EXPOSURE TO PESTICIDES AMONG FARM WORKERS OF MAVOKO DIVISION IN MACHAKOS DISTRICT, KENYA.

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ABSTRACT

About 40.7% pesticides used to control pests on farms worldwide and in Kenya are toxic. Over 60% workers in Kenya are exposed to pesticides due to lack of knowledge, negative attitude and poor practice. Ministry of Agriculture reported that over 70% unspecified pesticides used on farms in Mavoko Division were toxic and farm workers who applied them complained of unspecified health complications of which 60% were pesticide related. Hence, there was need to investigate the allegations. The main objective of the study was to investigate factors contributing to pesticide exposure among farm workers of Mavoko Division in Machakos District, Kenya. The study, whose specific objectives were: to assess knowledge, attitude and practice on pesticide use; identify and quantify pesticides used; and investigate post-exposure symptoms, was conducted on 160 workers who had been employed for over two years on farms in Lukenya location. Simple random sampling was done. Eighty exposed and 80 unexposed workers were interviewed and observed when handling pesticides and doing other work, respectively. Qualitative and quantitative data collected was analyzed using Statistical Package for Social Sciences ver. 15.0. Descriptive statistics for frequencies and percentages was done; test for significance was done using Pearson's Chi-square at 5% significance level and cross tabulations were done to test for associations between factors. Results showing that 43.7% exposed workers had not been trained revealed they lacked knowledge on pesticide risks and safe use. 68.7% were unable to understand and interpret label instructions reflecting on their low education level since about 90% had only primary level education. Workers had a negative attitude towards pesticide risks and use of protective clothing. Over 37% said a mask and overalls were uncomfortable to wear. The claim by workers that they had a positive attitude was not demonstrated in their practice as observations showed that none used full protective equipment, while 25% did not use any when spraying. Observed poor hygienic practices such as washing spray pump without soap and protection; not washing hands after spraying; failure to change, wash clothes and bathe after spraying exposed workers to pesticides. Observations showed that 68% pesticides used such as Ogor and Alphacypermethrin were toxic WHO Class II. All exposed workers experienced post-exposure symptoms which could be attributed to pesticide exposure. Symptoms mostly experienced were; flu/cold (28.5%), headache (36.3%) and nausea (20.9%). Only 2.5% unexposed workers experienced a headache which could be due to high temperatures. Basing on study findings, it is concluded that most farmers lacked knowledge on pesticide risks and safe use, their attitude towards risks and protection was negative, their practice was poor; pesticides used were toxic; and post exposure symptoms experienced were due to pesticide exposure. It is recommended that; knowledge, attitude and practice of workers be improved through training; class 11 pesticides be restricted; and awareness be created on post-exposure symptoms and need to seek medication.

CHAPTER ONE

INTRODUCTION

1.1. Background Information

Pesticides are chemical substances used to control pests (insects, bacteria, fungi and nematodes). Agricultural pesticides are used to prevent and control of pests as an effort to reduce crop losses estimated at 10 – 30% (World Health Organization, 1990). There are an estimated 450 million waged agricultural workers in Africa, 20 million being children aged between 5 – 14 years (Forastieri, 2007). In Kenya, the number employed on agricultural farms as permanent and casual workers is not well documented although Kibwage *et al.* (2007) reported an increase of workers on tobacco farms by 67% from 1972 to 1991, and 36% between 1991 and 2000. In Machakos District, about 70% of the inhabitants work in the agricultural sector (KCBS, Ministry of Finance, 2001).

Although agricultural pesticides have played a major role in controlling pests some, organophosphates and carbamates, are highly toxic and harmful to the farm worker over time (Food and Agricultural Organization, 1983). Kibwage *et al.* (2007) reported an unquantified increased foetal mortality and abortions in females who applied pesticides on tobacco farms in Nyanza Province, Kenya. Organophosphates and carbamates appear harmless and safe to use but pose the most serious health risks to farm workers. These include; community, environmental and occupational health risks that have not been adequately studied in Kenya. Health risks can be divided into: acute effects (appear immediately or very soon after exposure); and chronic effects (may manifest years later). Acute effects include: morbidity and mortality; burns;

paralysis; and blindness. Chronic effects include: miscarriages; fetal deformities; skin and eye irritations; and neurological disorders (Arnold, 1990). According to Kimani (1995), acute poisoning from pesticides is a common occurrence and has been increasing with time. Three out of nine workers who sprayed parathion on wheat in Molo, Nakuru District were hospitalized. Investigations by Kimani (1995) in 20 hospitals in Kenya between 1989 and 1990 reported 455 cases of organophosphate and carbamate pesticide poisoning on farms in various parts of Kenya including Mavoko Division.

In order to protect human health and the environment, NEMA (2006) enforced a water quality regulations legal notice No. 121 which provides guidelines and standards for discharge of pollutants including poisons and toxins such as pesticides into the aquatic environment. Regulations apply to water used for domestic, industrial, agricultural, recreational, fisheries, wildlife, and for any other purposes.

The Ministry of Agriculture (2005) reported that over 70% of pesticides used on farms in Mavoko Division were highly toxic and farm workers who frequently applied them complained of health complications related to pesticide risks. This study aimed to investigate factors contributing to pesticide exposure among farm workers of Mavoko Division in Machakos District, Kenya. There was need for this study to assess knowledge, attitude and practice on pesticide use, identify and quantify pesticides used, and investigate post-exposure symptoms. This data could be used to enhance training programs to educate farm workers in Mavoko Division and other parts of Kenya on pesticide risks and safe use that would reduce exposure. NEMA and Pest Control and Products Board could also use this data to enforce the pesticide regulation to protect human health and the environment.

1.2. Problem Statement

The increased use of agricultural pesticides in Kenya has greatly boosted pesticide imports (Appendix 1). Increase in use has increased exposure as there is an average of 69 deaths per year, over 40% acute and unquantified chronic poisonings among Kenyan farm workers (Kibwage *et al.*, 2007). A report by Ministry of Agriculture (2005) highlighted that a variety of unspecified pesticides were being used to control pests on crops to improve production in Mavoko Division but over 70% of the pesticides workers applied were highly toxic. Furthermore, the report alleged that some farm workers who applied pesticides had complained of health complications of which 60% were pesticide related risks. Nevertheless, the report did not give information on the knowledge of the workers on pesticide risks, attitude and practices that could influence this exposure.

1.3. Objectives

1.3.1. Main objective

To investigate factors that contribute to pesticide exposure among farm workers of Mavoko Division in Machakos District, Kenya.

1.3.2. Specific objectives

1. To assess the knowledge, attitude and practice on pesticide use by farm workers in Mavoko Division.
2. To identify and quantify pesticides used by farm workers in Mavoko Division.
3. To investigate post-exposure symptoms of pesticide use in Mavoko Division.

1.4. Justification

One of the biggest concerns over increasing use of pesticides in pursuit of improved agricultural output in Kenya is the unquantified increased infant mortality, miscarriages, eye damage and skin disorders among farm workers due to pesticide exposure (Kibwage *et al.,* 2007). There was need to investigate Ministry of Agriculture (2005) report that over 70% unspecified pesticides used to control crop pests in Mavoko Division are highly toxic and that some farm workers who applied them complained of health complications of which 60% were pesticide related risks. Although it has been shown by Wortman *et al.* (1991) that knowledge, attitude and practice influence uptake of safety measures, there was no information in Ministry of Agriculture (2005) report on farm workers' knowledge, attitude, and handling practices that may have led to the reported exposure in Mavoko Division.

There was need for this research in Mavoko Division to obtain data on gaps in the Ministry of Agriculture (2005) report on knowledge of farm workers on pesticide risks, attitude towards risks and protection, identify and quantify pesticides used, and investigate whether symptoms experienced were due to pesticide exposure. This thesis research would determine how exposure occurs on farms in Mavoko Division and obtained information could be used to enhance training programs to educate farm workers in Mavoko Division and other parts of Kenya on pesticide risks and safe handling practices that would reduce exposure. NEMA and Pest Control and Products Board could also use the information to enforce the pesticide regulation to protect human health and the environment.

1.5. Research Hypotheses

1. Farm workers in Mavoko Division have knowledge on pesticide risks, a positive attitude towards use of personal protective equipment and practice safe handling of pesticides.
2. Farm workers in Mavoko Division are exposed to a variety of less toxic pesticides.
3. Post-exposure symptoms experienced among farm workers in Mavoko Division are associated with pesticide exposure.

CHAPTER TWO

LITERATURE REVIEW

2.1. Pesticide Usage Worldwide

Agricultural pesticides (nematicides, fungicides and insecticides), whose use dates back to classical Greek and Rome, fall under the major groups of organophosphates and carbamates. Their use is a worldwide practice considered beneficial, as it raises agricultural productivity, improves the quality of farm products and reduces 10 – 30% crop losses (Hassail, 1982). According to Kaoneka and Ak'habuhaya (2000), worldwide use of pesticides is about 8 million tones of which 30% is in developing countries (Hayes, 1991).

In Africa, organophosphate and carbamate insecticides are the most important plant protectants used making up 63% of total pesticides applied (Thebe, 2007). Pesticides are sold, not only to professional users, but also to members of the public in lower concentrations and smaller packages for use on farms (Gordon, 1990).

2.1.1. Pesticide Usage in Kenya

In Kenya, pesticides have been used for over 90 years (Kimani, 1997). Increased use of organophosphate and carbamate pesticides in various parts of Kenya, including Mavoko Division, is evidenced by increased importation (Appendix 1). Accordingly, quantities of insecticides and fungicides imported and used in Kenya have greatly increased from 1076 and 654 tonnes in 1986 to 2995 and 2340 tonnes, respectively, in 2009/2010 (Appendix 1).

2.2. Health and Safety Measures

Due to the risk associated with pesticide exposure, care is needed while handling them. Use of proper personal protective equipment (PPE) are necessary during all stages of pesticide handling from manufacture through application to safe disposal inorder to minimize exposure. Exposure is often the result of ignorance which can be dealt with by education and training of workers who handle pesticides. Education, training and information are essential and must be provided to all workers (WHO, 1990). Failure to take adequate precaution has resulted in unquantified acute and chronic poisonings among farm workers in Kenya (Kimani, 1997).

2.2.1. The legislation

The general labour laws of a number of countries exclude agricultural workers completely or partially (International labour organisation, 1999). Although chapter 346 pest control products Act is an Act of parliament that regulates importation, exportation, manufacture, distribution and use of pesticides in Kenya (Laws of Kenya, 1985), there is no provision for occupational health and safety laws applicable to the agricultural sector (Forastieri, 2007). Water Quality Regulations Legal notice No. 121 (NEMA, 2006) does not have a provision specifically on pesticides but on general pollutants (poisons, toxins, noxious, radioactive waste) into the aquatic environment. However, it is a requirement that every agricultural pesticide label must display 'signal words' and categories of pesticides in bold print that tell the user the toxicity (how deadly the product is to people) of the product. Signal words and symbols (which indicate the product's potential risk to the user) include: Danger-Poison (skull and crossbones included), Danger, Warning and Caution. According to Lehto (1992) these significant words represent the category of toxicity and give an indication of their potential hazard, as shown below, in Table 2.1, and Appendix 2 and 3.

Category I Labels of these pesticides have signal words 'Danger—Poison' and the skull with crossbones. They may be corrosive to the eyes, skin and lungs, may cause severe skin irritation and eye damage. Most are restricted use pesticides due to increased risk to human health.

Category II The word 'Warning' is on labels for moderately toxic pesticides. Skin and eye irritations that could last longer than one week can result from exposure to these pesticides considered restricted-use.

Category III&IV The word 'Caution' is on labels. Pesticides are much less toxic to use. Mild skin and eye irritation results from exposure to these chemicals. Pesticides sold over-the-counter have signal word Caution.

Table 2.1: Toxicity categories by hazard indicator

TOXICITY CATEGORIES				
HAZARD INDICATORS	I (highly toxic)	II (toxic)	III (moderately toxic)	IV (slightly toxic)
Oral LD_{50}	$\leq$ 50 mg/kg	50-500 mg/kg	500-5,000 mg/kg	> 5,000 mg/kg
Inhalation LD_{50}	$\leq$ 0.2 mg/litre	0.2-2 mg/litre	2-20 mg/litre	> 20 mg/litre
Dermal LD_{50}	$\leq$ 200 mg/kg	200-2,000 mg/kg	2,000-20,000 mg/kg	> 20,000mg/kg
Eye effects	Corrosive; corneal opacity not reversible within 7 days	Corneal opacity reversible within 7 days; irritation persisting for 7 days	No corneal opacity; irritation reversible within 7 days	No irritation
Skin effects	Corrosive	Severe irritation at 72 hours	Moderate irritation at 72 hours	Mild or slight irritation at 72 hours

Source: Ware (1998).

Key: $\leq$ means LD_{50} is up to and including the figure shown

> means LD_{50} is higher than the figure shown

2.2.2. Safe handling and storage of pesticides

The most important tool to the layman in the safe use of pesticides is the label on the container. It is recommended that before handling and using a pesticide, one must read the label, understand the label directions and follow the instructions printed on it carefully. Pesticides are safe to use, provided they are used according to the label instructions. The saying that 'safety is a state of mind' is an old rule used in industrial safety engineering. But pesticide safety is more than a state of mind. It must become a habit with those who sell, handle and apply pesticides and with those who supervise those who do (Ware, 1978). Appendix 4 has guidelines on safe handling of pesticides.

2.2.3. Education and training

Education and training are fundamental to safety (Edelman, 1991). It was noted by Edelman (1991) that one reason for over-exposure of workers to pesticides was their lack of appreciation of the hazards associated with pesticides. Other factors are attitude and lack of knowledge on hazards of pesticides. A study on treatment of pesticide poisoning indicated that 99% of the workers could not tell to which class the pesticide belonged (Kibwage *et al.*, 2007). Education directed towards change in attitude and/or methods of increasing safety in handling pesticides is effective in reducing hazards from pesticide exposure. Kimani (1997) reported that the number of poisoning cases dropped from 118 to 15 after initiating a training programme on pesticide safety. And that a training of 280,000 Kenyans conducted from 1991 to 1993 resulted in an increased understanding of pesticides and their toxic effects. However, adoption of safe use has been slow. For example, in a follow up to investigate the extent of adoption, it was found that less than 30% of the trained farmers were adapting the safety guidelines as per their training. As mentioned, good education must lead to understanding and recognition of danger. The need for appropriate care then becomes an obvious matter (Njer, 1994).

2.2.4. Protection when handling pesticides

Protective devices and practice play a big role in limiting exposure to pesticides. Devices are designed to reduce chances for human exposure. Research has shown that although all pesticide workers are exposed to pesticides, applicators using knapsacks are the most exposed as compared to ground applicators using other equipment (Arnold, 1990). Accordingly, a number of routes of exposure to workers have shown that the principal route is the skin while the respiratory route is much less important (Arnold, 1990). Skin protection from contact with pesticides during handling and application would significantly reduce exposure. The choice of protective devices should depend on the work being done and the hazard likely to be associated with it (Kimani, 1997).

During mixing and spraying of highly toxic pesticides, respirators (having an air filter or cartridge) are needed. A clean rag tied over the mouth and nose (plate 2.1) will reduce exposure. Protective clothing is useful in reducing exposure to the skin. 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 a period of time. Research has shown that cotton overalls laundered daily provide significant protection but should not be washed together with family washing (Kimani, 1997). According to Kimani (1997), nylon-knit gloves and long-sleeved shirts minimize exposure. Gloves can prevent 90-95% of pesticide from reaching hands (Quantai, 1994). Choice of proper fabric is important because different fabrics afford different protection and, different chemical agents behave differently depending on the fabric used (Kimani, 1997).

Plate 2.1: A worker spraying with improvised mask

Photograph by courtesy of Kaloki Peter

Eye protection devices are necessary to protect the eyes from splashes of pesticides. Contact lenses are not allowed when working because they may trap the pesticide and increase contact to the eye (Ware, 1978). Face shields are preferred to safety glasses. Avoidance of exposure may be achieved by using practices such as spraying downwind. Leaking pumps, valve springs and nozzles may lead to a lot of contamination; therefore maintenance of equipment can help to reduce exposure. Removal of contamination after accidents such as the quick clean up of spills is important. Water, soap and other cleaning materials should be available in case of emergency (Anonymous, 1992).

2.2.5. Treatment

Onset of symptoms is rapid and effects may develop within a few hours. It is recommended that if any worker gets poisoning from pesticides, he or she should immediately seek medication, carrying along the pesticide label (Morgan, 1980). Atropinization (atropine given intravenously) is given to relieve muscarinic effects, and to provide central respiratory stimulant action (Kimani, 1997). Since the toxicity of organophosphate and carbamate pesticides is due to inhibition of cholinesterase, the reaction of these enzymes would offer a therapeutic measure. This is achieved by administering oximes such as pyridine – 2 – aldoxime methiodide (PAM) and diacetyl monoxime (DAM). In case of parathion poisoning, 1 gram of PAM or more is recommended intravenously (Ngowi and Partanen, 2002).

2.3. Factors that Influence Uptake of Occupational, Health and Safety (OHS) Measures

2.3.1. Knowledge

According to Wortman *et al.* (1991), knowledge is the awareness or familiarity of a person gained from skills or by experience. It also includes a person's range of information, theoretical or practical understanding of an issue. The more knowledgeable a person is about an issue the clearer his opinions thus; the more likely he is to act in ways that match his views. Increased knowledgeability on hazards and risks improves awareness and utilization of protective measures. The knowledge that pesticides are hazardous must be deduced from ones' knowledge or acquired by experience. Hayes (1991) reported that workers had little knowledge relating to hazards, safety rules and proper personal preventive behavior. He further stated that workers are more likely to underestimate even high risks if they have been exposed for an extended period of time. Knowledge plays a vital role in preventing behavior in that they are likely to notice and interpret warnings on pesticide containers.

2.3.2. Attitude

According to Wortman *et al.* (1991), attitude is disposition to respond favourably or unfavourably towards something, event, idea or situation. Attitude, therefore, encourages people to act as if they like or dislike something. A worker's attitude towards safety measures affects how long and how well he/she is to live. The cognitive, emotional and behavioral components of attitude are evolved in risk perception process. This refers to the understanding of perpetual realities and indicators of hazards and toxic substances such as pesticides. Attitude also plays a role in risk assessment, as it is applied to issues such as whether and to what extent a person will be exposed to danger (Zimolong and Trimpop, 1998). Changing the attitude towards pesticide risks and use of protective equipment will lead to decreased prevalence of pesticide poisoning among farm workers (Zimolong and Trimpop, 1998).

2.3.3. Practice

Workers may willingly take preventive measures by protecting themselves to exclude hazards or deliberately not take preventive measures when using pesticides. Preventive behavior is partly self controlled and partly enforced by the legal standards and requirements of the company or employer (Wortman *et al.*, 1991).

2.3.4. Demographic factors

Demographic factors that influence uptake of safety measures include: age, gender and marital status (Zimolong and Trimpop, 1998). Individual differences in risk acceptance are likely to be influenced by factors such as overconfidence, sensation or experience seeking. Age, gender and marital status influence risk acceptance, with the young, males and married workers taking highest risks at work. Men take higher risks compared to women (Zimolong and Trimpop, 1998).

2.3.5. Socio-economic factors

Zimolong and Trimpop (1998) have shown that education level, training and income influence uptake of safety measures, with the poorly trained and educated taking the highest risks. When education increases knowledge and leads to understanding and recognition of danger, need for appropriate care becomes an obvious matter. The poorly paid go for risky jobs to earn a living (Zimolong and Trimpop, 1998).

2.4. Exposure to Pesticides

Despite the mentioned safety measures intended to minimize exposure to pesticides and or its effects, unquantified poisoning and other health effects among farm workers have been increasing in Kenya (Ohayo *et al.*, 1999). Agricultural pesticides may appear harmless, but some pose serious health risks to farm workers. Their hazards affect workers, their families and the general public, in order of decreasing exposure (Appendix 5) but greatly increasing the population at risk. A study by Ngowi and Partanen (2002) where pesticide exposure was self reported indicated that about 60% of the workers, ranging from ages 19 to 51 years, reported having been poisoned by pesticides sometime in their life. 91% of the workers were aged between 21 – 40 years. Studies on exposure during spraying estimated that a spray man receives a dermal contamination of 55.8 mg/hr when using a high pressure hand sprayer. Dermal exposure to dimethoate during mixing, loading and spraying was estimated to range between 25.5μg/25cm^2 and 0.11μg/25cm^2 on the lower leg. The combined dermal and inhalation exposure for applicators, mixers, and agricultural workers was estimated to range between 0.00005 and 0.39mg/kg/day of dimethoate. For a 60kg worker, the range would be 0.03-23.4mg/day. It was concluded that applicators were receiving substantial exposures that lead to significant depression of acetyl cholinesterase (Karembu, 1990).

Fatal cases resulting from pesticide exposure in Kenya have been increasing from 57 in 1973 cases compared to 101 cases in 1991 (Kimani, 1997). These cases are likely to be only a small proportion of all known cases since many cases of morbidity and mortality go unreported mostly on flower and tobacco farms. Information is lacking on actual pesticide handling practices that may explain how exposure occurs though studies carried out indicate that workers who regularly use pesticides frequently mishandle them (Maitai, 1994). These findings were confirmed by Karembu (1990), but actual exposure was not quantified. Many cases of pesticide poisoning on farms were attributed to pesticide exposure (Kimani, 1997). The worker must, therefore, use proper protective clothing to prevent exposure. The main routes of exposure are: dermal; inhalation; oral; and the eye (Arnold, 1990).

2.4.1. Dermal exposure

Absorption through the skin is the most common route of exposure to pesticides and occurs when the chemical comes into contact with the worker's skin or mucous membrane (Arnold, 1990). Percutaneous absorption frequently is unnoticed since dermal irritation rarely occurs, unless the pesticide possesses the irritative property. Dermal exposure can occur to more sensitive tissues when urinating with contaminated hands, or by wiping the sweaty forehead or the back of the neck. Touching treated surfaces or handling empty containers without wearing gloves may cause dermal exposure (Patty, 1963; Gordon, 1990).

2.4.1.1. Field re-entry

Walking through a recently treated field has led to dermal exposure to many farm workers and re-entry safety intervals have been established (Ware, 1978). Safety waiting intervals between application of pesticides and re-entry into all treated fields to work or harvest the treated crop must be followed to prevent unnecessary exposure. For all pesticides, it is necessary that workers wait until sprays have dried and dusts have settled before reentering treated fields (Kimani, 1997). If it is necessary for workers to re-enter fields earlier than the required waiting intervals, they must wear full protective clothing. Several workers receive poisoning resulting from re-entering fields treated with pesticides, as it was observed that workers would fall ill if they re-entered treated fields soon after application and at times long afterwards (Kimani, 1997). Several workers have developed weakness, nausea, headache and severe depression after re-entering fields previously treated with dimethoate. Dermal dimethoate exposures of 0.48mg/cm^2 have been reported (Kimani, 1997). Compounds that have been mostly implicated in re-entry poisoning are the organophosphates (such as; parathion, malathion and dimethoate) due to their inherent toxicity and the relative ease with which the oxidation metabolites are formed under field conditions (Ware, 1978; Hayes, 1991).

2.4.2. Inhalation

The second most frequent exposure according to Patty (1963) is through the respiratory tract. Breathing pesticides exposes the lungs to the product. Inhalation exposure provides the fastest route of exposure into the bloodstream. Exposure can occur while mixing different formulations of pesticides and during burning of empty containers. Intoxication may occur with highly toxic members of organophosphate group such as tetraethyl pyrophosphate (TEPP), demeton (systox), parathion (O,O-diethyl O-p-nitrophenyl thiophosphate), and phosdrin. Pesticides such as paraquat reach the lung after absorption through the skin, causing lung cell injury which reduces the area for oxygen exchange in the lungs, leading to reduced oxygen supply to body tissues (Kamrin, 1988). Investigation by Ohayo *et al.* (2000) showed that there was a significant relationship between exposure and respiratory symptoms.

2.4.3. Oral exposure

Oral exposure (through the mouth) may be due to spraying operations if good personal hygiene practices are not followed. Pesticides can contaminate the hands through handling of the container and even spills during mixing of the pesticide (Arnold, 1990). Small amounts of the chemical may end up on cigarettes, chewing tobacco, food, or drinks touched by contaminated hands. Hands could also be an oral source of exposure especially when not thoroughly washed with water and soap after spraying (Ware, 1978). Once ingested, the gastro-intestinal tract (GIT) is an efficient mechanism for absorption of pesticides. Although they remain in the mouth for a short time, some are absorbed through the mucous membranes. After absorption, the toxicant passes to the stomach with no significant absorption occurring in the oesophagus. The pesticide taken in may be modified at the lower end of GIT by internal micro-organisms or broken down to less toxic compounds. However, some of the metabolized pesticide products may be more toxic than the parent compound (Arnold, 1990).

2.4.4. Ocular exposure

Pesticide exposure may also occur through the eye. Splashing of liquid chemicals and dust from granular pesticides during handling, mixing or rinsing of containers is a source of risk to the eyes. Pesticide labels provide specific requirements for the personal protective equipment (PPE) which will give maximum protection and reduce pesticide exposure. A study by Ohayo *et al.* (2000) indicated that there was a significant relationship between exposure and eye symptoms.

2.5. Health Risks of Pesticides

Use of pesticides in Kenya has created substantial health impacts, although the exact toll is difficult to pinpoint due to various chemicals and types of exposure (Kibwage *et al.,* 2007). Not all pesticides are equally risky, and not all people are equally at risk (Lippman, 1992). Types of toxicity vary and include local effects such as skin irritation; general effects such as in-coordination, behavioural changes and organ structure changes (Revine, 1992). Effects can be divided broadly into: acute effects, which appear immediately after exposure; and chronic effects, which may manifest many years later (Elbaz, 2009).

2.5.1. Acute effects

Exposure to pesticides can lead to an array of acute effects, depending on the pesticide's toxicity and the dose absorbed by the body. For pesticides with high acute toxicity, exposure can produce symptoms within minutes or hours, most of which last only a short time and the majority of victims recover completely without long term complications (Katzung, 2001). However, a few people may suffer permanent damage of some kind. Poisoning symptoms include; skin rashes/irritations, burns, flu-like symptoms, headache, dizziness, nervousness, blurred vision, stomach cramps, diarrhea, chills, fever, a feeling of general numbness, and abnormal size of eye pupils. In some instances, there is excessive sweating, tearing, or mouth secretions. Severe cases of poisoning may be followed by nausea and vomiting, fluid in the lungs, changes in heart rate, muscle weakness, breathing difficulty, confusion, convulsions, coma, paralysis and/or death (Ware, 1978; Arnold, 1990).

Air temperature and the exposed person's general health condition influence the severity of these symptoms. Toxic reactions may be worse for those suffering from poor nutrition or dehydration, and warmer temperatures also may increase the toxic effects. This means that field laborers working in the heat may be more susceptible to poisoning (Rosenstock *et al.*, 1991).

2.5.2. Chronic effects

There is concern about possible adverse effects on worker's health arising from continual long term low level exposure. Chronic effects (such as carcinogenesis, teratogenesis, reproductive toxicity and mutagenesis) become apparent after prolonged accumulative exposure to pesticides (MacFarlane *et al.*, 2009). Health effects of great concern to a farm worker include; cancer, miscarriages, fetal deformities, skin and eye irritations and neurological disorders (Arnold, 1990).

2.5.2.1. Carcinogenesis

According to Arnold (1990), cancer is one of the most serious diseases linked to pesticides. It is considered a chronic effect, although it may appear after shorter exposures. The proportion of individuals who get it is related to the degree of exposure, but the extent of the tumor spread or growth is independent of exposure. Studies suggest that exposure to pesticides have an increased risk of developing tumor types such as leukemia, myeloma, Hodgkin's, and non Hodgkin's lymphomas, lung, stomach and colon cancer. Studies by Wiklund (1989) reported increased testicular cancer and higher death rates from malignant brain tumors due to exposure.

2.5.2.2. Teratogenesis

Teratogenesis is the formation of birth defects in offsprings often as a result of maternal exposure to a toxicant (such as pesticide). These abnormalities arise most commonly from alteration of the developing cells, leading to improper functioning of the cells or interference with differentiation so that the proper cell types do not form or do not form in the proper number or location (Arnold, 1990). Events that result in teratogenesis may also result in death of the embryo or foetus. Some of the birth defects that result from toxicant exposures are heritable and may appear in future generations as well as the present one (Kolb, 1993).

2.5.2.3. Reproductive toxicity

Human reproductive toxicity includes a variety of effects on the reproductive capacity which include decrease in fertility due to reduced sperm count and percentage of conceptions leading to live birth or foetal toxicity (Arnold, 1990). Foetal toxicity is distinguished from teratogenicity in that toxicity does not lead to birth defects, but, instead to miscarriage, fetal deaths, reduced birth weight or size. Agents that affect fertility of males or females may produce their effects after a short-time exposure of the mother during gestation which manifests later (Kamrin, 1988). A study by Regidor *et al.* (2004) indicated that paternal agricultural works in the areas where pesticides were massively used increased the risk of fetal death from congenital anomalies. The risk also increased miscarriage of foetuses conceived during the time periods of maximum use of pesticides.

2.5.3. Effect on nervous system

The nervous system has been recognized as a target organ for pesticide toxicity. Several studies have shown that as high as 70% of people with acute occupational pesticide poisoning from organophosphate and carbamate pesticides later suffer neurological damage (Katzung, 2001). Symptoms of this poisoning include weakness, tingling, or even paralysis in the legs due to dieback of some nerve endings, reduced memory and attentiveness. In addition, organophosphate and carbamate pesticides may cause delayed polyneuropathy and or neurobehavioural effects (Arnold, 1990). Organophosphate (example Malathion) and carbamate (example carbofuran) pesticides, the most toxic group, cause acute and chronic effects on the nerve function. They exert their action in mammals by attacking the system of neural transmission hence interfering with the transmission of nerve impulses along the axons (projections connecting nerve cells). This results in disruption of the central nervous system which may lead to death or paralysis (Katzung, 2001).

2.5.3.1. Mechanism of organophosphate and carbamate pesticide poisoning

Organophosphate and carbamate pesticides inhibit both cholinesterase and pseudo-cholinesterase activities thereby causing accumulation of acetylcholine at synapses and over stimulation of neurotransmission (Eyer, 2003) as shown next page. However, Carbamate pesticide poisoning effects are of shorter duration than those observed with organophosphate pesticide poisoning (Katzung, 2001). Carbamates are also less toxic than organophosphates in that ranges of doses that cause minor poisoning and those which result in lethality are larger for carbamates than organophosphates (Katzung, 2001).

Hydrolysis of acetylcholine by cholinesterase

$$\underset{\text{acetylcholine}}{(CH_3)_3N\text{-}CH_2\text{-}CH_2\text{-}O\text{-}\overset{\overset{O}{\|}}{C}\text{-}CH_3} + H_2O \xrightarrow[\text{sterase}]{\text{choline-}} \underset{\text{choline}}{(CH_3)_3N\text{-}CH_2\text{.}CH_2\text{-}OH} + \underset{\text{acetic acid}}{CH_3CO_2H}$$

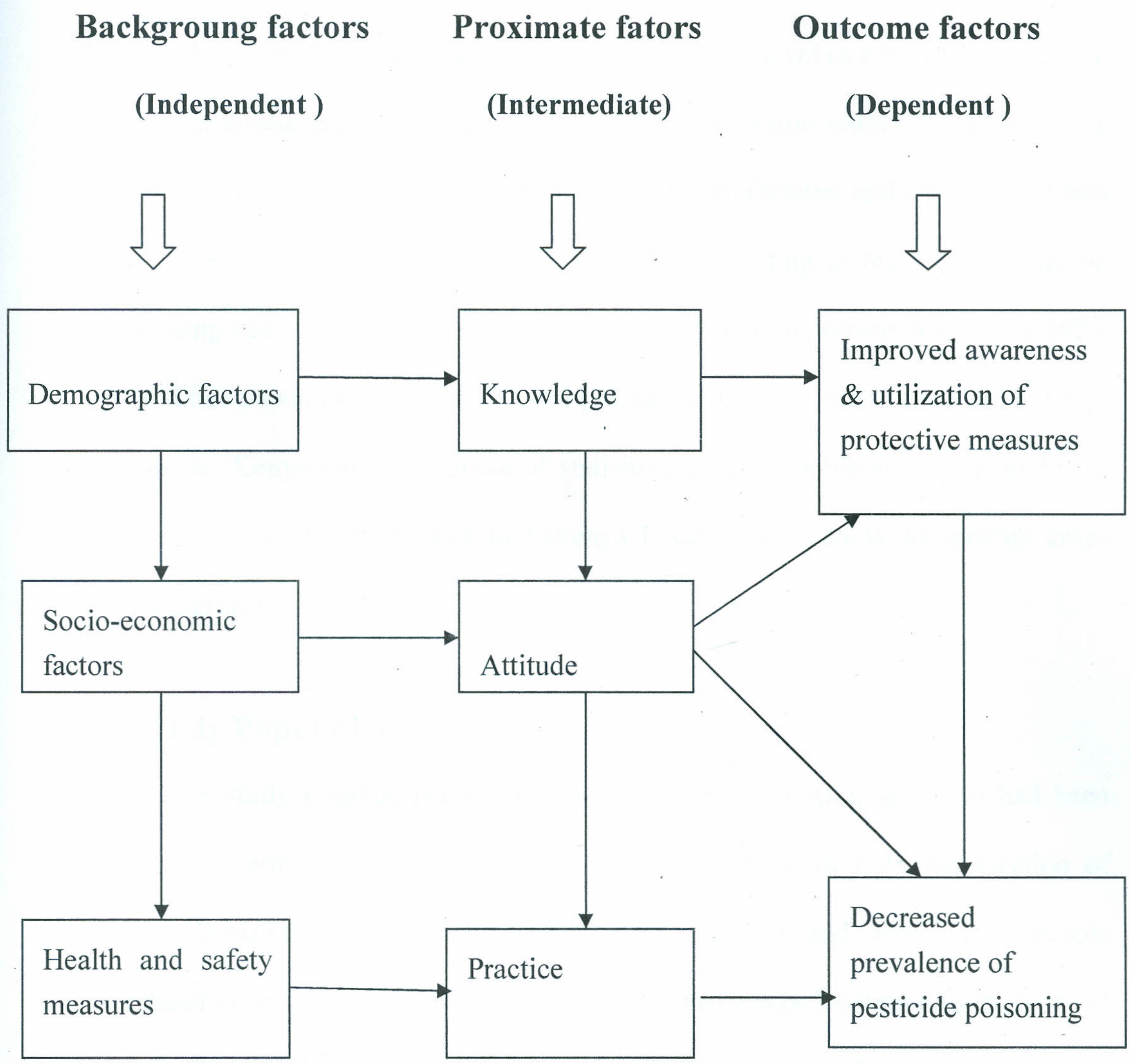
Inhibition of enzyme acetyl-cholinesterase (as shown above) is through phosphorilation of the esteratic site causing first, excitation and then depression of the parasympathetic nervous system. This inhibition results in accumulation of acetylcholine at the cholinergic synapses (post synaptic membrane), disturbing transmission at parasympathetic nerve endings, sympathetic ganglia, neuromuscular endplates and certain central nervous system regions (CNS). The membrane is then unable to return to its resting state. Accumulation of acetyl-choline results in over stimulation of muscles, nerves and other parts of the body. Eventually, convulsions, paralysis and death occur. The enzyme choline-esterase hydrolyses the neurotransmitter acetylcholine at the cholinergic nerve synapses and its inhibition effects on the nervous system are the most meaningful index of the risk of poisoning.

Symptoms of poisoning which mimic the action of acetylcholine include; headache and symptoms of a common cold, decrease in blood pressure, mental confusion and nausea (Katzung, 2001). Investigation by Ohayo *et al.* (2000) showed that there was a significant relationship between exposure and acetyl-cholinesterase inhibition, acetyl-choline-esterase activity, and respiratory, eye, and central nervous system symptoms.

2.6. Conceptual Framework

Below is the adapted conceptual frame work for assessment of exposure to pesticides on farms in Mavoko Division of Machakos District, Kenya.

Fig. 2.1: Conceptual framework for assessment of pesticide exposure in Mavoko Division.



Adapted from Oso and Onen (2005) and modified

CHAPTER THREE

METHODOLOGY

3.1. Study Area

The study was conducted in Mavoko Division of Machakos District, (Appendix 6) which boarders Kajiado District to the West and Thika to the North. It stretches from latitudes 0^0 45' south to 1^0 31' south and longitudes 36^0 45' east. Topography of the division varies from 700m above sea level (a.s.l) to 1700m a.s.l. It receives an erratic annual average rainfall of 500 – 1300mm within 2 seasons. Long rains start from March to May and Short rains between October and December. Mean monthly temperatures range from 12^0C to 25^0C. According to the 2009 population and housing census, Lukenya, the specific location of study, covers an area of 592.4 Km^2 and has a total population of 32,675 (18,444 males and 14,231 females) in 9,614 households (Kenya national bureau of statistics, 2010). Inhabitants of Kinanie sub-location, the specific study area in Lukenya Location (Appendix 6), irrigate crops using water from river Athi.

3.2. Study Population

The study targeted people who were currently working and who had been working on farms consistently for two years and above in Lukenya location of Mavoko Division in Machakos District. One hundred and sixty (160) people (calculated in section 3.3.) working on farms in Kinanie sub- location (Appendix 6) of Lukenya location were purposively and randomly selected from the population employed and working on farms.

3.3. Sample Size

Sample size was calculated using Fisher's formular in Mugenda and Mugenda (1999).

$$n \geq Z^2 Pq / d^2$$

Where;

n = Desired sample size if target population >10,000

Z = The standard normal deviate at required confidence level (95%), = 1.96

P = Proportion in the target population estimated to have characteristics being studied = 0.5

q = 1-P, (1-0.5) = 0.5

d = maximum tolerable error, 5% = 0.05

Therefore; $n = 1.96^2 \times 0.5 \times 0.5 / 0.05^2$

$= 0.9604 / 0.0025$

= 384 workers

Since target population was <10,000, the sample size was adjusted using Fisher's formular in (Mugenda and Mugenda, 1999).

$$nf = n \div (1 + n) / N$$

Where;

nf = Desired sample size when population < 10,000

n = Desired sample size when population > 10,000 = 384

N= Estimated population size working on farms for ≥ 2 years = 160

Therefore, $nf = 384 \div (1 + 384) / 160 \quad = 159.6$

= 160 workers

160 farm workers in Kinanie sub-location were interviewed and observed.

3.4. Research Design

The research design was Cross Sectional that used both quantitative and qualitative methods to collect data. Simple random sampling, but purposive, was done (to get the sample frame) basing on the principle in Mugenda and Mugenda (1999) that only those with the required information with respect to the objectives of the study to be selected. Purposive sampling was therefore done with a specific plan of interviewing and observing farm workers who mixed and sprayed pesticides on farms in Kinanie sub-location (Appendix 6) as the exposed group and those who did not mix and spray pesticides as the unexposed group.

3.4.1. Sampling procedure

3.4.1.1. Selection of exposed and unexposed groups

Permission to conduct the study was obtained from the Divisional Agricultural Extension Office (Appendix 7). Simple random sampling, but purposive, was done. A list of 80 exposed and another of 80 unexposed workers who had worked on farms for two years and above in Kinanie sub-location of Lukenya location was made, making 160 calculated in section 3.3. These workers were willing to participate by signing the consent form (Appendix 8). Exposed 80 workers who had consistently handled, mixed or sprayed pesticides for 2 years and above were purposively selected from farms along river Athi in Kinanie sub-location of Lukenya location where pesticides are intensively used. Unexposed 80 workers were purposively selected from workers who had consistently worked on farms away from the river but in other parts of Kinanie sub-location (Appendix 6) without handling pesticides for 2 years and above.

3.4.1.2. Inclusion and exclusion criteria

Farm workers who had worked on the farm for two and above years and handled pesticides by either mixing or spraying and were willing to participate by signing the consent form (Appendix 8) were recruited as the exposed group. Those who had worked on the farm for not less than two years and did not mix or spray pesticides and were willing to participate by signing the consent form (Appendix 8) were recruited as the unexposed group. The exposed and unexposed workers recruited were not on any treatment. Those farm workers whose age was 18 years and below, those not willing to participate by signing the consent form (Appendix 8), those who had worked on the farm for less than 2 years, those who did not work on farms, and workers who were on treatment were excluded from the study.

3.4.2. Pre-test and training

After obtaining permission by my research assistant and consent from the farm workers by signing a consent form (Appendix 8), the questionnaire and observation checklist were pre-tested on 5 farm workers of Kinanie sub-location in Lukenya location. For the sake of uniformity of data, my research assistant was trained in the objectives of the research; familiarization of the questionnaire and observation checklist; how to record information; and sampling procedure and skills.

3.4.3. Data collection

Data was collected from 160 (calculated in section 3.3.) farm workers through interviews and by direct observation when mixing and spraying pesticides and doing other farm work.

3.4.3.1. Interviews

A face to face question-answer process was conducted using a structured open and close-ended questionnaire (Appendix 9). Exposed workers were interviewed before and after spraying pesticides to get data on their knowledge, attitude and practices on pesticide use; types and quantities of pesticides mixed and sprayed and post-exposure symptoms experienced after spraying pesticides. Participants were then interviewed and followed up for 2 weeks to find out whether and when they experienced post-exposure symptoms. Unexposed workers who did not spray pesticides but did general work such as weeding and planting were interviewed before and after working and then followed up for 2 weeks to interview and record the symptoms they may have experienced after working.

3.4.3.2. Observations

Observations regarding the workers' different practices leading to exposure were made using an observation check list (Appendix 10). Exposed farm workers were observed and assessed while diluting, spraying and after spraying pesticides to obtain information on practice. This included; the condition of spray pump; protective clothing used; type, class and quantities of pesticides diluted and sprayed. Information on hygienic behavior immediately after spraying was assessed such as; washing of hands and spray pump; changing and washing clothing; and bathing. The practice of unexposed workers who did general work was also observed while working and after working.

3.5. Data Analysis

Qualitative and quantitative data collected from interviews and observations was entered into MS Excel, coded and analyzed using Statistical Package for Social Sciences (SPSS) ver. 15.0. Descriptive statistics was carried out for frequencies and percentages of demographic factors; factors on knowledge, attitude and practice; type and pesticides mixed and sprayed; and post exposure symptoms experienced by farm workers. Analysis of Regressions was done using Pearson's Chi-square at 5% significance level ($p < 0.05$) to test for significance between assessed factors. Cross tabulations were done to test for association between assessed factors.

3.6. Study Limitations and Scope

This research was to be done in Mathatani sub-location (Appendix 6) which had more farm workers than Kinanie location but my research assistant in the area was uncooperative. This reduced the sample frame. Due to unbearable high temperatures in Kinanie we worked upto noon. The research, therefore, took longer than originally scheduled.

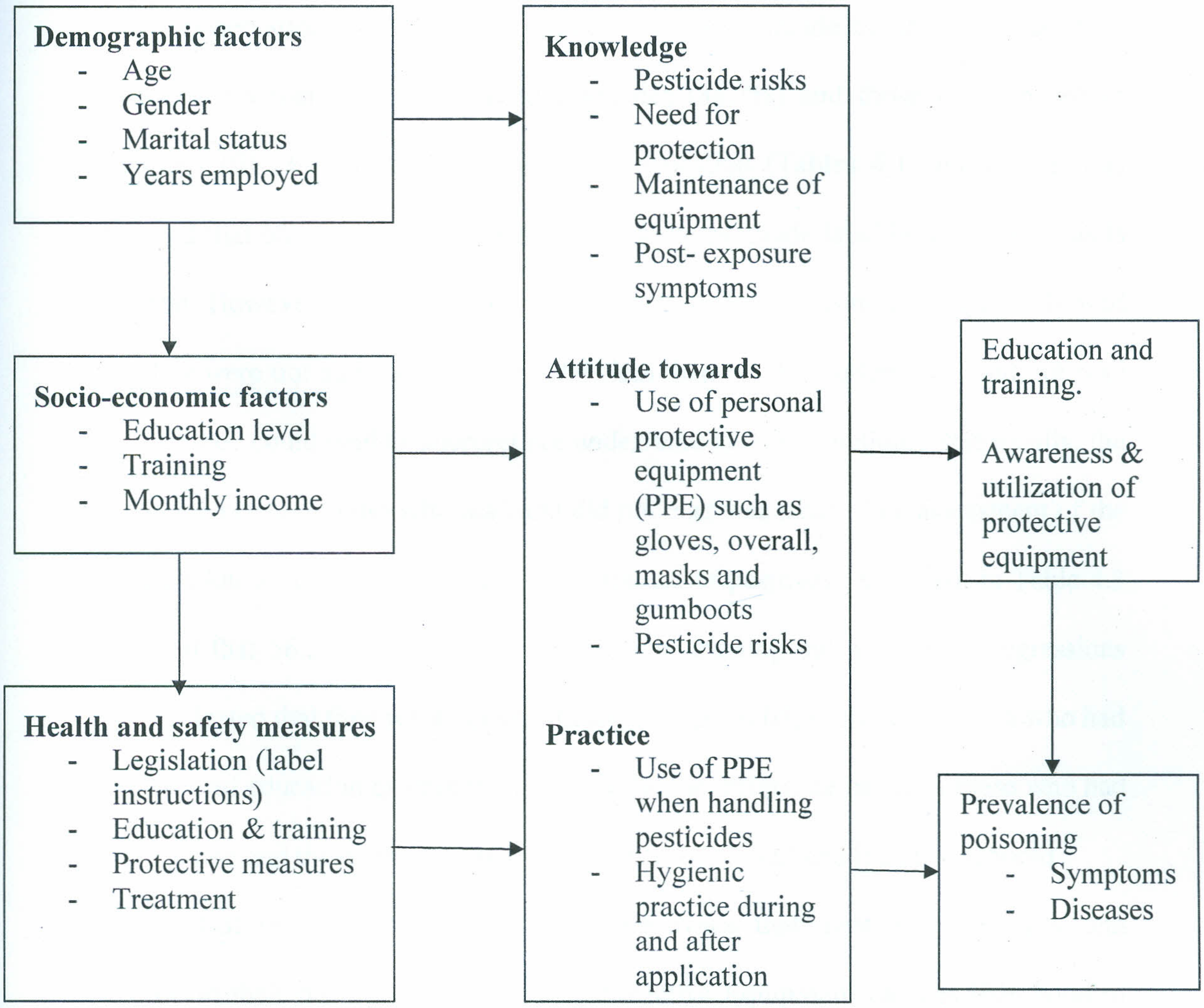
3.7. Ethical Considerations

Permission to carry out this research was obtained from the Divisional Agricultural extension Office of Mavoko Division (Appendix 7). Consent was obtained from workers, and only those willing to participate by signing the consent form (Appendix 8) were recruited in the study. Permission (verbal) to take photographs and use them in this thesis was obtained from the workers.

3.8. Operational Framework

Below is the adapted operational frame work for assessment of pesticide exposure in Mavoko Division.

Fig. 3.1: Operational framework for assessment of pesticide exposure in Mavoko Division.



Adapted from Oso and Onen (2005) and modified

CHAPTER FOUR

RESULTS

4.1. Assessment of Knowledge, Attitude and Practice on Pesticide Use by Farm Workers

4.1.1. Knowledge of workers on pesticide use

Observations on assessment of knowledge on pesticide use indicated that most farm workers that were exposed to pesticides (88.7%) and those not exposed to pesticides (91.2%) had only primary level education (Tables 4.1 and 4.2). It was observed that only 31.3% read instructions on the pesticide label before mixing as is required. However, analysis of regressions done using Pearsons Chi-Square showed that they were not significantly ($p > 0.05$) less than 68.7% workers who did not read because they could neither interpret nor understand label instructions. Statistically, the difference between those who read and did not read was small. The assessment of the worker's knowledge on the toxicity and safe use of pesticides as shown in Table 4.3 indicated that 56.3% had received education or training but analysis of regressions done indicated that they were not significantly ($p > 0.05$) more than 43.7% who had not received education or training. Statistically, the difference between those who had been trained and those who had not been trained was small and it can be ignored.

Most exposed workers (97.5%) were aware that; pesticides are toxic and harmful to their health; use of Personal Protective Equipment reduces likelihood of poisoning (96.2%) and that maintenance of the spray pump was necessary in order to reduce poisoning (98.7%). However, 96.2% workers interviewed knew that they should protect themselves when mixing or spraying pesticides; they would be poisoned if they did not protect themselves (95%); Personal Protective Equipment should be used at all times while handling pesticides (97.5%); and that safety is the responsibility of both employer and worker (97.5). Only 5% did not know they would be poisoned if they did not protect themselves; Personal Protective Equipment needed to be used at all times while handling pesticides (2.5%); and that safety was the responsibility of both employer and worker (3.7%). Most workers (88.7%) knew signs of pesticide poisoning while only 11.3% did not know.

Table 4.1. Socio-economic and demographic factors of exposed farm workers

Factor	**Exposed to pesticides (n = 80)**		
Sex	**Frequency**	**%**	**p-value**
Male	65	81.2	
Female	15	18.8	0.012
Age (yrs)			
19-30	43	53.8	
31-40	34	42.5	< 0.001
41-50	3	3.7	
Marital status			
Single	30	37.5	
Married	44	55.0	< 0.001
Widow/Widower	4	5.0	
Divorced/Separated	2	2.5	
Education Level			
Primary	71	88.7	
Secondary	9	11.3	0.001
Monthly Income			
1500-3000	7	8.8	
3001-4500	40	50.0	0.042
>4500	33	41.2	
Years Employed			
2-5	69	86.2	< 0.001
5-10	7	8.7	
>10	4	5.1	

Regressions done using Pearson's Chi-Square showed very high significant ($p < 0.001$) differences between factors of knowledge. There were big differences between farm workers who responded they were knowledgeable and those who were not knowledgeable. Statistically, interviews showed that workers had knowledge on pesticide risks and their safe use. Analysis of Cross tabulations showed that there was no association ($p > 0.05$) between knowledge and practice. Statistically, the knowledge of workers was not related to practice. Practice of those who claimed to have knowledge on risks was the same (poor) as those who were not knowledgeable.

Table 4.2. Socio-economic and demographic factors of unexposed farm workers

Factor	**Not exposed to pesticides (n = 80)**		
	Frequency	**%**	**p-value**
Male	15	18.8	
Female	65	81.2	0.001
Age(yrs)			
19-30	34	42.5	
31-40	43	53.7	0.049
41-50	3	3.8	
Marital status			
Single	34	42.5	
Married	41	51.2	0.035
Widow/Widower	3	3.8	
Divorced/Separated	2	2.5	
Education Level			
Primary	73	91.2	
Secondary	4	5.0	< 0.001
Tertiary	3	3.8	
Monthly Income			
1500-3000	4	5.0	
3001-4500	11	13.8	0.001
>4500	65	81.2	
Years Employed			
2-5	72	90	< 0.001
5-10	6	7.5	
>10	2	2.5	

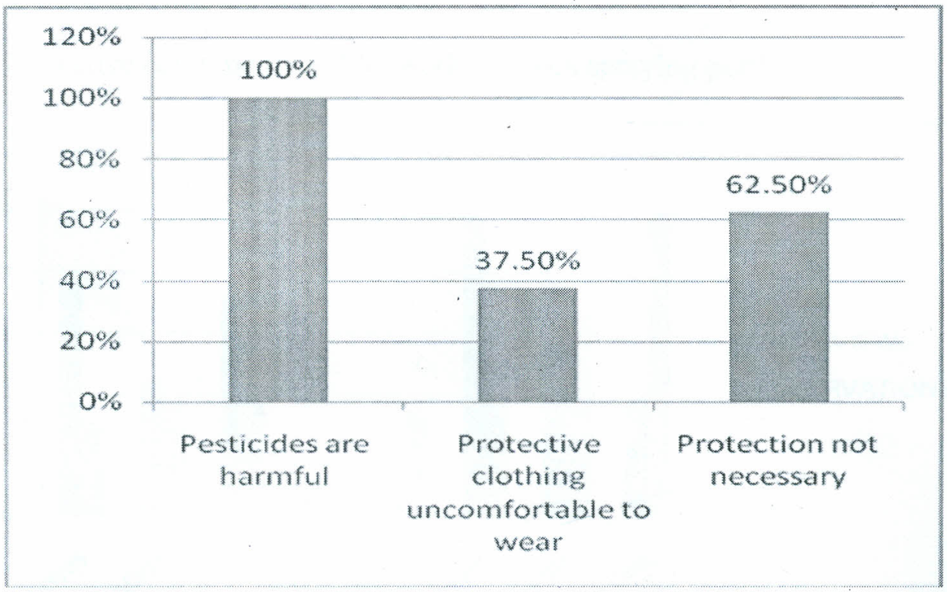
Table 4. 3. Factors on knowledge and attitude of exposed farm workers

Knowledge		Frequency	Percent	p-value
Received education or training on safe use of pesticides	Yes	45	56.3	0.462
	No	35	43.7	
What should you do when mixing or spraying pesticides	Protect self	77	96.2	< 0.001
	Don't know	3	3.8	
What will happen if you don't protect yourself	Be poisoned	76	95.0	< 0.001
	Don't know	4	5.0	
Do you know signs of pesticide poisoning	Yes	71	88.8	< 0.001
	No	9	11.2	
Pesticides are harmful to your health	Agree	78	97.5	< 0.001
	Don't know	2	2.5	
Personal Protective Equipment should be used at all times while handling pesticides	Agree	78	97.5	< 0.001
	Don't know	2	2.5	
Use of Personal Protective Equipment reduces likelihood of poisoning	Agree	77	96.2	< 0.001
	Don't know	3	3.8	
Maintenance of spray pump is necessary to reduce poisoning	Agree	79	98.7	< 0.001
	Don't know	1	1.3	
Safety is the responsibility of both employer and worker	Agree	78	97.5	< 0.001
	Don't know	2	2.5	
Attitude towards pesticides and protective clothing				
Pesticides are harmful		80	100	< 0.001
Protective clothing uncomfortable to wear		30	37.5	0.382
Protection not necessary		50	62.5	0.634

4.1.2. Attitude of workers towards pesticides and protection

Assessment on the attitude of farm workers towards pesticides and use of protective clothing is shown in Table 4.3 and Figure 4.1. Data indicated that 37.5% of the workers had a negative attitude towards using protective clothing such as the mask because they were uncomfortable to wear due to difficulties in breathing, and overalls due to high temperatures.

Fig. 4.1: Attitude of farm workers towards pesticides and protection



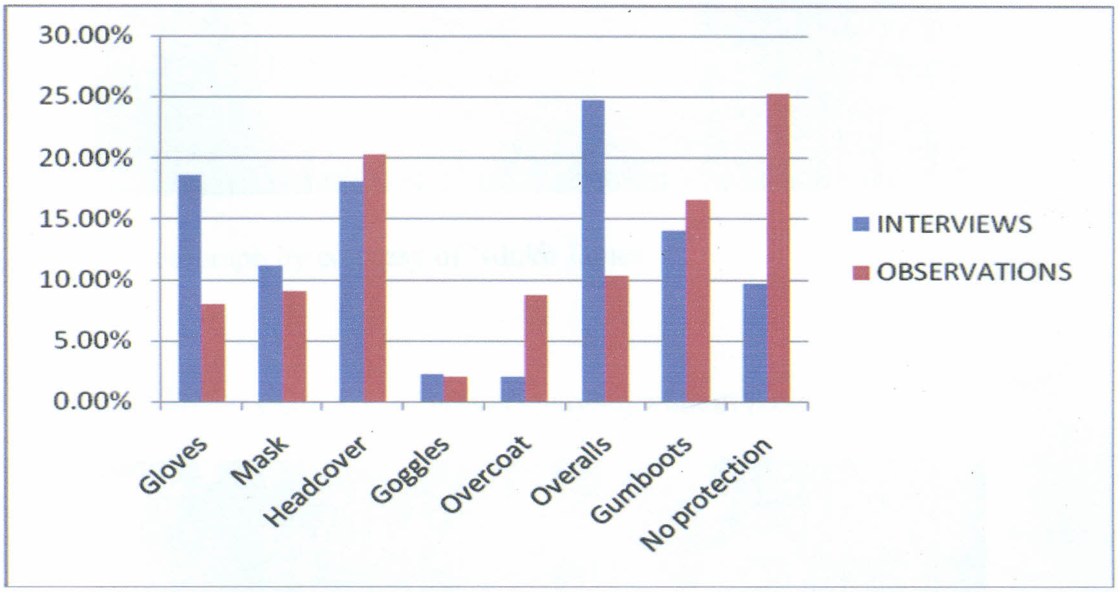
Over 62% saw it not necessary to protect themselves while mixing and handling pesticides. They believed they were careful enough not to be contaminated. However, all (100%) workers exposed claimed to have a positive attitude towards harmfulness of pesticides. However, data analyzed by cross tabulations showed no association between attitude of workers and other factors ($p > 0.05$). Statistically, all workers had the same (negative) attitude towards pesticide risks and safe use.

4.1.3. Practice of the workers

4.1.3.1. Use of personal protective equipment (PPE)

Results (Fig. 4.2 and 4.3) indicate that workers used different Personal Protective Equipment (PPE). Regressions done using Pearson's Chi-square at 5% indicated that PPE used by farm workers when mixing and spraying pesticides varied significantly ($p < 0.001$). Workers did not protect themselves the same way or in any order but types of protective equipment used varied in a big way.

Fig. 4.2: Protective equipment used by workers when spraying pesticides

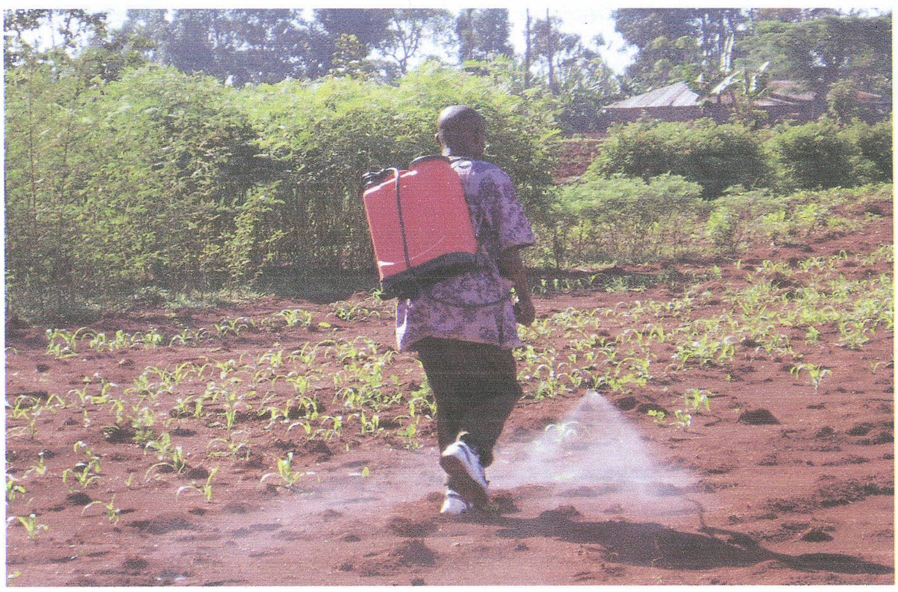


Nevertheless, none of the workers used the complete set of protective equipment. Plate 4.1 shows a worker spraying without head cover and mask and Plate 4.2 shows a worker spraying without any protection. About 10% interviewed responded that they did not use any protection when spraying and 8% when mixing. From observations, about 25% did not protect themselves when spraying and 35% when mixing pesticides. Reasons given for not protecting themselves or using full protective equipment were; the employer did not provide (43.4% when mixing, 55.7% when spraying); they could not afford (35.8% when mixing, 48.3% when spraying).

Plate.4.1. A worker spraying without covering the head and face

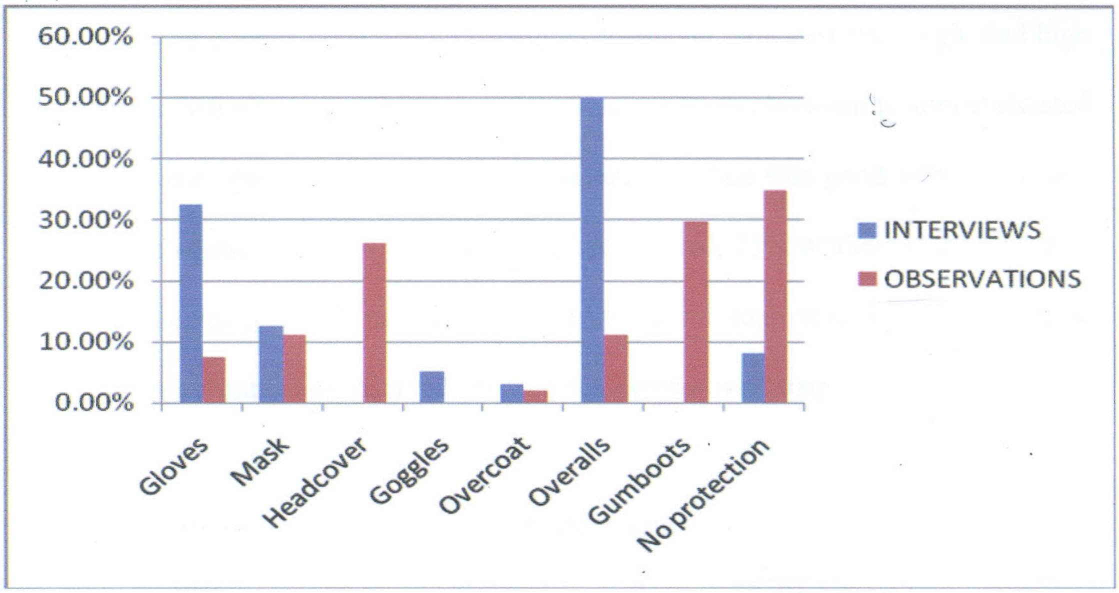
Photograph by courtesy of Nduku James

Plate.4.2. A worker spraying without protection



Photograph by courtesy of Munyao Edward

Fig. 4.3: Protective equipment used by workers when mixing pesticides



Some workers did not use personal protective equipment such as a mask because they were uncomfortable to wear (6.5% when mixing and 20.5% when spraying). Some workers (65.2% when mixing, 3.7% when spraying) responded that protection was not necessary. Findings indicated that the majority of workers (88.7% exposed, and 91.2% unexposed) had only primary level education; they had a minimum and maximum monthly income of Ksh 4,500 and Ksh 6,500 respectively; and had been exposed to pesticides for a period of between 2-5 years (about 90%), see Tables 4.1 and 4.2. Cross tabulations done to analyze data did not reveal any association ($p > 0.05$) between use of Personal Protective Equipment and other variables. Statistically, practice of workers whether trained or not trained, more or less educated was poor (the same).

4.1.3.2. *Hygienic practice of workers*

Results shown in Table 4.4 indicate that farm workers had a poor hygienic practice. Regressions done using Pearson's Chi-square indicated very high, and high significant differences ($p < 0.001$; $p = 0.001$), respectively, between factors associated with hygienic practice. Workers whose hygienic practice was good were much less than those whose practice was poor. When interviewed, 25% workers responded they cleaned the spray pump immediately after use with soap and with protection as recommended but when observed only 3.8% cleaned it with soap and with protection.

Table 4.4: Hygienic practice of exposed farm workers

	Interviews			**Observations**		
	Frequency (n=80)	%	p-value	Frequency (n=80)	%	p-value
Cleaned spray pump immediately						
Yes, with soap & protection	20	25.0	0.014	3	3.8	< 0.001
Yes, with soap & without protection	17	21.2		5	6.3	
Yes, without soap & with protection	20	25.0		8	10.0	
Yes, without soap & without protection	18	22.5		51	63.6	
NO, after using two times	5	6.3		13	16.3	
Wash hands immediately						
Yes, with soap	32	40.0	0.001	9	11.3	< 0.001
Yes, without soap	38	47.5		14	17.5	
NO, after work without soap	10	12.5		57	71.2	
Change clothes immediately						
Yes	23	28.7	0.001	6	7.5	< 0.001
NO, evening or following day	47	58.8		61	76.2	
NO, no need to change	10	12.5		13	16.3	
Wash clothes immediately						
Yes	8	10.0	< 0.001	4	5.0	0.001
NO, evening or following day	52	65.0		43	53.7	
NO, after using several times	20	25.0		33	41.3	
Bath immediately						
Yes	5	6.3	< 0.001	0	0.0	< 0.001
No, evening or following day	75	93.7		80	100.0	

When interviewed, 21.2% of the workers responded that they washed the spray pump immediately after use with soap but without protection yet observations revealed that only 6.3% washed spray pump immediately after use with soap but without protection. When interviewed 25% responded they washed the spray pump without soap but with protection while observation showed that only 10% did. However, observations revealed that most workers (63.6%) washed the spray pump without soap and without protection immediately after spraying. Although only 6.3% interviewed responded that they did not wash the spray pump immediately after use but after using twice, it was observed that 16.3% did not wash immediately after use.

When interviewed, 40% of the workers responded that they washed hands with soap after spraying as required but observations revealed that only 11.3% washed hands with soap after spraying. Although 47.5% workers claimed they washed hands immediately without soap when interviewed, observations revealed that only 17.5% washed hands without soap immediately after spraying. However, observations revealed that the majority of the workers (71.2%) did not wash hands immediately after spraying.

Whereas 28.7% of the workers responded they changed clothes immediately after spraying pesticides when interviewed, observations revealed that only 7.5% changed clothes immediately after spraying. However, observations revealed that the majority of the workers (76.2%) did not change clothes immediately after spraying. Interviews indicated that 12.5% of the workers did not change clothes immediately after spraying because they saw no need to change, but observations revealed that 16.3% did not change clothes immediately after spraying because they saw no need to change.

Washing clothes immediately after spraying pesticides as is required was not common. Although interviews indicated that 10% of the workers washed clothes immediately after spraying, observations revealed that only 5% washed clothes immediately after spraying. Whereas interviews indicated that 65% of workers did not wash clothes immediately after spraying but washed in the evening or the following day, it was observed that 53.7% did not wash clothes immediately after spraying. Interviews indicated that 6.3% of the workers bathed immediately after spraying pesticides but observations revealed that none bathed immediately after spraying pesticides as is recommended.

Cross tabulations done to analyze data did not show any association ($p > 0.05$) between hygienic practice of workers and knowledge. The practice of workers was the same (poor) for those trained and not trained, less and more educated. The knowledge workers claimed to have did not influence their practice.

4.2. Identified Pesticides Used on Farms in Mavoko Division

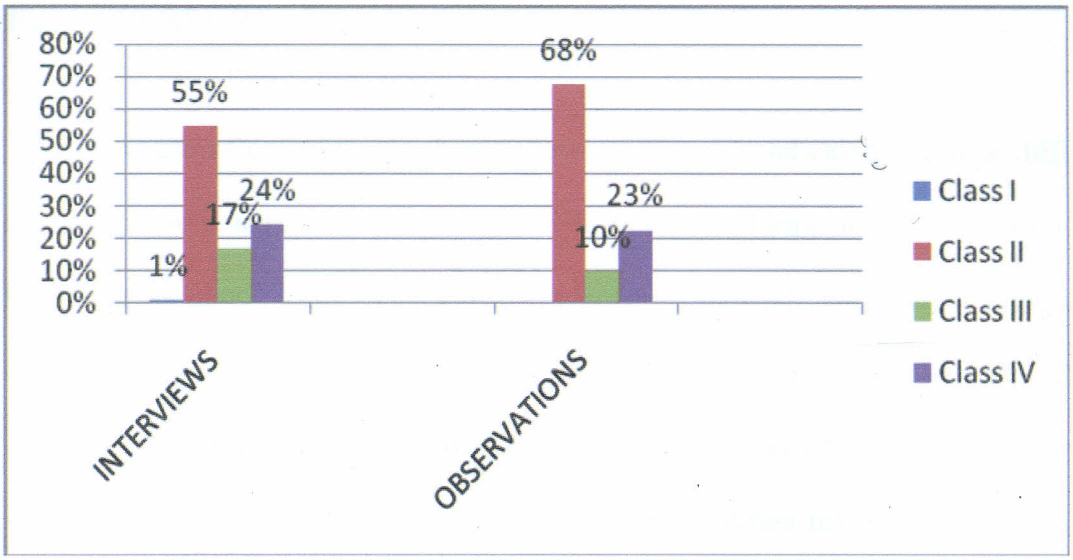
Results of objective number 2 indicating pesticides used on farms in Mavoko Division are shown in Table 4.5 and Figure 4.4. Interviews indicated that 12 different pesticides ranging from WHO Class l (highly toxic) to WHO Class IV (slightly toxic) were mixed and sprayed by workers on farms in Mavoko Division. Out of the pesticides used, two (1.5%) pesticide was highly toxic (WHO Class I), six (55%) were toxic (WHO Class II); two (17%) moderately toxic (WHO Class III); and three (24%) were slightly toxic (WHO Class IV).

Table 4.5: Pesticides used by farm workers in Mavoko Division

Name of pesticide	Active ingredient	WHO Toxicity class	Quantity/ week	Frequency	%
		Interviewed			
Agrinate	Methomyl 90%	I (Highly toxic)	50g	2	1.5
Alphacypermethrin	Alphacypermethrin	II (Toxic)	25-100ml	15	11.0
Bull dock (Alfatox 10 EC)	Beta Cyfluthrin	II (Toxic)	100ml	4	2.9
Copper oxychloride	Cobox 5 WP	IV (Slightly toxic)	100-400gm	4	2.9
Cyclone	Cypermethrin 10% WV + Chlorpyrifos 35WV	II (Toxic)	100-200ml	6	4.4
Ogor (Dimethoate)	Ogor 40 EC + Dimethoate	II (Toxic)	200-500gm	39	28.6
Dithane M 45 (Mancozeb)	Mancozeb	III (Moderately toxic)	250-500gm	6	4.4
Duduthrin	Lambda- cyhalothrin	II (Toxic)	250-500ml	8	3.5
Karate WG	Lambda-cyhalothrin	II (Toxic)	100-500gm	6	4.4
Ortiva SC	Azoxystrobrin	IV (Slightly toxic)	35ml	3	2.2
Oshothane 80 WP	Mancozeb	III (Moderately toxic)	100-500mg	17	12.5
Ridomil	Metalaxyl	IV (Slightly toxic)	100-500gm	26	19.1
Total				**136**	**100**
		Observations			
Alphacypermethrin	Alphacypermethrin	II (Toxic)	50ml	12	16.9
Cyclone	Cypermethrin 10% WV + Chlorpyrifos 35WV	II (Toxic)	200ml	3	4.2
Duduthrin	Lambda- cyhalothrin	II (Toxic)	250ml	3	4.2
Karate WG	Cyhalothrin	II (Toxic)	100-400gm	9	12.7
Malathion	Malathion	III (Moderately toxic)	400ml	2	2.8
Dithane M 45	Mancozeb	III (Moderately toxic)	500g	5	7.1
Orgor (Dimethoate)	Orgor + Dimethoate	II (Toxic)	80-400ml	21	29.6
Ortiva SC	Azoxystrobrin	IV (Slightly toxic)	80ml	5	7.1
Ridomil Gold	Metalaxyl M + Mancozeb	IV (Slightly toxic)	100-500gm	9	12.7
Thiorit jet	Sulphur (elemental)	IV (Slightly toxic)	500ml	2	2.8
Total				**71**	**100**

Source of active ingredients: Pest Control Products Board (2011)

Fig. 4.4: Classes of pesticides used on farms in Mavoko Division



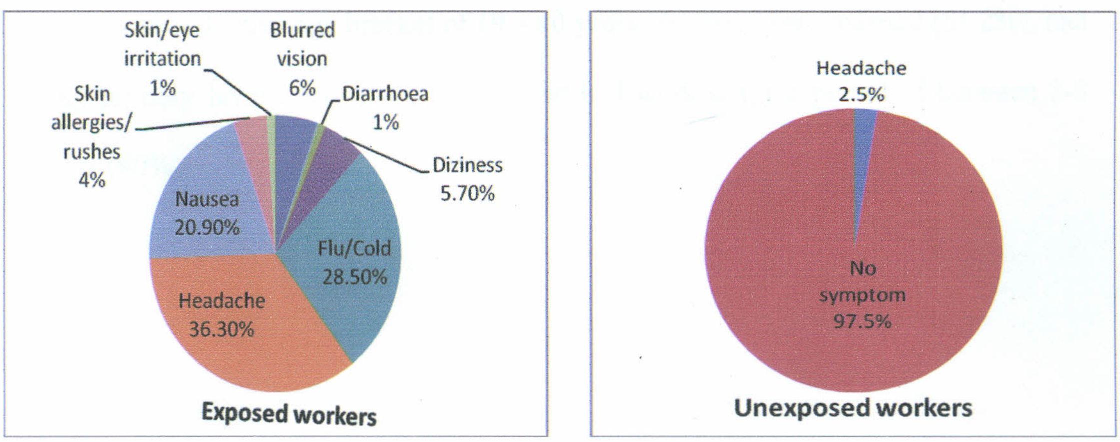
From observations, 10 different pesticides were mixed and sprayed by workers in Mavoko Division. Out of these, five (68%) pesticides were WHO Class II; two (10%) were WHO Class III and three (23%) were WHO Class IV. Rates and quantities varied with the pesticides but were within the recommended ranges.

However results (Figure 4.4) revealed that class 11 pesticides were more used by the workers than other classes of pesticides. Analysis of regressions done using Pearson's Chi-square showed very high significant differences ($p < 0.001$) between the classes of pesticides used, indicating that the gap between the classes of pesticides used (class 1 – 1V) was big. Workers were expected to be exposed to a variety of less toxic pesticides as per the hypothesis, but they were mostly exposed to a variety of class 11 that are toxic.

4.3. Investigated Post-Exposure Symptoms of Pesticides Used on Farms in Mavoko Division

Results of objective number 3 shown in Fig. 4.5 indicated that nine different symptoms were experienced by exposed workers on farms in Mavoko Division. Regressions done using Pearson's Chi-square showed very high significant differences ($p < 0.001$) between post-exposure symptoms experienced by all (100%) exposed workers interviewed. This indicated that there was a big difference between various symptoms experienced by the farm workers. When interviewed, about 21% workers reported that symptoms occurred during pesticide application while 79.2% had symptoms during and immediately after application.

Fig. 4.5: Post- exposure symptoms experienced by exposed and unexposed workers



Only two (2.5%) unexposed workers experienced only a headache, which could have been caused by high temperatures in the area. Symptoms mostly experienced by exposed workers were; flu/cold (28.5%), headache (36.3%) and nausea (20.9%). Only 3.3% exposed workers reported to have sought medication since symptoms cleared after resting or drinking water. All (100%) exposed workers reported that none of their family members has had a long term effect related to pesticides. Cross tabulations done to analyze data did not show any association ($p < 0.05$) between post exposure symptoms reported and a particular pesticide because workers sprayed a mixture of pesticides. However, cross tabulations showed an association ($p < 0.001$) between exposure to pesticides and post exposure symptoms.

Findings (Tables 4.1 and 4.2) also showed that the majority of workers who were exposed to pesticides were males (81.2%); fell under an active reproductive age bracket of 19-40 years (96.3%); were married (55%); had only primary level education (88.7%), had a monthly income of between Ksh 3,000 and Ksh 4,500, respectively, and had been exposed to pesticides for a period of between 2-5 years (86.2%). The majority of the unexposed workers were females (81.2%), also fell under a reproductive age bracket of 19 – 40 years (96.2%), were married (51.2%), had only primary level education (91.2%), and had worked for a period of between 2-5 years (90%).

CHAPTER FIVE

DISCUSSION

5.1. Assessment of Knowledge, Attitude and Practice on Pesticide Use by Farm Workers

5.1.1. Knowledge of workers on pesticide use

Results for objective number 1 (Table 4.3) showed a very high significant difference ($p < 0.001$) between factors associated with knowledge on pesticide risks and safe handling practices of exposed workers. Safety labels warn of the potential negative effects of pesticides on health and advice users to protect themselves. It is, therefore, important and a safety requirement for workers to read, understand and follow these instructions before mixing and spraying pesticides (Oluyede and Akinnifesi, 2007; Ware, 1978). In this study, 68.7% did not read the instructions on the pesticide label because they lacked the ability to interpret and understand. This could be attributed to their low level of education since about 90% exposed workers had only primary level education. About 44% exposed workers had not received education or training on pesticide use, an indication that the level of knowledge on pesticide use of many exposed workers was low. These findings are in agreement with those of Olurominiyi (2006), Kimani (1997) and Hayes *et al.* (1991) who reported that most workers had little knowledge relating to hazards, safety rules and proper personal preventive practices. There is, therefore, a need to train and educate all workers who handle pesticides on agricultural farms in Kenya.

Increase in knowledge and understanding of pesticide risks would increase the worker's sense of control and willingness to practice safety behaviour which would reduce exposure (Lankerster, 2002; Quandt *et al.,* 2006). Njer (1994) reported that a training of 280,000 Kenyans resulted in an increased understanding of the toxicity of pesticides. Lack of knowledge by 5% workers on whether pesticides would poison them if they didn't use protective clothing; protective clothing should be used all the time (2.5%); and that it was the responsibility of both the employer and worker concerning safety (2.5%), can be attributed to lack of or inadequate provision of information through education and training. Similar observations were reported by Olurominiyi (2006) that low level of knowledge on pesticides and their safe use was due to lack of participation by workers in education and training programmes.

If good education must always increase knowledge and lead to understanding and recognition of danger, then need for appropriate care becomes an obvious matter. Although 95% of the wokers knew that they needed to protect themselves when using pesticides because they would be poisoned, their practice did not demonstrate this level of knowledge. It was observed that 35% mixed and 25% sprayed without using any protective clothing and even those who protected themselves were somehow exposed because they did not use full protective clothing. It is important to know symptoms of pesticide poisoning so as to seek medication (Kimani, 1997). 88.7% workers who knew were significantly more than the 11.3% who did not know but this was not of any benefit because only 5.2% sought medication as is required. Workers in this study stand a risk of chronic health effects due to continuous exposure to toxic pesticides (Quandt *et al.*, 2006). It is important for workers to benefit from the knowledge received by adapting it but adoption seems to be slow (Olurominiyi, 2006). These findings are in agreement with Njer (1994) who reported that less than 30% of trained workers were adapting safe guidelines as per their training.

5.1.2. Attitude of workers towards pesticides and protection

Generally, workers had a negative/poor attitude towards protecting themselves. Observations in Table 4.3 and Figure 4.1 indicated that 37.5% did not use personal protective equipment such as the mask because they were uncomfortable to wear due to difficulties in breathing, and overalls due to high temperatures. These findings are similar to those of Hanshi (2003) and Kimani (1997) who reported that workers did not use protective clothing because of discomfort and due to high temperatures. Over 62% workers saw it not necessary to use protective clothing while mixing and spraying pesticides because they believed they were careful enough not to be contaminated. Most likely, they may have believed that pesticides were not harmful to their health. Such beliefs which were also reported by Quandt *et al.* (2006) and Ngowi *et al.* (2007) greatly influenced the practice of workers in this study, which promoted exposure.

Although all the workers (100%) exposed responded that they had a positive attitude towards the harmfulness of pesticides to their health, this was not reflected in their practice since observations revealed that none used full protective clothing. A worker's attitude towards safety measures affects how long and how well he/she is to live. Attitude also plays a role in risk assessment, as it is applied to issues such as whether and to what extent a person will be exposed to danger (Zimolong and Trimpop, 1998). There is need to change beliefs of farm workers in this study area to increase the value of safe behavior such as use of personal protective equipment. This can be achieved through enhancing training and health education programs.

5.1.3. Practice of the workers

5.1.3.1. Use of personal protective equipment (PPE)

Results of this study (Figures 4.2 and 4.3) reflected a high level of unsafe use of pesticides as regressions done showed very high significant differences ($p < 0.001$) between personal protective equipment used by farm workers. It was observed that none of the workers used the complete set of protective equipment when spraying and mixing pesticides as is required; 25.2% did not protect themselves at all when spraying and 34.8% when mixing pesticides. This was because they could not afford to buy protective clothing (34.6% mixing and 62.3% spraying) due to their small monthly income of between Ksh 1,500 and Ksh 6,500 (Tables 4.1 and 4.2). This is in agreement with the study of Hanshi (2003) who reported that 83% farm workers did not use protective clothing because of lack of purchasing power and 40% because of discomfort.

Although some workers improvised by using a cloth as a mask, this could only be effective when combined with other protective gears to offer full protection. Use of no or incomplete protective clothing exposed workers to pesticides through the skin and by inhalation (Ohayo *et al.,* 2000; Ngowi *et al.*, 2007)), and could be attributed to the very high significant ($p < 0.001$) post exposure symptoms experienced by exposed workers (Fig. 4.5). Exposure can often be prevented or minimized by wearing full protective clothing. Arbuckle *et al.* (2002) reported that use of full protective clothing by applicators reduced exposure in his study. Assessment made from observations during spraying operations showed that protective clothing used was made of cotton fabric, which was soaked with pesticides from leaking spray pumps (30%) during spraying. This brought the pesticide closer to the skin, leading to dermal exposure.

However, this situation could have been worse had workers in this study not used any protective clothing at all since the majority of pesticides mixed and sprayed were WHO Class II and Class III. Whereas it is a safety requirement (Appendix 4) that full protective clothing be used when handling all pesticides ranging from WHO Class I – Class IV, this was not practiced in this study.

5.1.3.2. Hygienic practice of farm workers

Hygienic practice of workers in this study as shown in Table 4.4 was very poor. There were very high significant differences ($p < 0.001$) between factors associated with hygienic practice. It was observed that only 3.8% washed the spray pump with soap and protection, 11.3% washed hands with soap, 7.5% changed clothes, 5% washed clothes and none bathed immediately after spraying pesticides as is recommended. Worker practices have been suggested as ways to reduce pesticide exposure and are included as recommended practices in the U.S. Environmental Protection Agency Worker Protection Standard training (Appendix 4). A pesticide applicator is, therefore, required to adopt them inorder to prevent or minimize exposure. Cleaning the spray pump after using several times (16.3%) or cleaning without soap as the majority (63.6%) of the workers did promoted dermal exposure. Washing of hands without soap and or after work (88.7%) exposed the worker to pesticides the whole day. These findings are similar to those of Quandt *et al.* (2006) who reported that levels of pesticides on the hands of a worker could be reduced to 96% by hand washing.

Continuing to work in the same clothing used during spraying without changing (92.5%); washing them in the evening or the following day (53.7%); and after using several times (41.3%) exposed the workers to pesticides the whole day or for days. Bathing immediately after spraying pesticides as is recommended was uncommon. Bathing in the evening or following day exposed workers to pesticides. These findings are similar to those of Quandt *et al.* (2006), Ohayo *et al.* (2000) and Hanshi (2003) who reported that poor hygienic practice of workers had contributed to exposure on farms and thus, to the high prevalence of post-exposure symptoms. Due to the fact that the parts of the skin not protected (including hands) were contaminated with large amounts or traces of pesticides, dermal exposure of the workers in this study continued the whole day by even scratching other body parts. Poor practice of workers contributed to exposure which was reflected in the high prevalence of post-exposure symptoms (Fig. 4.5) reported by the exposed workers.

All unexposed workers did not wash hands, change and wash clothing, and bathe immediately after working just like most exposed workers. Since the unexposed had not handled pesticides they stood no risk of poisoning from pesticides like the exposed workers.

5.2. Identified Pesticides Used on Farms in Mavoko Division

Results for objective number 2 (Table 4.5 and Fig. 4.4) indicated that workers mostly sprayed toxic (WHO Class II) pesticides (56% interviewed; 69% observed). One pesticide (1%) was highly toxic (WHO Class I), 19% interviewed and 7% observed were moderately/less toxic (WHO Class III) and 24% interviewed and 24% observed were least toxic (WHO Class IV). These results are in agreement with results of a survey done by Ohayo *et al.* (1999) which showed that workers on farms mostly sprayed toxic Class II pesticides. WHO Class II pesticides fall under a toxic class that has small lethal oral, dermal and inhalation doses (Tables 2.1 and Appendix 2). Small quantities of exposure by inhalation, ingestion, or contact with the skin and eyes can cause severe acute effects such as skin and eye irritation. WHO Class III and Class IV pesticides have larger lethal doses but also cause the same acute effects though mild. Apart from skin and eye irritations, all categories of pesticides are known to cause acute effects such as headaches, blurred vision, nausea and confusion (Eyer, 2003) which were experienced by workers in this study. Cross tabulations that analyzed data showed there was a relationship ($p < 0.001$) between exposure to pesticides and post exposure symptoms, indicating that symptoms were caused by the pesticides applied. Results which showed that only 2.5% of the unexposed workers experienced a headache after working whereas all exposed workers experienced symptoms (Fig. 4.5) of pesticide poisoning also confirms that symptoms were caused by the toxic pesticides used. Full protection was, therefore, required when handling them to prevent or minimize exposure. Although quantities mixed and sprayed per week for all pesticides were within recommended rates, post-exposure symptoms such as headache, skin and eye irritation reported by respondents (Fig. 4.5) was an indication of acute effects of pesticide poisoning (Restrepo, 1990; Eyer, 2003).

Safety measures should be taken inorder to reduce poisoning as is recommended since a portion of pesticides to which an individual is exposed is absorbed as the pesticide dose and can be lethal to the worker (Quandt *et al. 2006*).

5.3. Investigated Post-Exposure Symptoms of Pesticides Used on Farms in Mavoko Division

Results for objective number 3 indicating that only 2.5% unexposed workers experienced a headache could have been caused by unbearable high temperatures in Mavoko Division. These findings are in agreement with those of Ohayo *et al.* (2000) who reported that post-exposure symptoms experienced by un-exposed workers on farms in Nyanza Province were caused by high temperatures. Although nine (9) different symptoms (Fig. 4.5) were experienced by exposed farm workers, those mostly experienced were; flu/cold (28.5%), headache (36.3%) and nausea (20.9%), which are known acute effects of pesticides (Eyer, 2003; Ngowi *et al.*, 2007). This could be due to the fact that the majority of the pesticides the workers sprayed were toxic WHO Class II, (55% interviewed and 68% observed) whose small lethal doses cause such acute effects (Table 2.1 and Appendix 2).

Symptoms could be attributed to pesticide exposure since analysis by cross tabulations indicated that there was a relationship between post exposure symptoms and pesticide exposure. Furthermore, 40.1% workers experienced them during pesticide application and 59.9% during both application and for about 2 days after application. As per the hypothesis it can be deduced that post exposure symptoms experienced by farm workers was as a result of exposure to the toxic pesticides used.

Spraying toxic pesticides without wearing full protective clothing exposed the workers through the mouth, skin, and by inhalation. Exposure can often be prevented or minimized by wearing full protective clothing and by adhering to safe hygienic practices (Quandt *et al.*, 2006), which was not followed by workers in this study.

These results are in agreement with Ohayo *et al.* (2000) and Ngowi *et al.* (2007) who reported that farm workers in Nyanza province and Tanzania, respectively, experienced same post- exposure symptoms after spraying WHO Class I and Class II pesticides without fully protecting themselves and adopting good hygienic practice. Although quantities of pesticides mixed and sprayed were within recommended rates, protection was required. Post-exposure symptoms such as headache, skin and eye irritation reported by respondents was an indication of poisoning from the pesticides.

Out of 80 workers who were exposed to pesticides, the majority: were males (81.2%); fell under an active reproductive age bracket of 19-40 years (96.3%); were married (55%) and had been employed (and thus, receiving poisoning) for a period of between 2-5 years (86.2%). These results are in agreement with Zimolong and Trimpop (1998) who reported that the young and poorly educated males take the highest risks at work places and that men take high risks compared to women.

Continuous exposure for months and years as a result of frequent number of spray operations will expose the workers to lethal doses whose health effects (long term) would manifest in the future (Oluyede and Akinnifesi, 2007). In addition, being in an active reproductive age bracket, teratogenicity and reproductive toxicity could manifest in the families of the exposed workers in the near future (Kolb, 1993). This is in agreement with Redigor *et al.* (2004) who reported unquantified increased risk of foetal death from congenital anomalies in families of married workers who sprayed pesticides on agricultural farms. Due to the fact that workers mixed and sprayed a combination of two or more classes of pesticides, poisoning could not be associated to a particular class of pesticides.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Results of this study indicated that the level of knowledge on pesticide use of workers on agricultural farms in Mavoko Division was low/poor. About 43.7% had not been trained or educated and thus not received information relating to risks and safe use of pesticides. Inability to understand and interpret label instructions on pesticides by 68.7% exposed workers could, therefore, be attributed to their low level of education since results revealed that about 90% had only primary level education. Generally, workers had a negative attitude towards toxicity of pesticides and use of protective clothing. About 38% did not use protective clothing when handling pesticides because they were uncomfortable to wear and 62.% workers saw it not necessary to protect themselves because they believed they were careful enough not to be contaminated. Such beliefs greatly influenced practice which promoted exposure.

Although 100% exposed workers claimed to have a positive attitude towards the harmful effects of pesticides, this was not demonstrated in their practice while spraying. None of the workers used full protective clothing as recommended while 25.2% did not use protective clothing when spraying and 34.8% when mixing. Poor hygienic practice such as washing spray pump after using severally (16%); washing without soap (73.6%); washing of hands without soap (17.5%) and after work (71.2%); not changing and washing clothes used during spraying (over 76%); and not bathing immediately after spraying (100%) exposed the workers to pesticides.

Although pesticides used by farm workers in Mavoko Division ranged from WHO Class I – Class IV, most (55% interviewed; 68% observed) were WHO Class II that are toxic. Quantities of pesticides used were within the recommended ranges. However, since all pesticides used are known to cause various health effects, workers needed to use full protective clothing in order to prevent or minimize exposure.

The main symptoms experienced by exposed workers after spraying pesticides were; flu/cold (28.5%), headache (36.3%) and nausea (20.9%) which are known acute effects of pesticides and could thus be attributed to exposure to the toxic pesticides used by the workers. Low knowledge, poor attitude and high level of unsafe use of toxic pesticides were major factors that influenced exposure.

6.2. Recommendations

1. There is an urgent need to raise awareness of alarming exposure to pesticides on agricultural farms through training and health education. This will increase knowledge, improve attitude and practice on pesticide use.

2. The pest control and products board (PCPB) should stop approving importation of WHO Class I and Class II pesticides. PCPB should also enforce the legislation with a clause indicating mandatory provision of protective equipment by the employers. This will ensure farm workers are not exposed to highly toxic pesticides.

3. Awareness be created among farm workers on how to identify post-exposure symptoms and the need to seek medication when poisoned.

6.3. Suggestions for Further Studies

1. Intensive research be done to establish how best knowledge, attitude and practice of the farm worker can be improved.

2. Research to be done in the homes of farm workers to investigate pesticide exposure to family members and to establish whether there are chronic and long term health effects within their families.

3. A study be done to measure amount of pesticides a farm worker is exposed to and assess other factors of exposure such as re-entry into sprayed fields to work or harvest and disposal of pesticide containers.

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