaga District, August-November, 1994

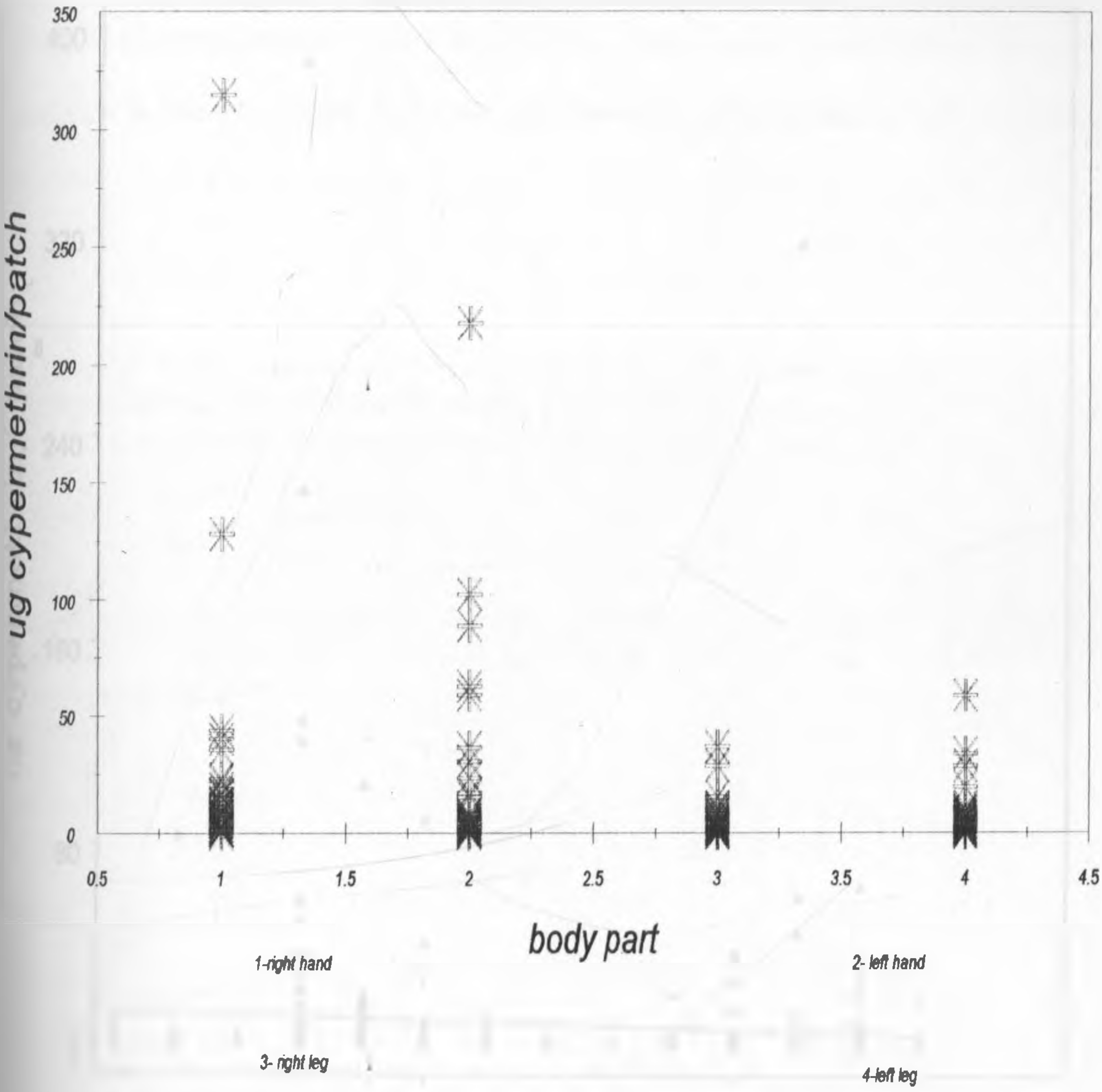
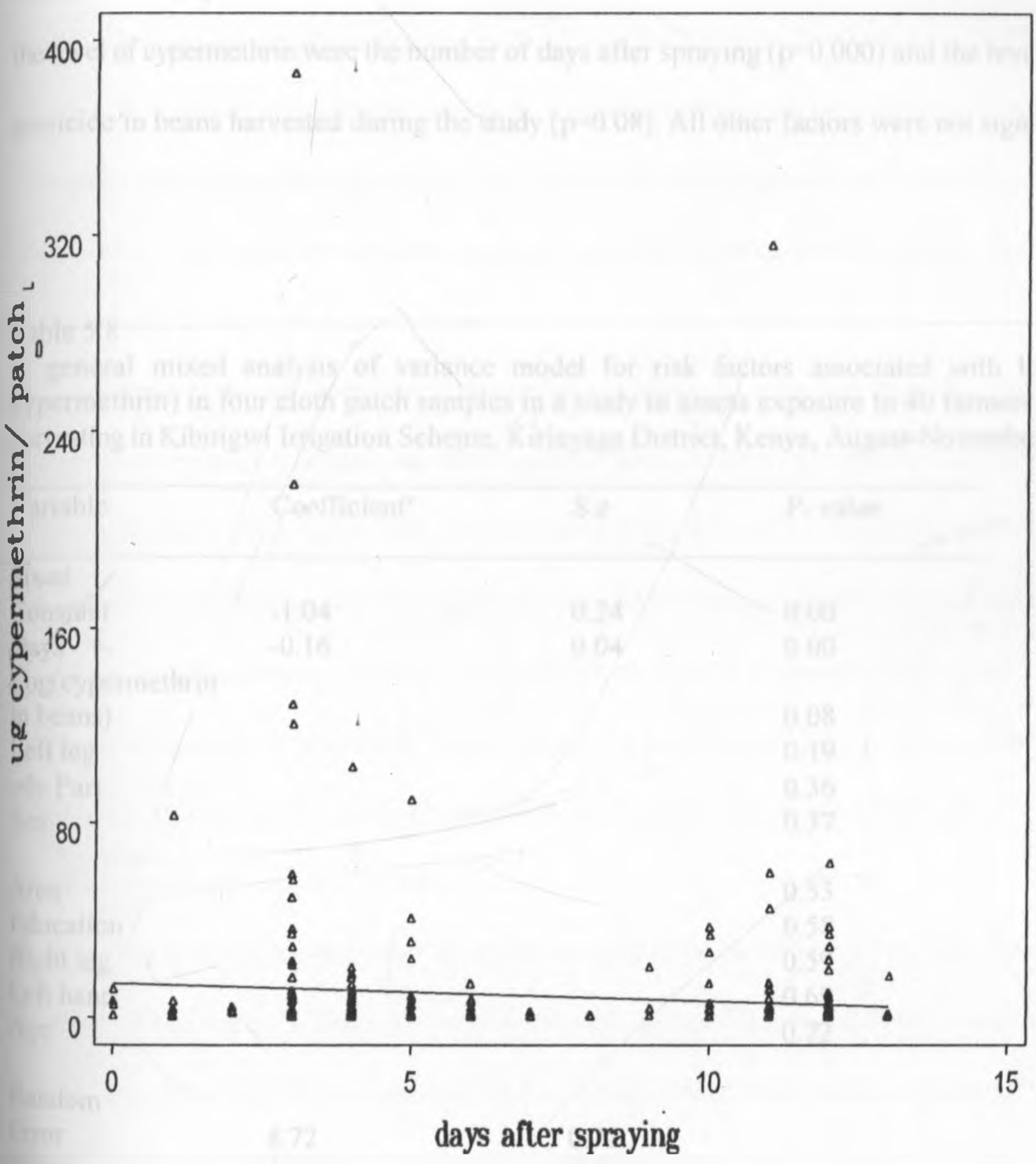


Figure 20: Dissipation of cypermethrin residues in cloth samples of 40 farmers harvesting beans and the number of days after spraying in Kibirigwi Irrigation Scheme, Kirinyaga District, August- November, 1994.



Association between risk factors and recovered pesticide levels.

Cypermethrin levels in cloths were analysed at the body part level using general mixed model analysis of variance and the results are presented in Table 5.8. The 2 factors that affected the level of cypermethrin were the number of days after spraying (p=0.000) and the level of the pesticide in beans harvested during the study (p=0.08). All other factors were not significant.

Table 5.8
A general mixed analysis of variance model for risk factors associated with log(total cypermethrin) in four cloth patch samples in a study to assess exposure to 40 farmers during harvesting in Kibirigwi Irrigation Scheme, Kirinyaga District, Kenya, August-November, 1994.

Variable	Coefficient[a]	S.e	P- value
Fixed			
Constant	-1.04	0.24	0.00
Days	-0.16	0.04	0.00
Log(cypermethrin in beans)			0.08
Left leg			0.19
ody Part			0.36
Sex			0.37
Area			0.53
Education			0.58
Right leg			0.59
Left hand			0.69
Age			0.72
Random			
Error	8.72	0.73	
Farm	1.26	0.53	

[a] - only coefficients for significant variables are listed

5.5 DISCUSSION

5.5.1 EXPOSURES FROM DIMETHOATE AND OMETHOATE DURING WEEDING

The results of the analysis of samples from the weeding study show that during weeding, the workers collect variable amounts of pesticides on their clothes. Pesticides were collected on cloths placed over the farmers clothings. In their normal working clothing, women were observed not to cover their hands and feet and for the men the hands were bare. Therefore for the women, the hands and the legs would be exposed to contamination and for the men, the hands would be likely to be contaminated.

The risk factors that were expected to contribute to exposure were the waiting time before re-entering sprayed plots and weeding larger areas. Analysis of variance showed that area was significant as a risk factor. This seems reasonable since it was expected that in the presence of dislodgable residues on the crop, a worker who weeds faster and therefore covers a wider area is likely to collect more pesticide. Brouwer **et al**. (1992) associated high work rate with increased exposure to pesticides in rose culture. In the present study, however, there was no difference between levels of dimethoate for those weeders who weeded below 20 m^2 (median) area and those who weeded above it.

The number of days after spraying was expected to be negatively correlated to the amount of exposure. This was the pattern although the correlation coefficient was small ($r = -0.06$). The mean level recovered decreased with time. Mean levels could be grouped as day 1 significantly higher than days 3 and 4 ($p<0.001$). The same was generally true for omethoate levels but after an initial decline there was a slight increase from day 5 to days 10 and 12. The ratio of omethoate to dimethoate was low in the first five days (<1) and highest by the 12th day. This persistence of organophosphate oxygen analogues under field conditions was observed for paraoxon (Milby **et al**., 1964) and it was later confirmed that the oxon compound was responsible for cases of illness that were reported long after pesticide application (Popendorf and Leffingwell, 1982) . For this reason, exposure to pesticides on re-entering treated plots is considered less predictable than exposure to applicators because exposure to field workers could be due to a mixture of residues resulting from complex environmental chemistry (Spear, 1991).

No particular body part was found to be significantly more exposed than the rest. The body part treatment means were not significant in the analysis of variance. This was unexpected since it was supposed that the hands are more at risk of exposure due to handling of foliage. In studies on exposure during harvesting, for example, hands have been shown to be the most exposed compared with other body parts (Popendorf **et al.**, 1979, Zweig **et al.**, 1983). These studies were, however, carried out for orchard crops such as citrus where the legs would have much less contact with foliage. The highest mean was for the left leg. These findings are similar to those of Ritcey **et al.** (1987) who found that for workers harvesting strawberries, the legs accumulated more captan than the hands. The exposure per area was smaller for the legs than for hands due to the larger surface area for the legs. The workers, however, did not separate exposure from the right and left hand or the right and left leg. In the present study, the left leg was also found to have more omethoate than all other body parts. Lavy **et al**. (1993) investigated dermal exposure for weeders and other forest nursery workers in various places in the United States. It was difficult to make conclusions about the results of this study due to multiple exposures received by the workers. However,it was reported that the amount of exposure per patch was high for weeders entering areas sprayed soon after pesticide application. For example, at one site, a high level of 109 ug/patch was reported for weeders entering fields 0 days after spraying and 67 ug/patch after 11 days. The pattern was, however, not consistent and mean exposures could be higher with longer waiting periods. Such inconsistency was also reported by Ritcey **et al**. (1987) but in a harvesting operation. They reported higher levels for workers who harvested 24 hours after spraying captan and lower levels 30 minutes after spraying. This type of inconsistency in exposure patterns was attributed to differences in work rate (Popendorf and Spear, 1974).

The reported exposures were for 4-5 minutes only whereas weeding is usually done for at least 6 hours in a day. Exposures calculated on the basis of a six hour working day were slightly higher. Calculation of these values as a percentage of toxic dose, however, showed that the levels were lower than 1% toxic dose, the standard threshhold value for acceptable risk (WHO, 1982).

The re-entry period for dimethoate set by the California Department of Agriculture is 3 days. It appears that after 2 weeks some residues are still on foliage and with the inconsistent potential pattern of omethoate exposure since time of spraying suggested by the literature, longer re-entry interval may be needed to ensure that the level of residues of omethoate are sufficiently low.

5.5.2 EXPOSURES TO DIMETHOATE AND OMETHOATE DURING HARVESTING

Harvesters were exposed to both dimethoate and omethoate to varying degrees. The highest exposure was on both hands for dimethoate and the right hand alone for omethoate. This was expected because the hands are most active during harvesting as they handle both foliage and beans. The legs had more omethoate than dimethoate. This may be attributed to the fact that legs would be more in contact with leafy foliage which may be laden with moisture and therefore likely to have more omethoate since dimethoate decomposes faster under warm and humid conditions, usually found on the lower parts of plants (Lesivuori **et al.**, 1988). Ritcey **et al.** (1987) reported that gloves had more residues per surface area of skin than leggings for workers who harvested strawberries after captan application but the total exposure for the leggings was higher. In a comparable study, Brouwer and coworkers (1992) reported that during cutflower cutting and sorting in the Netherlands, the mean dermal exposure to avermectin from cutting 23 hours after application was 13 ug/hr. In the present study, mean exposures were 2.3 ug/hr for dimethoate and 2.4 ug/hr for omethoate for harvesting done after 14 days since the beans were last sprayed. Liesivuori **et al**. (1988) analysed for dimethoate and omethoate on the gloves of greenhouse workers who were harvesting roses and found 0.48 mg/cm^2 dimethoate and 1.1 mg/cm^2 omethoate. These results cannot be compared with the ones of the present study because the workers did not report the period of time the workers harvested before the gloves were taken.

The amount of omethoate was greater than dimethoate in 28 of 328 samples. There were more samples with omethoate among those collected after 5 days (18/28) compared with those collected before (10/28). The ratio of omethoate to dimethoate was found to increase with the number of days after spraying. The lowest ratio recorded was 0.40 by the 5th day and the highest was 37.5 by the 12th day. Spear **et al**. (1975) reported a similar trend for paraoxon and parathion residues in California citrus orchards. The ratios increased from 0.168 two days after application to 0.825 on day sixteen while the largest ratio he reported was 4.0. In a different study that seems to be more in agreement with the results of the present study, Spear **et al**. (1977) reported ratios as high as 30:1 in citrus groves where poisoning had occurred and most ratios exceeded 10:1. It was concluded that photochemical oxidants may have been involved in converting parathion to paraoxon

Exposure to both dimethoate and omethoate was found to be correlated with the amount of pesticide on the harvested beans. The correlation coefficient was higher for dimethoate ($r=0.7$) than omethoate ($r=0.053$). Omethoate is formed by the oxidation of dimethoate and, therefore, the total amount of the omethoate is subject to environmental and other factors, whereas the amount of dimethoate would be directly related to the total amount on the beans and foliage.

Studies have been done to assess the amount of dislodgable foliar residues and their relationship to dermal exposure among field workers (Brouwer **et al.**, 1992). The workers reported that dermal exposure during cutting, bundling and sorting carnations depended principally on dislodgable foliar residues. A combination of dislodgable foliar residues and work rate effect accounted for between 0.15 and 0.86 of the variation in dermal exposure of the workers. The dislodgable residues were found to be correlated to application rate though this was not always the case (Brouwer **et al**. 1992), due to the possibility of the presence of residues before application. In the present study, the application rate was not recorded because the study was to measure the amount of exposure on a crop meant not to have sprayed with dimethoate but with cypermethrin. However, the rate commonly used had been confirmed earlier to be the recommended one of 30 ml of 40% concentration in 20 l of water to cover between 120-1260 m^2 area of bean plots depending on the work rate of the farmers. Due to the big variation in work rate therefore, the amount of residues on foliage is likely to vary considerably.

Residues on foliage are of concern because of the possibility of transfer of residues onto workers' skin and clothing. This was confirmed in this study since the armsleeves and leggings were found to contain pesticides. Farmers in the scheme complained of headache and weakness after picking beans. These symptoms agree with those of organophosphate poisoning detected among field workers elsewhere (Spear **et al.**, 1977). The problem was found to be more acute with prolonged hours of work. In California, for example, workers would fall ill at about midday complaining of headache, nausea and weakness and depending on the extent of exposure, more severe symptoms of organophosphates poisoning would develop. Re-entry standards had to be set up by the State Department for parathion in orchards and are still in operation (Spear, 1991). Others who have set intervals are the United States Federal Government (Zweig **et al.**, 1980) and

Hungary (Adamis **et al.**, 1985).

The California State Department set re-entry interval for dimethoate at 4 days and in Hungary the interval is 3 days. These intervals are based on an application rate of 300-700g active ingredient (a.i) /ha. With the 400 g/l formulation used in the scheme, nearly 2 litres may be used on a hectare. Some of the farmers in the Scheme were using upto 3 l/ha as in the case where 30 ml of dimethoate in 20 litres of water was used on 120 m^2. At present, the farmers re-enter the sprayed fields any time without regard to when they were last sprayed. Therefore, it is likely that exposure occurs due to the pesticide laden foliage and may explain the ill health reported by the farmers during and after work in bean fields. The re-entry intervals for California and Hungary are not adequate for these farmers because they are too short to ensure lower levels of the two pesticides in foliage.

The workers harvested beans for only 5 minutes, a period which may be too short for the farmers to report any illness. Their normal working hours are 6 hours or longer.

The exposure levels in this study were below the 1% toxic dose reported to be the threshhold level for toxic effect from exposure to a toxic pesticide (WHO, 1982). However, the presence of both dimethoate and omethoate on the armsleeves and on the leggings indicates that the use of protective clothing would reduce exposure to the pesticides during harvesting. Gloves would also protect the hands and the leggings (or equivalent) would protect the legs from foliage as a harvester goes through the crop.

5.5.3 EXPOSURES TO CYPERMETHRIN DURING BEAN HARVESTING

Residues of cypermethrin were detected in cloths worn during harvesting. The most exposed was the right hand followed by the left hand, the right leg and lastly the left leg. This was expected because the hands were in more contact with foliage during picking. For most harvesters, the right hand is the one that actually picks, while the left one holds the beans before they are emptied into the harvesting container. This may explain why the right hand had more residues than the left. It is not clear why the right leg had more residues than the left.

This general trend in exposure to the different body parts was also observed by Ritcey **et al.**(1987) during harvesting of strawberries. The highest residues per unit area were found on gloves compared with sleeves and leggings.

A wide range in total exposure per person was found (0.2-414 ug). This difference was possibly due to the difference in work rate. Popendorf and Spear (1974) carried out a preliminary survey of work rate during fruit harvesting. They reported differential work rates depending on crop, sex and age of worker and the quality of crop demanded. More recently, Brouwer **et al.** (1992) suggested that work rate was a determinant of dermal exposure and was second in importance only to the amount of dislodgable residues for cutflower cutting, sorting and bundling. In the present study, work rate may be partly assessed by the area covered during five minutes of picking. Other factors may come into play, however, such as the density of the crop thereby controlling the rate of movement, availability of pods on the crop and the quality of pods the worker is interested in picking. For example, a worker interested in picking a high grade of beans will pick slowly and therefore cover a smaller area than a less cautious one. In this study, picking larger areas was correlated with higher residues but not significantly so. More refined measures and a large sample size would have been required for a more powerful comparison.

Variation in results may also be due to difference in the application rate of the pesticide. Though the farmers were advised on how much pesticide to mix, there can be large differences in the actual area covered with the same spray mix. Davis (1980a) has highlighted the importance of reporting the rate of application when reporting results of exposure studies. In retrospect, therefore, it would have been useful to record the actual area covered by each farmer as he sprayed.

The risk factors for exposure appear to be the number of days that lapsed before harvesting and the body part that was exposed. The two factors were found to significantly affect the total exposure. The most significant factor was the days. This was expected because, logically, the longer the waiting time after spraying, the more the amount of cypermethrin that will be degraded under field conditions. Though the highest residues were found on the third day and the lowest on the eigth day, there was a general declining trend as the number of days increased after spraying. The same result was reported by Estesen **et al**. (1982) who reported that 80% of cypermethrin residues were detected in cotton foliage after 3 days compared to 40% after 6 days.

The different body parts had varying levels of contamination. In a pairwise comparison of means, however, only the left hand was significantly different from the left leg ($p<0.03$). This was also confirmed with the mixed model analysis of variance.

The level of residues in the beans harvested during the study was also weakly correlated with total exposures ($p=0.1$). These residues indicate the amount of cypermethrin available on bean foliage. It is therefore not surprising that the two residue levels were correlated. Brouwer **et al**. (1992) reported that the variation in dermal exposure to various pesticides in carnation culture is mostly due to dislodgable foliar residues. The correlation in the present study was lower than for Brouwers and coworkers' study. This can be explained since they measured foliage rather than just bean levels giving a better measure of dislodgable foliar pesticide available.

Calculation of percent toxic dose was done as described by Durham and Wolfe (1962) and Al-Jaghbir **et al**. (1992) assuming a dermal LD_{50} of 2100 mg/kg b.w. (Worthing and Walker, 1987) and that respiratory exposure was negligible and could be ignored. Assuming a five-hour working day and a body weight of 70 kg, it was found the percent toxic dose did not exceed 1%, the value above which toxic effect is expected on exposure to a toxic agent. The highest percent toxic dose was 0.001% and the mean was 0.0001%

The results obtained from this study indicate that farmers are exposed to small amount of cypermethrin during harvesting of french beans. Cypermethrin is identified as a skin sensitizer (EHC, 1989). According to IPCS documents (IPCS, 1989), this sensitization is a warning sign that a worker has been exposed and that work practice should be reviewed. Thus a potential risk from cypermethrin exists for these farmers. In another study, cypermethrin was reported to cause a transient facial sensation when applied to the ears of human volunteers at a rate of 130 ug/cm^2 (Flannigan and Tucker, 1985). This report agreed with an earlier one by Le Quesne **et al**. (1980) in which it was observed that workers exposed to cypermethrin accidently developed an abnormal facial sensation not associated with any inflammation. This kind of effect was not reported by the farmers. During this study, the farmers harvested for only five minutes. This period is certainly too short for such an effect to be observed, and observation over a longer period is required.

In another study on dermal exposure to cypermethrin, it was reported that up to 6% of a mean dermal exposure of 46 mg/hr was absorbed through the skin. Other adverse effects have been reported from exposure to cypermethrin, mutagenicity in mice (Amer and Aboul-ela, 1985) and immunosuppression (EHC, 1989).

5.6 CONCLUSIONS

The results of this study may be used to draw several tentative conclusions. During weeding, exposure from dimethoate and omethoate may occur though exposure levels were low. The number of days after spraying is important in determining exposure. Residues were present in foliage two weeks after spraying. The formation of omethoate under field exposures was unpredictable and may present a major source of contamination during weeding. The re-entry interval of 4 days for dimethoate set by California Department of Agriculture is too short under our conditions. Protective clothing during weeding would help to reduce exposure.

During harvesting, exposure to dimethoate depends to a large extent on the amount available in foliage but for omethoate, the levels were not predictable. For both pesticides, the hands were more exposed than the legs. The hands were also the most exposed to cypermethrin. Protective clothing especially on the hands is needed to reduce contamination during harvesting. The number of days after spraying determines whether it is safe to reenter sprayed fields or not. Residues may be picked up on clothing by the 13th day though the level is much below the % toxic dose. The concentration of cypermethrin in bean pods also determines the amount of exposure. Individual differences in work rate may encourage exposure. The farmers do not exceed the ADI for cypermethrin (0.05 mg/kg b.w).

CHAPTER SIX

SUMMARY AND RECOMMENDATIONS

This study investigated the extent to which agricultural workers and their families in Kibirigwi Irrigation scheme are exposed to pesticides.

The survey on pesticide handling and usage found that a wide range of pesticides were used or stored on the farms visited. 85% of the farms visited used pesticides. More than 70% of these farmers stored pesticides inside their homes often not securely. Therefore, pesticides may be within reach of children and may also contaminate houses and indoor air. Household exposure may also originate from undisposed empty pesticide containers which are occasionally used for domestic purposes.

Pesticide contaminated food may also be a source of exposure since pre-harvest intervals were not observed for most of the pesticide-crop combinations. One of the reasons for this is that among pesticide packs examined in sixty-five farms, 57% and 23% were either unlabelled or mislabelled respectively. Even for those that were labelled, many farmers admitted that they did not read labels but relied on extension officers or pesticide sellers for instructions. Thus, there was little probability that pre-harvest intervals and other labelled safety procedures were followed.

As far as exposure due to agricultural practice was concerned, more than 80% of sprayers leaked. Protective clothing was also not worn during either mixing or spraying. Work clothes were not removed after work and therefore, the farmers continued to be exposed even after the spraying work was over. It was concluded, therefore, that the farmers in the area are handling pesticides unsafely and were unnecessarily exposed to pesticides. Priority should be given to improving storage practices to reduce the possibility of household exposure especially due to spillage and accidents. In addition, protective clothing and practices need to be improved and only pesticides with labels should be bought and used.

The extent of pesticide exposures for the general rural population in Kibirigwi was investigated and reported in Chapter 3. The study on contamination of tables found that more than half the households had tables that were contaminated with different organophosphates. Malathion was the most common. The reason for this was probably because this pesticide is widely used to protect grains in storage from pest attack. Since it is normally mixed with grain, farmers may consider malathion safe and are therefore less cautious with it than with other pesticides. Nine table swab samples also contained cypermethrin residues. In general, the presence of these pesticides on dining tables indicated that farmers were not careful about where they place pesticides and that pesticides can easily contaminate their food. Children would be the most vulnerable to this source of exposure. Pesticides should be isolated from areas where food is kept. Contaminated clothing, sprayers and other equipment should also be kept separate from food preparation and living areas.

It was found that beans grown in the scheme and harvested according to the recommendations of the extension staff contained residues of dimethoate, omethoate and cypermethrin. It was surprising to find that dimethoate and omethoate were present in beans even though they were supposed to have been sprayed at least 2 weeks before the first sampling. Furthermore, samples in the upper range exceeded the Maximum Residue Limit (MRL) of 2 ppm. Either, the farmers sprayed them despite instructions not to spray or the pre-harvest interval of 14 days was not adequate. These beans are usually consumed in the homes and it was found that it is possible for people to exceed the ADI for dimethoate if they consumed even less than 1 kg of beans/ day. Furthermore dimethoate is also applied on other food crops such as kale and cabbage. These combined sources would lead to an excess of dimethoate in the diet.

The case of cypermethrin in beans was more worrying. The mean cypermethrin residue also exceeded the MRL of 0.5 ppm and thus the ADI would also be exceeded. It is recommended that beans and other foods should be washed thoroughly before cooking. The theoretical daily intake for dimethoate, omethoate and cypermethrin should be calculated so that pre-harvest intervals that will assure the farmer of an acceptable residue level may be set. Studies on persistence of residues of these pesticides under Kenyan conditions are needed in order to be able to set realistic pre-harvest intervals especially for omethoate.

As another measure of general exposure, analysis of pesticides in mothers milk showed that mothers had a wide range of organochlorine pesticides in their milk. This was expected because in many parts of the world mothers milk has been found to contain organochlorine pesticides particularly DDE and DDT. A peculiar thing was the presence of lindane in 11/36 samples. This indicated that mothers may have been recently exposed to lindane possibly through the diet. This is likely because lindane is available, though it is only recommended for control of pests in non-food crops. All samples contained *p'p'*DDE but only three contained either *o'p'* or *p'p'*DDT. The DDT/DDE ratio was less than one except in one case. This indicated that the mothers have not likely been exposed recently to DDT. Cases of recent exposure to DDT may be originating from dicofol, a product that is registered for use in Kenya but may also contain DDT impurities. For all organochlorines, at an estimated intake of 130 ml/kg b.w and assuming a 3.5% fat in milk, the Acceptable Daily Intake for breastfeeding infants was exceeded, except for β-BHC which was not calculated. However, since no major adverse health effects in children have been associated with the presence of organochlorine pesticides in mothers' milk, it can be concluded that babies consuming this milk are not exposed to a high health risk. However, samples of mothers milk need to be obtained and analyzed, occasionally, as an indicator of trends in organochlorine residues. It appears that in the study area there are occasional exposures to DDT and more regular exposures to lindane.

Health status of people in the scheme was also reported in Chapter 3. Farmers complained of a number of illnesses which they associated with pesticides. The most common complaints were skin related illness (8/65), coughing (4/65) and chest pains and tightness (3/65). The last two were associated with mild organophosphate poisoning while the skin related complaints were associated with captafol and ethylenebisdithiocarbamates. It is likely that these farmers are exposed to these groups of pesticides (since they were widely used except for captafol which was banned in 1988) and the effects they experience are related to them. However, due to the large number of pesticides and ill-defined exposures to farmers, adverse health effects due to pesticides are difficult to assess. This would require a more detailed follow-up study with frequent (bimonthly) clinical examinations and supportive clinical testing to assess the extent to which pesticides may be causing illness among the farmers and their families.

Studies on exposure of sprayers to dimethoate, the most commonly used organophosphate, and its oxgygen metabolite, omethoate were reported in Chapter 4.The results of this study indicate that hands were commonly contaminated. Out of 39 farmers, 31 were most contaminated on the hands compared with 6 cases where the legs were the most contaminated and 2 for the back. Observation showed that this occurred during mixing of the concentrate with water and especially where spillage or splashing occurred. Since the right hand is the most active during mixing, then it is not surprising that in 21 cases, it had the most contamination. This implies that farmers could lessen their exposure greatly by wearing gloves and improving their mixing technique. When total exposures were considered, 16 farmers would be at risk of exceeding the ADI of 1.4 mg/day if we assume an absorption rate of 10% which is accepted as a reasonable estimate of the proportion of pesticide that may penetrate into the body through the skin. Women also appeared to be more at risk than men probably due to a slow work rate which was associated with smaller area and more contamination on the clothing. The presence of omethoate on sample cloths was worrying because it is more toxic than dimethoate and a more potent cholinesterase inhibitor. A high risk of exposure was associated with splashing and spilling during mixing. To avoid this risk which was associated with certain farmers, it is recommended that one or two of the "good" farmers may be hired by the "bad" ones to instruct or help them with spraying.

The studies on acetylcholinesterase levels in whole blood before and after spraying indicated that there is little difference in enzyme levels before and after spraying. The cloths that the farmers wore for sampling acted as protective clothing. They had been tested to confirm that they would not be easily penetrated by liquid. Without them, the farmers would have been exposed. In their normal spraying operations farmers hardly wear protective clothing. It was concluded that protective clothing may prevent exposure which would be associated with depression in enzyme levels of exposed farmers. It is also apparent that farmers have experienced long-term exposure to acetylcholinesterase agents and that short term exposure effects are relatively unimportant. In addition, farmers who had higher levels of enzyme after spraying were possibly experiencing normal variation.

The enzyme levels of Kibirigwi and Kabete residents were different. The results of the pH method, considered to be more accurate than the spectrophotometric method, indicated that the Kibirigwi residents had a lower mean level than residents from Kabete. This may be due to environmental contamination with anti-cholinesterase agents even for those who are not farmers but live in Kibirigwi. It was apparent that Kibirigwi residents experience chronic exposure and therefore, they have low overall enzyme levels. However, it is not easy to draw firm conclusions about this study because, normal fluctuations in enzymes are quite varied in individuals and over time. Furthermore, enzyme levels are also affected by other factors not studied in this case. A longer follow-up study is needed in order to confirm whether the observed trends are continuous or fluctuate with spray periods in the scheme.

To investigate exposures to workers in the field, farmers weeded and harvested sprayed plots. The results of the weeding study showed that exposure occurred during weeding and the earliest day that farmers could weed without collecting significantly high residues of dimethoate was after 4 days since residues for 1-3 days were significantly higher than for the rest of the days. The case was different for omethoate because on the 10 th day, levels were second only to the first day as opposed to dimethoate which showed a definite declining trend. During harvesting, residues of dimethoate and omethoate were also detected on the clothing even though the beans were not sprayed with these chemicals for at least 2 weeks before sampling. Though the levels of the two pesticides were low, the possibility of undue exposure is likely especially from omethoate which declined at first and started increasing to reach a second small peak by the 10 th day. The adverse health reports of weakness, headache and nausea reported by the farmers may be associated with residues of the two pesticides on foliage. It is recommended that pre-harvest intervals need to be reassessed after information on the pattern of dissipation for both the parent compounds and metabolites for a pesticide have been studied under Kenyan conditions. This is because the parent compound and the metabolites degrade differently. In the case of oxon metabolites such as omethoate, they are unpredictable and more toxic than the parent compound and therefore might pose more danger than the parent compound.

Cypermethrin was also detected in the cloths after harvesting. The levels were higher for dimethoate and omethoate because it is sprayed closer to harvesting. As in the two organophosphates, the hands are usually the most contaminated. The amount of dimethoate in the cloths was correlated with the amount of the pesticide in the beans. This was expected because residues in the cloths would either originate from foliage or pesticide laden soil. In harvesting studies, the worker does not come into contact with soil and therefore the residues mostly originate from the foliage. It is suggested, therefore, that the level of pesticide on foliage when determined çan be used to predict possible exposure to harvesters. It was found that the residues on the clothing do not exceed the 1% toxic dose and thus may not constitute a real danger to the harvesters. However, the use of protective clothing during harvesting would considerably reduce exposure during work.

It was concluded that there are two safe use practices likely to reduce contamination to pesticides among this group of farmers. The use of gloves when mixing pesticides would greatly reduce exposure since the largest proportion of exposure occurred on the hands. In addition, better pesticide mixing practice would reduce splashing and contamination on the hands. The usual recommended pre-harvest intervals were found to be mostly too short for safety. Practical determination of degradation patterns of pesticides and their metabolites are needed under field conditions before pre-harvest intervals for pesticide/crop combinations are set. The results of such studies would also help in setting re-entry intervals for various crop-pesticide combinations during field operations such as weeding and harvesting which at present are completely lacking. The MRLS also need to be reviewed for the different application rates followed by the farmers.

Farmers in this scheme may be experiencing exposure to pesticides and poor health resulting from this exposure. A study to compare the health status of people living in this scheme and that of a non-spraying control group is needed in order to investigate the effect of exposure to pesticides on this population. This information would be used to predict health status of people in other areas of Kenya exposed to similar risk factors.

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APPENDICES

Appendix I

Questionnaire on agricultural practices, pesticide usage and handling administered to 65 farmers in a study to investigate pesticide usage and handling in Kibirigwi Irrigation Scheme, Kirinyaga District, Kenya, December, 1992- March, 1993.

Interviewer:________________________ Date:____________________

Local Extension Agent Present: ______________________________________

Land Registration number of farm: ___________________________________

SECTION A: GENERAL QUESTIONS

1. Name of Respondent: ____

2. Age:(years) ________

3. Sex: ________

4. Names and ages of other family members living on this farm:

1) Name: ____________________________ Age: (years) _______
1) Name: ____________________________ Age: (years) _______
1) Name: ____________________________ Age: (years) _______
1) Name: ____________________________ Age: (years) _______
1) Name: ____________________________ Age: (years) _______
1) Name: ____________________________ Age: (years) _______
1) Name: ____________________________ Age: (years) _______
1) Name: ____________________________ Age: (years) _______

5. How many years have you farmed this shamba? (years) _______

6. How many acres is this shamba? (acres) _______

6. Can you read this label? (grade) _______

7. Do you have regular employment off the farm (Y/N?) _______

If YES, is it full-time or part-time (full/part) _______

SECTION B: CROPPING PRACTICES

1. Which crops do you grow?

	Acreage	For Sale	For Food
Maize	______ (acres)	______ (Y/N)	______ (Y/N)
Beans	______ (acres)	______ (Y/N)	______ (Y/N)
French beans	______ (acres)	______ (Y/N)	______ (Y/N)
Tomatoes	______ (acres)	______ (Y/N)	______ (Y/N)
Cucumbers	______ (acres)	______ (Y/N)	______ (Y/N)
Onions	______ (acres)	______ (Y/N)	______ (Y/N)
Coffee	______ (acres)	______ (Y/N)	______ (Y/N)
Kale	______ (acres)	______ (Y/N)	______ (Y/N)
Cabbages	______ (acres)	______ (Y/N)	______ (Y/N)
Carrots	______ (acres)	______ (Y/N)	______ (Y/N)
Potatoes	______ (acres)	______ (Y/N)	______ (Y/N)
Green pepper	______ (acres)	______ Y/N)	______ (Y/N)
Other (specify)	______ (acres)	______ (Y/N)	______ (Y/N)

2. List the agricultural inputs you use on your farm?

Manure ______ (Y/N)
Fertilizer ______ (Y/N)
Pesticides ______ (Y/N)
Purchased seeds ______ (Y/N)
Purchased seedlings ______ (Y/N)
Other ________________ (Y/N)
________________ (Y/N)
(specify)

3. Do you follow a plan for rotating your crops?______ (Y/N)

4. How do you dispose of the crop residues from the previous crop?

Burned ______ (Y/N)
Fodder ______ (Y/N)
Plough In ______ (Y/N)
Other ____________ (Y/N)
(specify)

5. Do you intercrop? ______ (Y/N)

If Yes, specify the crops ______________________________

6. Do you use any method other than pesticides to reduce crop pests?
______ (Y/N)

If Yes, manual removal ______ (Y/N)
spreading ash ______ (Y/N)
planting pest repellant crops ______ (Y/N)
other ____________________ (Y/N)
(specify)

7. Do you mulch your crops to reduce weeding?______ (Y/N)

SECTION C: ANIMAL HUSBANDRY

1. Which animals do you raise?
Dairy cattle ______ (Y/N)
Beef cattle ______ (Y/N)
Goats ______ (Y/N)
Sheep ______ (Y/N)
Chickens ______ (Y/N)
Other ____________________ (Y/N)
(specify)

2. Do you use pesticides to control insects on these animals?

	Pesticide Used	Product(s)
Dairy cattle	______ (Y/N)	____________________
Beef cattle	______ (Y/N)	____________________
Goats	______ (Y/N)	____________________
Sheep	______ (Y/N)	____________________
Chickens	______ (Y/N)	____________________
Other ____________________ (specify)	(Y/N)	____________________

3. For each of the pesticides listed above, state the frequency of use and the concentration used if known.

Pesticide | Frequency of use | Concentration
(1= twice/week)(give
(2= once /week) measurements)
(3= regularly less than 2)
(4= as needed)

____
____
____
____

4. For each of the pesticides above, how are they applied?

Pesticide | Method of Application

Communal dip sprayed | Hand Other (specify)

________________ ______ ______ ______
________________ ______ ______ ______
________________ ______ ______ ______
________________ ______ ______ ______

5. Have any animals become sick after pesticide application? ______(Y/N)

If YES, specify the problem

____
____

SECTION D: CROP AND HOUSEHOLD PESTICIDE USE

1. Do you use pesticides on the following crops? Specify the pesticides used.

	Used	Product(s)
Maize	______(Y/N)	____________
Beans	______(Y/N)	____________
French beans	______(Y/N)	____________
Tomatoes	______(Y/N)	____________
Cucumbers	______(Y/N)	____________
Onions	______(Y/N)	____________
Coffee	______(Y/N)	____________
Kale	______(Y/N)	____________
Cabbages	______(Y/N)	____________
Carrots	______(Y/N)	____________
Green pepper	______(Y/N)	____________
Potatoes	______(Y/N)	____________
Others	______(Y/N)	____________
____________ (specify)	(Y/N)	____________

2. For the pesticides listed above, where did you purchase them?

Product(s)
Through the irrigation scheme____________
From local shops ____________
From Salesman ____________
From other farmers ____________

Other ____
(specify)

3. For each of the pesticides listed above, tell who advised you on its use?

Product(s)
Agricultural extensionist ______________________________
Shopkeeper ______________________________
Salesman ______________________________
Other farmers ______________________________
Other ____
(specify)

4. For each of the pesticides listed above, how many days must you wait before eating or selling your crop? Also for each, is your container labelled?

Pesticide	Pre-harvest Period (days)	Labelled
______	______	(Y/N)
______	______	(Y/N)
______	______	(Y/N)
______	______	(Y/N)
______	______	(Y/N)
______	______	(Y/N)
______	______	(Y/N)

5. In the last 5 years, have crop pests increased? ______ (Y/N)

6. In the last 5 years, have you increased your pesticide usage? ______ (Y/N)

7. For each crop you grow, list the major crop pest control problem(s).

	Crop pest problem	Name pest(s)
Maize	______ (Y/N)	______
Beans	______ (Y/N)	______
French beans	______ (Y/N)	______
Tomatoes	______ (Y/N)	______
Cucumbers	______ (Y/N)	______
Onions	______ (Y/N)	______
Coffee	______ (Y/N)	______
Sukuma	______ (Y/N)	______
Cabbages	______ (Y/N)	______
Carrots	______ (Y/N)	______
Other ______	(Y/N)	______
______	(Y/N)	______
______	(Y/N)	______

8. Do you pesticides use in the following circumstances?

Product(s)

To control insects in pit latrines ______ (Y/N) ________________
To prevent wood damage ______ (Y/N) ________________
For seed storage ______ (Y/N) ________________
To control animal pests ______ (Y/N) ________________
Other use ________________________ (Y/N) ________________
________________________ (Y/N) ________________
(specify)

9. Are there any pesticides you have used in the past which you don't use now? ______ (Y/N)

If Yes, specify the pesticides ____
____
____

SECTION E: PESTICIDE HANDLING

1. Do you store pesticides at home? ______ (Y/N)

If YES, where?

In the sleeping area ______ (Y/N)
In the kitchen ______ (Y/N)
In a storage shed ______ (Y/N)
Other ________________ (Y/N)
(specify)

2. Do you have special containers for storing each pesticide? ______ (Y/N)

3. Do you have special containers for mixing pesticides? ______ (Y/N)

4. List the pesticide application equipment you use.

Backpack sprayer ______ (Y/N)
Low volume applicator ______ (Y/N)
Other ________________ (Y/N)
________________ (Y/N)
(specify)

5. What safety equipment do you use when mixing pesticides?

Gloves ______ (Y/N)
Face Mask ______ (Y/N)
Goggles ______ (Y/N)

Overalls ______ (Y/N)
Other ____________________ (Y/N)

6. What safety equipment do you use when spraying pesticides? (specify)

Gloves ______ (Y/N)
Face Mask ______ (Y/N)
Head Covering ______ (Y/N)
Overalls ______ (Y/N)
Gum Boots ______ (Y/N)
Others ______ (Y/N)

7. What happens to pesticide containers after use?

Thoroughly washed (soap + water)
and reused for chemicals only ______ (Y/N)
Thoroughly washed for general reuse ______ (Y/N)
Rinsed and reused for chemicals only ______ (Y/N)
Rinsed for general reuse ______ (Y/N)
Disposed of / not reused ______ (Y/N)

7a. If disposed of, how?
Burned ______ (Y/N)
Buried ______ (Y/N)
Sold ______ (Y/N)
Other __________ (Y/N)

SECTION F: FOOD CONSUMPTION

1. Check the foods which the family consumes.

	Staple (almost every day)	Regular (>2 times/week)	Occasional (< once/week)
Maize	______	______	______
Beans	______	______	______
Meat	______	______	______
Milk	______	______	______
Eggs	______	______	______
Tomatoes	______	______	______
Cucumbers	______	______	______
Onions	______	______	______
Sukuma	______	______	______
Cabbages	______	______	______
Carrots	______	______	______
Other	______	______	______
	______	______	______
	______	______	______

(specify)

2. Do you wash your food before cooking it? _____(Y/N)

3. Where do you **usually** obtain your drinking water?

Borehole ______ (Y/N)
River ______ (Y/N)
Springwell ____ (Y/N)
Other_____________ (Y/N)
(specify)

SECTION G: HEALTH

1. Has anyone in your family had a serious health problem in the last 12 months?
______ (Y/N)

If YES, specify who and describe the problem.

Person(s)	Complaint	Duration (weeks)	Health official diagnosis

2. Have you any health problem with a pesticide use?______ (Y/N)

If YES, what was the problem

Headache______ (Y/N)
Dizziness______ (Y/N)
Nausea ______ (Y/N)
Diarrhea ______ (Y/N)
Other ______________ (Y/N)
_____________ (Y/N)
_____________ (Y/N)
(specify)

Appendix II

List of pesticides used or stored in Kibirigwi Irrigation Scheme December, 1992-March, 1993

Actellic
Afalon
Aldrin
Ambush
Antracol
Anvil
Bayleton
Carbaryl
Copper
Copper Nordox
Daconil
Decis
Delapon
Delnav
Deltamethrin
Derazeb
Diazinon
Dieldrin
Dimethoate
Dipterex
Dithane
Ekalux
Ethion
Folimat
Furadan
Gramoxone
Inacide
Kelthane
Lebacyid
Malathion
Marshal
Milraz
Mocap
Murtano
Neocidol
Nexion
Polyram-Combi
Rhodocide
Ripcord
Round-Up
Saprol
Sevin
Stelladone
Sumicidin
Sumithion
Supadip
Thiodan
Triatix

Appendix III

Levels of organochlorine pesticides in mothers milk (α ug/kg) and the number of times (β) the Estimated Daily Intake exceeded the Acceptable Daily Intake for 5kg babies consuming this milk assuming an intake of 130 ml/kg body weight of milk per day, Kibirigwi Irrigation Scheme, Kirinyaga District, May, 1993.

	Sum DDT		Heptachlor		Aldrin		Dieldrin		γ -BHC	
	α	β	α	β	α	β	α	β	α	β
1	0.15	8	0.001	0	0.001	0	0.001	0	0.001	0
2	0.46	23	0.001	0	0.001	0	0.001	0	0.001	0
3	0.05	3	0.001	0	0.001	0	0.001	0	0.001	0
4	0.1	16	0.001	0	0.001	0	0.001	0	0.001	0
5	0.03	2	0.001	0	0.001	0	0.126	0	0.001	0
6	0.52	26	0.02	200	0.001	0	0.128	0	0.001	0
7	0.43	22	0.001	0	0.029	290	0.001	0	0.001	0
8	0.15	8	0.001	0	0.001	0	0.001	0	0.001	0
9	0.15	8	0.001	0	0.029	290	0.001	0	0.049	6
10	0.48	24	0.03	300	0.001	0	0.001	0	0.001	0
11	0.50	25	0.001	0	0.001	0	0.001	0	0.023	3
12	0.07	4	0.001	0	0.001	0	0.001	0	0.001	0
13	0.29	15	0.001	0	0.001	0	0.001	0	0.001	0
14	0.20	10	0.001	0	0.009	90	0.001	0	0.031	4
15	0.47	24	0.001	0	0.001	0	0.001	0	0.001	0
16	0.04	2	0.001	0	0.001	0	0.001	0	0.001	0
17	0.22	11	0.001	0	0.001	0	0.001	0	0.012	2
18	0.07	4	0.001	0	0.001	0	0.001	0	0.001	0
19	0.10	5	0.001	0	0.001	0	0.001	0	0.008	1
20	0.24	12	0.001	0	0.001	0	0.066	0	0.008	1
21	0.62	31	0.001	0	0.001	0	0.001	0	0.040	5
22	0.05	3	0.04	400	0.001	0	0.001	0	0.001	0
23	0.05	3	0.04	400	0.001	0	0.001	0	0.001	0
24	0.35	18	0.001	0	0.001	0	0.001	0	0.001	0
25	0.18	9	0.001	0	0.001	0	0.001	0	0.003	0
26	0.36	18	0.001	0	0.001	0	0.001	0	0.001	0
27	0.02	1	0.001	0	0.001	0	0.001	0	0.001	0
28	0.03	2	0.001	0	0.001	0	0.001	0	0.001	0
29	0.05	3	0.07	700	0.001	0	0.001	0	0.009	1
30	0.01	1	0.001	0	0.001	0	0.001	0	0.004	1
31	0.65	33	0.001	0	0.001	0	0.001	0	0.036	5
32	0.05	3	0.001	0	0.001	0	0.001	0	0.001	0
33	0.11	6	0.001	0	0.001	0	0.001	0	0.001	0
34	0.07	4	0.001	0	0.001	0	0.001	0	0.001	0
35	0.11	6	0.001	0	0.001	0	0.001	0	0.001	0
36	0.22	11	0.001	0	0.001	0	0.001	0	0.001	0

Appendix IV

Descriptive variables age (A=years), sex (S), time (T=min), area(m^2) and residues of dimethoate in 6 cloth patch samples on the (right hand (RH), left hand(LH), right leg(RL) and left leg(LL)), back (B) mask (M), total and % toxic dose for 39 farmers in a study to assess exposure to dimethoate during spraying in Kibirigwi Irrigation Scheme, Kirinyaga District, February- June,1994(ug dimethoate).

A	S	T	AREA	RH	LH	LL	RL	B	M	TOTAL	%DOSE
38	1	53.0	800	3.39	12.87	0.46	2.53	4.20	2.03	25.48	0.0001
40	1	12.3	216	1.528	5.73	2.39	0.99	0.29	0.179	1.09	0.0002
36	1	12.7	480	2.522	6.93	67.82	71.8	21.80	0.601	71.49	0.0003
42	1	25.0	1260	144.85	4.00	2.52	2.50	40.64	3.32	197.83	0.0004
60	1	19.5	540	8.81	208.50	4.78	3.28	4.56	0.61	230.54	0.0005
30	1	8.0	400	92.66	0.35	4.68	3.46	1.50	336.96	439.61	0.0009
57	1	21.2	476	247.51	25.11	167.07	3.81	11.76	17.05	472.31	0.001
28	1	16.6	276	196.69	130.95	55.25	8.90	113.86	6.88	512.53	0.001
50	1	17.2	198	530.54	81.59	3.48	53.68	88.17	12.99	770.36	0.0016
30	1	8.00	198	542.54	20.01	121.43	42.18	141.40	2.58	970.14	0.002
30	1	10.4	348	1055.37	10.04	0.61	0.30	1.32	0.43	1068.07	0.0022
33	1	18.6	240	200.18	1154.79	7.75	5.21	57.14	1.84	1426.91	0.0029
65	1	17.0	480	1139.00	418.84	5.58	2.09	7.53	10.41	1583.45	0.0032
35	1	14.00	400	469.36	44.89	5.00	68.83	154.56	1.47	1744.11	0.0036
35	1	53.00	660	94.56	1628.95	13.07	77.50	103.95	2.31	1920.34	0.0039
35	1	11.80	380	2124.45	15.56	6.52	114.14	18.60	1.20	2280.47	0.0047
28	1	11.60	144	106.61	2265.5	67.60	7.84	2.48	5.53	2395.62	0.0049
69	1	20.00	330	709.97	3149.53	11.49	21.60	192.57	2.05	4087.21	0.0083
22	1	44.00	180	2483.61	2392.58	33.44	226.89	12.60	3.10	5152.22	0.0105
59	1	19.46	952	2089.58	3625.92	3.60	14.47	4.16	1.26	5738.99	0.0117
50	0	14.20	972	814.61	1346.56	183.39	1455.43	3111.37	1.20	6912.56	0.0141
32	1	15.00	760	62.69	7156.28	20.93	6.89	103.68	4.13	7354.60	0.0150
50	0	12.00	920	237.55	535.42	254.67	8942.49	203.33	2.31	10175.77	0.0208
22	1	17.50	448	1276.46	3845.55	331.26	3345.43	573.52	88.95	9461.17	0.0193
30	1	11.20	222	11425.58	49.30	11.87	2.20	15.07	1.73	11505.75	0.0235
60	1	11.00	494	67.65	1225.34	4815.64	5372.53	2.19	2.83	11486.18	0.0234
60	1	12.00	588	3615.11	692.17	7887.69	88.25	17.32	6.10	12306.64	0.0251
38	1	18.60	128	6.80	175.63	1590.03	860.43	5697.35	4.41	16064.65	0.0328
70	1	25.50	260	9377.42	3485.11	415.05	6718.82	60.10	18.33	20074.83	0.0410
50	1	10.10	120	15753.66	3513.53	1360.49	13.10	11.69	27.70	20680.22	0.0422
25	1	12.00	576	12907.82	10460.46	166.09	105.53	24.39	33.15	23697.44	0.0484
50	1	12.00	168	18417.48	2054.20	2758.00	6819.44	362.93	213.46	30625.60	0.0625
60	1	14.00	288	1780.23	25452.00	87.45	36.39	6856.23	13.16	34225.46	0.0698
30	1	20.00	312	85.51	13855.83	15215.92	9381.78	173.13	11.11	38723.28	0.0790
32	1	16.50	288	31764.78	662.11	9.72	12327.21	5.74	13.05	44782.61	0.0914
25	1	10.00	120	44714.31	839.67	103.58	31.16	0.00	17.29	45706.01	0.0933
50	0	15.00	616	34821.20	7815.86	26.41	9223.24	169.31	6.01	52062.03	0.1062
35	1	10.00	308	13157.07	6112.62	6578.90	4466.48	66.00	15.45	30396.52	0.0620
45	0	20.00	480	93415.14	811.72	0.00	589.18	1358.69	228.57	96403.30	0.1967

[a] 1= male, 0= female.

Appendix V

Descriptive variables age (A=years), sex (S), time (T=min), area(m^2) and residues of omethoate in 6 cloth patch samples (right hand(RH), left hand(LH), right leg(RL), left leg(LL), back and mask)and total for 39 farmers in a study to assess exposure to omethoate during application in Kibirigwi Irrigation Scheme, Kirinyaga District, February- June,1994(ug omethoate.)

	AGE	SEX[a]	TIME	AREA	RH	LH	LL	RL	B	MASK	TOTAL
1	38	1	53.00	800	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2	40	1	12.32	216	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3	36	1	12.66	480	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4	42	1	25.00	1260	0.001	0.001	0.001	0.001	0.001	0.001	0.001
5	60	1	19.50	540	0.001	0.360	0.001	0.001	0.001	0.001	0.360
6	30	1	8.00	400	72.940	0.001	0.001	0.001	0.001	0.200	73.140
7	57	1	21.20	476	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8	28	1	16.60	276	0.001	0.001	0.001	0.001	1.900	0.001	1.900
9	50	1	17.20	198	0.260	0.001	0.001	5.900	1.700	0.001	7.860
10	30	1	18.00	198	0.001	0.001	0.001	0.001	4.680	0.001	4.680
11	30	1	10.40	348	0.001	1.950	0.001	0.001	0.001	0.001	1.950
12	33	1	18.60	240	0.001	0.001	0.001	0.001	0.001	0.001	0.001
13	65	1	17.00	480	0.001	0.001	0.001	0.001	0.001	0.048	0.048
14	35	1	14.00	400	0.568	0.001	0.001	0.001	0.842	0.001	1.409
15	35	1	53.00	660	0.001	0.674	0.001	0.001	0.001	0.001	0.673
16	35	1	11.80	380	2.549	0.001	0.001	0.430	0.001	0.001	2.979
17	28	1	11.60	144	0.001	0.001	0.001	0.001	0.001	0.001	0.001
18	69	1	20.00	330	0.001	5.278	0.001	0.001	0.001	0.050	5.328
19	22	1	44.00	180	0.280	4.080	0.001	0.001	1.960	0.001	6.320
20	59	1	19.46	952	0.001	0.001	0.001	0.001	0.001	0.001	0.001
21	50	0	14.20	972	0.001	0.159	0.001	0.522	4.281	0.001	4.962
22	32	1	15.00	760	0.001	2.470	0.001	0.001	0.001	0.001	2.470
23	50	0	12.00	920	0.740	1.310	0.001	0.001	0.001	0.001	2.050
24	22	1	17.50	448	0.001	0.560	0.001	0.001	0.001	0.001	0.560
25	30	1	11.20	222	0.001	0.001	0.001	0.001	0.001	0.001	0.001
26	60	1	11.00	494	1.450	1.140	0.001	5.700	0.001	0.001	8.290
27	60	1	12.00	588	0.001	0.200	0.001	0.001	0.001	1.400	1.600
28	38	1	18.60	128	0.001	0.560	0.001	4.290	0.001	2.000	6.850
29	70	1	25.50	260	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30	50	1	10.10	120	16.560	1.890	1.550	0.350	0.340	0.001	20.690
31	25	1	12.00	576	0.001	0.001	0.001	0.001	0.001	0.001	0.001
32	50	1	12.00	168	0.001	227.940	0.001	0.001	0.780	0.001	228.720
33	60	1	14.00	288	0.001	0.001	0.001	0.001	0.001	0.001	0.001
34	30	1	20.00	312	0.110	1.700	0.001	2.510	1.060	0.001	5.380
35	32	1	16.50	288	5.160	0.001	0.001	1.440	0.001	0.001	6.600
36	25	1	10.00	120	2.710	0.001	0.640	0.001	0.001	0.001	3.350
37	50	0	15.00	616	2.000	0.001	15.860	0.001	0.001	0.001	17.860
38	35	1	10.00	308	0.001	0.001	0.001	0.001	1.450	0.001	1.450
39	45	0	20.00	480	2.000	0.001	0.001	0.850	2.500	2.280	7.630

[a] 1= male, 0= female.

pendix VI

scriptive statistics sex (S), days after spraying (D), area (A=m^2) and residues of dimethoate(D) and omethoate) in 4 cloth patch samples (right hand(RH), left hand(LH), right leg(RL) and left leg(LL)), total ethoate(DIM) and total omethoate (OME) for 40 farmers in a study to assess exposure to the two pesticides ing harvesting of french bean plots earlier sprayed with dimethoate in Kibirigwi Irrigation Scheme, Kirinyaga trict, August- November,1994(ug).

S[a]	D	A	RHD	LHD	RLD	LLD	RHO	LHO	RLO	LLO	DIM	OME
0	3	5.0	0.057	0.001	0.027	0.012	0.022	0.001	0.001	0.065	0.095	0.086
0	12	2.0	0.054	0.001	0.528	0.104	0.031	0.433	0.084	0.336	0.686	0.884
0	4	7.0	0.001	0.021	0.132	0.001	0.001	0.001	0.001	0.001	1.152	0.001
0	12	3.0	0.190	0.055	0.001	0.009	0.093	0.001	0.001	0.030	0.254	0.123
1	3	14.0	0.001	0.057	0.001	0.009	0.001	0.014	0.029	0.026	0.066	0.069
1	11	13.0	0.001	0.001	0.066	0.001	0.017	0.022	0.001	0.013	0.065	0.052
0	3	4.0	0.001	0.001	0.001	0.001	0.075	0.054	0.845	0.045	0.001	1.019
0	12	3.0	0.001	0.480	0.021	0.001	0.054	0.226	0.040	0.036	0.501	0.356
0	4	3.5	0.024	0.001	0.001	0.028	0.073	0.001	0.095	0.019	0.052	0.187
0	12	4.0	0.025	0.001	0.001	0.001	0.015	0.047	0.021	0.026	0.025	0.109
0	4	8.0	0.001	0.001	0.014	0.001	0.044	0.001	0.637	0.001	0.013	0.681
0	1	2.0	0.158	0.017	0.013	0.001	0.102	0.226	0.001	0.036	0.187	0.364
1	4	6.0	2.433	0.133	0.049	0.405	0.163	0.008	0.007	0.027	3.019	0.204
1	4	6.0	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.002	0.001
0	4	5.0	0.015	0.001	0.001	0.013	0.011	0.001	0.010	0.001	0.027	0.021
1	1	14.0	0.001	0.003	0.001	0.001	0.001	0.001	0.001	1.027	0.003	0.027
0	4	18.0	0.034	0.047	0.001	0.005	2.482	0.105	0.001	0.336	0.085	2.924
0	12	7.0	0.065	0.056	0.183	0.001	0.001	0.011	0.023	0.028	0.303	0.062
0	4	18.0	0.003	0.002	0.034	0.022	0.001	0.015	0.153	0.297	0.061	0.464
0	12	11.0	0.014	0.001	0.001	0.078	0.035	0.019	0.001	0.001	0.091	0.054
1	5	5.0	0.001	0.001	0.001	0.001	0.001	0.121	0.006	0.007	0.001	0.139
1	12	10.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1.224	0.001	1.224
1	4	4.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	11	9.0	0.001	0.001	0.001	0.001	0.389	0.001	0.001	0.001	0.001	0.387
1	4	14.0	0.001	0.001	0.013	0.008	0.001	0.001	0.001	0.001	0.020	0.001
1	12	14.0	0.061	0.001	0.007	0.323	0.001	0.001	0.001	1.646	0.389	1.646
0	4	4.0	0.008	0.007	0.001	0.012	0.014	0.001	0.031	0.147	0.027	0.192
0	12	7.0	0.001	0.001	0.001	0.007	0.089	0.001	0.013	0.094	0.007	0.196
1	4	18.0	0.010	0.022	0.016	0.026	0.001	0.013	0.009	0.009	0.073	0.031
1	11	13.0	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.003	0.001
1	6	14.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	7	6.0	0.001	0.001	0.006	0.001	0.001	0.001	0.001	0.001	0.005	0.001
1	3	4.0	0.001	0.016	0.001	0.001	0.001	0.001	0.001	0.001	0.015	0.001
1	10	2.0	0.001	0.001	0.001	0.016	0.001	0.001	0.124	0.001	0.015	0.124
1	3	8.0	0.015	0.073	0.764	0.047	0.001	0.073	0.001	0.001	0.899	0.073
1	12	8.0	0.001	0.001	0.001	0.001	0.661	0.062	0.001	0.001	0.001	0.723
0	5	2.0	0.001	0.001	0.001	0.001	0.106	0.017	0.001	0.026	0.001	0.149
0	12	30.	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
0	6	8.0	0.001	0.007	0.001	0.077	0.085	0.256	0.024	0.442	0.084	0.807

0	5	10.0	0.015	0.011	0.009	0.001	0.001	0.001	0.001	0.225	0.035	0.224
0	3	2.5	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	11	6.0	0.043	0.001	0.001	0.001	0.104	0.001	0.001	0.001	0.043	0.104
0	4	1.0	0.019	0.001	0.001	0.001	0.001	0.001	0.021	0.001	0.019	0.021
0	11	10.0	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.008	0.002	0.008
0	4	4.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
0	12	5.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	3	6.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	11	2.5	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	4	5.5	0.414	0.194	0.024	0.124	0.001	0.001	0.001	0.001	0.756	0.001
1	0	4.5	0.001	0.001	0.001	0.001	0.010	0.001	0.001	0.037	0.001	0.047
0	4	10.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.00.001
0	12	4.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
0	5	3.5	0. 001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
0	13	4.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	5	3.5	0.006	0.001	0.001	0.050	0.001	0.001	0.001	0.001	0.056	0.001
1	12	3.0	0.019	0.001	0.001	0.011	0.001	0.001	0.001	0.001	0.029	0.001
1	2	24.0	0.001	0.001	0.010	0.001	0.001	0.006	0.001	0.001	0.001	0.006
1	9	24.0	0.001	0.035	0.001	0.001	0.001	0.001	0.001	0.001	0.035	0.001
1	4	2.0	0.001	0.001	0.001	0.001	0.014	0.001	0.001	0.001	0.001	0.013
1	6	16.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
0	3	10.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
0	10	5.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	3	10.0	0.756	0.597	0.018	0.001	0.001	0.001	0.001	0.001	1.367	0.001
1	10	15.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	5	8.0	0.001	0.597	0.025	0.016	0.001	0.001	0.001	0.001	0.638	0.001
1	12	8.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.027	0.001	0.027
1	1	5.0	0.001	0.001	0.029	0.001	0.001	0.001	0.001	0.001	0.029	0.001
1	8	10.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	4	4.0	1.429	0.001	0.005	0.007	0.929	0.001	0.059	0.009	1.442	0.996
1	12	4.0	0.047	0.001	0.001	0.030	0.158	0.043	0.010	0.022	0.078	0.233
1	4	5.0	0.175	0.027	0.003	0.001	0.012	0.084	0.033	0.026	0.205	0.155
1	12	13.0	0.001	0.001	0.001	0.001	0.012	0.001	0.001	0.011	0.001	0.022
1	2	7.0	0.253	0.001	0.001	0.001	0.065	0.017	0.001	0.236	0.253	0.318
1	12	4.0	0.001	0.007	0.077	0.001	0.175	0.001	0.005	0.001	0.085	0.179
1	4	3.0	1.154	0.049	0.029	0.001	0.001	0.041	0.012	0.001	1.233	0.053
1	12	4.0	0.033	0.108	0.060	0.014	0.001	0.004	0.001	0.001	0.216	0.004
1	4	8.0	0.001	0.001	0.069	0.198	0.001	0.001	0.112	0.176	0.267	0.288
1	12	5.0	0.003	0.069	0.029	0.008	0.021	0.063	0.047	0.021	0.109	0.152
0	3	8.0	0.001	0.001	0.001	0.001	0.018	0.001	0.018	0.001	0.001	0.036
0	10	7.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

male, 0= female.

ppendix VII

scriptive statistics, area and residues of cypermethrin in 4 cloth patch samples (right hand(RH), left nd(LH), right leg(RL) and left leg(LL) and total per person for 41 farmers (each farmer harvested twice) in a dy to assess exposure to cypermethrin during harvesting of french bean plots earlier sprayed with the pesticide Kibirigwi Irrigation Scheme, Kirinyaga District, August- November,1994.

	SEX[a]	AGE		DAYS AREA	RH	LH	RL	LL	TOTAL
1	0	50	3	5.00	35.30	5115.24	0.001	0.001	50.552
2	0	50	12	2.00	8.00	60.50	100.999	1.244	11.750
3	0	25	4	7.00	6.754	0.001	0.001	1.607	8.361
4	0	25	12	3.00	0.001	0.001	0.001	0.001	0.010
5	1	40	3	14.00	8.795	217.264	1.968	0.001	228.026
6	1	40	11	13.00	13.103	0.001	3.3780	10.579	27.059
7	0	50	3	4.00	2.498	8.028	28.384	2.315	41.225
8	0	50	12	3.00	0.001	0.793	1.162	2.217	4.172
9	0	50	4	3.50	0.001	3.693	3.688	0.736	8.117
10	0	50	12	4.00	18.827	5.566	0.001	0.001	24.393
11	0	50	4	8.00	1.606	2.973	2.493	1.192	8.264
12	0	50	12	2.00	0.001	7.278	0.001	0.001	7.278
13	1	70	4	6.00	1.271	0.001	0.001	8.441	9.712
14	1	70	11	6.00	0.001	0.001	2.981	0.001	2.981
15	0	45	4	5.00	1.207	0.001	15.266	0.001	16.473
16	0	45	11	14.00	314.602	0.001	0.001	0.001	314.602
17	0	50	4	18.00	9.932	2.255	2.639	1.969	16.796
18	0	50	12	7.00	0.001	0.001	0.001	0.001	0.010
19	0	36	4	18.00	2.417	1.092	5.465	8.983	17.957
20	0	36	12	11.00	0.001	0.001	9.036	0.001	9.036
21	1	18	5	9.00	40.031	88.531	0.001	4.557	133.118
22	1	18	12	10.00	0.001	0.001	36.429	33.326	69.755
23	1	55	4	4.00	16.577	4.874	2.700	6.857	31.008
24	1	55	11	9.00	10.780	0.001	3.683	3.931	18.394
25	0	45	3	14.00	127.929	0.001	1.711	0.175	130.815
26	0	45	12	2.00	0.001	0.001	0.001	0.618	0.618
27	0	35	4	4.50	12.446	16.964	3.843	1.892	35.144
28	0	35	12	7.00	22.927	0.001	0.001	28.119	51.046
29	1	54	4	18.00	7.839	0.001	0.001	0.001	7.839
30	1	54	11	13.00	0.001	3.764	2.540	1.079	7.383
31	1	63	6	14.00	3.159	1.286	1.246	0.001	5.691
32	1	63	7	6.00	0.001	1.677	0.254	0.001	1.930
33	1	28	3	4.00	0.001	119.821	0.376	6.425	126.621
34	1	28	10	2.00	5.193	36.008	2.328	0.001	43.529
35	1	55	3	8.00	22.031	6.089	5.867	58.166	92.152
36	1	55	12	8.00	0.001	0.001	2.653	4.981	7.634
37	0	57	5	2.00	4.563	30.304	8.134	0.001	43.000
38	0	57	12	30.00	0.001	62.473	4.825	0.001	67.2975
39	0	45	5	10.00	7.531	23.249	6.697	1.959	39.436
40	0	45	6	8.00	0.001	5.893	1.019	6.609	13.522

41	1	70	3	2.50	0.001	0.001	0.001	0.001	0.010
42	1	70	11	6.00	0.001	0.001	0.001	0.207	0.207
43	0	55	4	1.00	0.001	102.079	2.069	19.286	123.434
44	0	55	11	10.00	43.568	58.722	10.533	2.608	115.430
45	0	30	4	4.00	0.965	0.001	0.169	0.267	1.399
46	0	30	12	5.00	0.001	0.001	0.001	0.001	0.010
47	1	40	3	6.00	1.058	1.616	7.639	1.422	11.734
48	1	40	11	2.50	0.001	7.056	0.474	4.153	11.683
49	1	15	0	4.50	0.001	6.059	10.751	4.850	21.659
50	1	15	4	5.50	0.001	0.001	0.001	0.001	0.010
51	0	50	4	10.00	3.323	3.047	1.708	0.001	8.077
52	0	50	12	4.00	3.515	2.678	0.001	0.001	6.193
53	0	50	5	3.50	1.124	4.253	0.001	3.566	8.943
54	0	50	13	4.00	15.963	0.619	0.001	0.649	17.231
55	1	37	4	10.00	1.533	0.001	0.754	0.623	2.909
56	1	37	4	20.00	0.001	0.754	0.001	0.001	0.754
57	1	25	5	3.50	1.425	1.152	0.695	0.001	3.271
58	1	25	12	3.00	0.001	0.001	2.194	0.001	2.194
59	1	37	2	24.00	3.614	1.592	1.117	1.628	7.951
60	1	37	9	20.00	0.001	3.204	20.051	0.661	23.915
61	0	60	4	2.00	0.001	0.333	0.103	0.001	0.436
62	0	60	6	16.00	12.821	0.001	0.001	0.001	12.821
63	0	60	3	10.00	22.330	0.001	0.001	0.001	22.330
64	0	60	10	5.00	0.267	0.001	0.001	3.029	3.296
65	1	45	3	10.00	2.174	9.987	0.001	2.029	14.191
66	1	45	10	15.00	5.027	0.001	2.569	0.001	7.596
67	1	40	5	8.00	0.001	0.001	0.001	0.001	0.010
68	1	40	12	8.00	0.001	0.526	0.359	0.434	1.319
69	1	35	1	5.00	1.997	3.446	0.001	0.233	5.675
70	1	35	8	10.00	0.001	0.001	0.001	0.001	0.010
71	1	19	3	4.00	2.448	5.588	385.913	20.482	414.431
72	1	19	12	4.00	2.089	4.106	2.089	0.001	8.284
73	1	55	4	5.00	2.393	5.816	2.762	0.001	10.969
74	1	55	12	13.00	1.244	0.001	0.001	0.001	1.244
75	0	29	12	4.00	5.819	0.001	0.781	0.001	6.601
76	0	29	1	7.00	82.217	2.592	1.029	6.171	92.008
77	1	22	4	3.00	1.863	0.001	0.001	0.151	2.014
78	1	22	12	4.00	0.001	0.001	0.431	0.206	0.636
79	1	21	3	8.00	0.001	0.001	0.001	0.696	0.696
80	1	21	12	5.00	0.001	1.232	0.453	1.819	3.504
81	0	45	3	8.00	55.971	33.173	0.001	48.629	137.773
82	0	45	10	7.00	13.008	25.889	32.874	0.001	71.771

=Male 0=Female.