AN ABSTRACT OF THE THESIS OF

Gholam Reza Nemati for the degree of Master of Science in Environmental Health presented on October 6, 1989.

Title: Factors Affecting Farmworkers' Injuries Due to Use of Pesticides in the United States and Their Relation to Reentry Time Intervals

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Abstract approved: ______________________

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More than 2.3 billion pounds of pesticides with a value of $4.1 billions are applied by farmworkers to agricultural crops each year. These chemicals applied to farm lands lead not only to acute and chronic health effects, they also enter the groundwater and food chain of populations. In recent years increased attention has been focused on the impact of pesticides on human health and the environment, as well as those who are in direct contact with pesticides, including farmworkers and workers in the chemical industry.

Although many organizations, including the Environmental Protection Agency, the Occupational Safety and Health Administration, and the National Institute of Occupational Safety and Health, and others at the federal and state level, have attempted to control the safe use of pesticides, many cases of illness and injury due to pesticide poisoning are reported each year in the United States.

The purpose of this study was to review the literature concerning injuries to farmworkers due to the use of pesticides over the last 20 years

in the United States in order to determine which factors contribute to an increase or a decrease in the number and extent of these injuries. These factors are considered and conclusions are reached, based on the observations and the limitations of previously conducted studies of this issue.

Injury to farmworkers due to pesticides is a multidimensional problem, solution of which is handicapped by a lack of documentation and evidence. The real number of injuries can not known, although estimates have been made. Moreover, there are extensive limitations to the determination of the extent of these injuries and their chronic health effects. Although data from case control and case report studies of farmworkers' injuries by pesticide poisoning could be used in order to reduce the number of poisonings and acute health effects, the application of these data for chronic effects are quit different.

Most of the studies previously completed on the chronic health effects of pesticide poisoning are epidemiologic studies, utilizing data obtained from farm owners and growers, a population not as fully exposed to pesticide chemicals and their residues as farmworkers. Therefore, this data cannot be considered representative of farmworkers, or the seasonal and migrant workers who are in direct contact with these chemicals. In addition, data from these studies cannot be extrapolated to the general population, which is exposed to considerably lower levels of pesticides through the food chain and the environment. These factors make it difficult to accurately determine chronic health hazards resulting from pesticidal exposure, though it is certain that pesticide exposure constitutes a serious and acute health hazard for those in frequent and direct contact with the increased amount of pesticides in use in agriculture in the U.S.

Factors Affecting Farmworkers' Injuries Due to Use of Pesticides in the United States and Their Relation to Reentry Time Intervals

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed October 6, 1989

Commencement June 1990

APPROVED:

Redacted for privacy

Associate Professor of Public Health in charge of major

Redacted for privacy

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Date thesis is presented October 6, 1989

Typed by B. McMechan for Gholam Reza Nemati

Acknowledgements

I would like to thank my faculty advisor, Dr. Annette M. Rossignol, and the members of my committee, Drs. Ian J. Tinsley, Jeff McCubbin, and David C. Lawson, for their support, timely advice and instruction. To my family, my wife Mahnaz, my daughter Bahark, and my son Babak, my eternal gratitude for their patience and understanding. I would also like to express my appreciation to my parents for their concern with my life. To my best friend, Kazem, I would like to express my sincere appreciation of his calm and helpful advice at just the times they were needed.

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CHAPTER I

INTRODUCTION

Background

The benefits of pesticide applications in agriculture and food production are undeniable. Without the use of pesticides it is doubtful whether sufficient food supplies could be produced for the increasing world population. In the United States, the decades of the 1940s and 1950s were characterized by major discoveries in the use of chemicals that aided the development of a highly successful agricultural system which promoted national economic strength, while offering security from the fear of vector-transmitted diseases. Though the methods of application and formulation of pesticides were improved in the early 1960s, the latter years of this decade and the 1970s were characterized by increased concern for the environment, resulting in the development of massive regulatory programs. In recent years attention has been focused on the impact of pesticides on human health and the environment in general, and particularly upon those who are in direct contact with pesticides, including farmworkers and workers in the chemical industry.

Pesticides or agrochemicals are chemicals designed to combat the attacks of various pests on agricultural and horticultural crops. The earliest record of the use of any material as a pesticide was recorded in the works of Homer, the Greek poet, who in about 1000 B.C. referred to the burning of sulfur for the fumigation of homes. However, it was not until the mid-nineteenth century that pests were controlled to any degree of success with chemicals. Between 1800 and 1825, pyrethrum, lime, sulfur and soaps were the materials used most effectively. Beginning in 1850, Quassia, Phosphorus Paste, and Rotenone were employed, and somewhat later Arsenical Paris Green and Kerosene emulsions were used as dormant sprays for deciduous fruit trees (1867-1868). Thus, the scientific use of pesticides had been initiated.

Pesticides fall into three major classes: insecticides, fungicides, and herbicides or weed killers, with such subcategories as rodenticides (for control of vertebrate pests), nematocides (to kill microscopic eelworms), molluscicides (to kill slugs and snails), and acaricides (to kill mites). Most common pesticides can be classified into two main chemical groups: inorganic and organic compounds. Inorganic compounds are derived from naturally occurring elements and do not contain carbon. Many of them are persistent, and several, including Arsenic, Mercury and Thallium, are cumulative poisons. Because of their toxicity to plants and animals, most inorganic pesticides have been replaced by organic compounds, which account for less than 10 percent of the insecticides presently in use. However, the copper compounds are still widely used as fungicides. Organic compounds are compounds of carbon and can be separated further according to their source. Naturally occurring organic insecticides are produced by plants and synthetic organics are manufactured compounds.

With respect to the chemistry of pesticides, those elements used most frequently in pesticides include carbon, hydrogen, oxygen, nitrogen, phosphorus, chlorine, and sulfur. The chemical formula of a pesticide is the printed description of one molecule of a chemical compound. The common name for the compound is officially selected by the appropriate professional scientific society and approved by the American National Standards Institute (formerly called United States of America Standards Institute) and the International Organization for Standardization. The common names for insecticides are selected by the Entomological Society of America, herbicidal names are selected by the Weed Science Society of America, and fungicidal names by the American Plytopthological Society. The trade name or brand name of a pesticide is given by the manufacturer or by the formulator. It is not uncommon to find several brand or trademark names given to a particular pesticide presented by the manufacturer in a variety of formulations. Common names are assigned to avoid the confusion resulting from the use of several trade names.

Statement Of The Pesticide Problem

About 2.3 billion pounds of pesticides, worth $4.1 billion, one-third of the entire world market, are sold to U.S. farmers each year. Until the early 1960s, most authorities had assumed that procedures for safeguarding the general public against ingesting pesticides also protected fieldhands, sprayers, and other laborers. However, epidemiologic studies of the Hughson, California (1963) incident have shown that the legal tolerance levels set to protect consumers do not provide workers protection from exposure to foliage, soil, or other sources of possible harm. Christen R. Bashor, an EPA workplace safety lawyer in Washington D.C,. believes that consumers face far less exposure than farmworkers, but that farmworkers do not command public attention (Rosemary, 1989). Exposure to pesticides is a worldwide problem. The issue is therefore international and should be faced on that level.

According to Task Group on Occupational Exposure to Pesticides, in a 1974 report to the Federal Working Group on Pest Management, in the United States there are 100,000 non-fatal exposures to pesticides each year. But the World Resource Institute (WRI) (Wasserstrom & Wiles, 1985), a Washington D.C. research group, recently released a study announcing that each year 300,000 U.S. farm worker are poisoned or injured on the job. Moreover, four to five million farmers and field hands are "protected in-adequately" from pesticide hazards because of poorly written and unforced pesticide regulations.

Once DDT (dichloro-diphynl trichloroethane) had proven to be an effective means of control for insect pests affecting several agricultural crops, organic insecticides became the major protective control method. The application of DDT stimulated intensive research to synthesize other organic pesticides for the control of food and forage crop pests. Subsequently, research was directed toward the evaluation of other organic pesticides in our food supply and their effects on man and animals. The knowledge subsequently drawn from these studies made it possible to effectively apply pesticides in ways that were not harmful to consumers. However, in recent years it become apparent that there is insufficient information concerning the hazards to workers involved in the production of pesticides and workers in the agricultural environment. For this reason, it is important to have establish a basis for the safe use of pesticides. When and as accomplished this step will be of obvious benefit to manufacturers who have spent millions of dollars developing their products and markets in the expectation of stable income and profits. Farmers may benefit in the form of income derived from the correct application of these products, just as the general public level of health will derive direct benefits from the safe application of agricultural pesticides, as well as from the psychological and economic benefits of increased consumer confidence in the safe character of agricultural products.

The assessment of potential health hazards to workers resulting from the use of pesticides requires knowledge of both the pesticide amounts to which farmworkers are exposed and their toxicity. In addition to the more immediate effects of acute pesticidal toxicity, such as life threatening crises, overdoses, suicides, or the results of premature entry into treated fields following application, the present concerns of those involved with occupational pesticides has been turned from immediate acute effects to chronic effects. In recent years this concern has been restricted to situations where work practices involve substantial and prolonged contacts with foliage which has been treated with pesticidal chemical sprays. One problem with determining the chronic health effect of exposure to pesticidal chemicals is to identify what data can be used. Animal studies have demonstrated that pesticides can be related to oncogenic, teratogenic, mutagenic, and delayed neurotoxic effects from the viewpoint of recent exposures, but what of the substances which display none of these properties? There are substantial obstacles to the assessment of the effects of long-term exposure to low levels of pesticides. Occupational exposure may be qualitatively assessed, but the variation in individual susceptibility and interaction with other factors that affect health must be considered (Wasserstrom & Wiles, 1985). The long-term effects of exposure to pesticides can only be studied in an epidemiologic framework, and the interpretation of these studies is at best difficult. The reason is that chronic exposure may occur in large populations as a result of dietary intake or environmental contamination over a long period of time. However, it is important to monitor the levels of the effect of environmental pollution on humans as well as the food supply, obtaining baseline data that will indicate qualitative and quantitative fluctuations in the concentration of these pollutants.

In the case of the regulation of pesticide use in the United States, the first major problem arose in 1925 when authorities in England rejected shipments of American fruit that bore arsenic residues in excess of British standards (Dunlap, 1981). In response, exporters washed the fruit and hired certified chemists to analyze each shipment prior to export. Thus British consumers received cleaner products than Americans and the case for setting domestic tolerance levels had been opened. In a study in 1969, Kahn (1976) compared farmworkers with men and women of similar backgrounds working in non-agriculture employment, discovering that farmworkers claimed to have experienced pesticidal symptoms 15 times more often than the controls.

Following four major poisoning incidents in 1970, California authorities established reentry standards for certain crops and chemicals, requiring physicians to report all cases of pesticidal intoxication to the State Health Department. In addition, the state's farmers were required to delay for specified intervals before returning their workers to fields that had recently been sprayed. Six month later these regulations were expanded to include "reentry" for a wider variety of crops and chemicals. In 1974, the federal government adopted similar standards (Pimentel, Andow, & Dyson- 1975).

Protecting agricultural field hands has an obvious value, and the regulation of pesticidal applicator training could further reduce the number of incidents. On the other hand, a General Accounting Office audit claimed that 2,855 violations of existing regulations took place between 1975-1980 in 11 surveyed states (Wasserstrom & Wiles, 1985). Two studies were carried out in 1977 by the Educational Testing Service (ETS) to evaluate whether or not certified applicator training programs improved pesticide management. According to Sluden (1981), farmers reported a greater awareness of personal danger after completing the training program and in some cases took steps to protect themselves. According to the ETS: "Training appears to be successful in teaching the participants to refer to labels for information on pesticide use, to mix and load in a place chosen to reduce the chance of an accident, and to dispose of containers properly" (Wasserstrom & Wiles, 1985).

Since 1973, when improved surveillance methods were put into effect, the number of poisoning incidents among field hands has risen each year by 13.9 percent (Wasserstrom & Wiles, 1985). In California, according to Moly Coye of the National Institute of Occupational Health and Safety in San Francisco, fieldhands currently suffer the highest rates of occupationally related illness in the state: seven cases per 1000 for full-time workers, which is twice the general average. Over 40 percent of these incidents were involved with only five compounds: Parathion, Diazinon, Phosdrin/Mevinphos, Methomyl, and Omite Propargite.

In general, American large-scale agricultural and food production is heavily dependent on the application of synthetic pesticides. According to Wasserstrom and Wiles (1985), as a regulatory organization the Environmental Protection Agency has not been able to provide effective administrative implementation of the legal codes governing the appropriate use of pesticides, and significant problems of occupational exposure remain unsolved. As stated by one EPA economist, "while pesticide producers, users, and consumers benefit from the use of pesticides, costs are distributed disproportionately throughout the population in terms of acute and chronic toxic effects such as cancer" (Wasserstrom & Wiles, 1985).

Since the determination of the health effects of farmworker exposure to pesticides is a complex and difficult problem, the data concerning the use of these chemicals should be examined in greater detail in order to determine whether reentry intervals have in fact prevented incidents of farmworker poisoning, or whether variation in the number of episodes is due to changing patterns of pesticide use. Any number of factors, including temperature, moisture levels, quantities of rainfall, variations in available sunlight, atmospheric conditions, methods of application (i.e., powder or emulsifiable formulation), pesticidal concentration, the region of application, the health status of involved persons and even personal diet, can affect the establishment of appropriate reentry intervals. On the other hand, since the dangers of pesticides have been established, growers and farmworkers must adhere to well defined reentry intervals and similar restrictions. Even when it is assumed or established that reentry intervals significantly decrease the poisoning rate, empirical evidence should be sought to ascertain that the time periods are of effective length.

Study Proposal

This study proposes to evaluate the literature concerning farmworkers' injuries and illnesses related to pesticidal chemical exposure during agricultural harvests or other agricultural field activities and their relation to reentry time intervals. Agricultural field activities include crop harvests and thinning, as well as the mixing, loading, and application of pesticides. Exposure to pesticidal chemicals can occur when workers fail to wear protective gloves and clothing or when they fail to delay field entry for a specific period of time set for a specific pesticidal applications. Accidents can result from poor chemical splitting in the field and farmworkers' behavior in treated areas, which may be related to the lack of effective regulatory legislation or law enforcement. The principal purpose of this study will be the assessment of the factors associated with farmworkers' exposure to pesticides and the identification of significant health effects caused by this exposure. The factors contributing to episodes of pesticidal injury will be summarized and interpreted in terms of recent research results which have implicated pesticidal chemical residues as a source of farmworker poisonings and injuries.

Definition of Pesticides

A pest may be described "as a troublesome or destructive animal or thing" and the suffix "cide" indicates the ability to inflict mortality upon animals or other natural objects (Ware, 1983). Thus, a pesticide is a product that kills animals, plants, or micro-organisms that are otherwise regarded as troublesome or destructive. This is in agreement with the definition established by the World Health Organization (1972):

> A pesticide is any substance or mixture of substances intended for preventing or controlling any unwanted species of plants and animals and also includes any substances or mixture of substances intended for use as a plant-growth regulator, defoliant or desiccant. The term pesticide includes any substance used for the control of pests during the production, storage, transport, marketing or processing of food for man or animals or which may be administered to animals for the control of insects or arachnids in or on their bodies. It does not apply to antibiotics or other chemicals administered to animals for other purposes, such as to stimulate their growth or to modify their reproductive behavior; nor does it apply to fertilizers

Definition Of Terms

CDB: Chlorinated dibenzodioxins.

CDF: Chlorinated dibenzofurans.

IARC: International Agency for Research on Cancer.

UNICC: International Union Against Cancer.

TMRC: Theoretical maximal residue concentration.

Homeostasis: A state of dynamic equilibrium.

Xenophobic: Chemicals which enter living cells and are foreign to the system.

Tolerance: The legal maximum residue concentration of a pesticide chemical allowed in a specific food or food items.

ETS: Educational Testing Service.

CEQ: Council on Environmental Quality.

PNP: Para-nitrophenol chemical metabolite of organophosphatepesticide parathion excreted in urine.

Oxon: Toxic oxygen analogues of parent pesticide chemicals are referred to as oxons.

Dislodgeable Residue: Refers to the toxicant-containing dust on the surface of plant parts.

Minimal Risk: A finite level of pesticide residue as dislodgeables or vapors to which reentering farm workers might be exposed can be considered as a "minimal risk" if the level poses no unreasonable adverse effects upon their health and well-being.

OSHA: Occupational Safety and Health Administration.

DOL: U.S. Department of Labor.

ETBAR: Estimated total body accumulation rate; the rate of accumulation of a pesticide on the body of an applicator, unprotected by clothing of any kind, measured in micrograms per hour.

Cleft Palate: A congenital fissure in the roof of the mouth forming a communicating passageway between the mouth and nasal cavities.

ECG (Electrocardiogram): A record of the electrical activity of the heart which gives important information about its condition. This examination is of value in the diagnosis of cases of abnormal cardiac rhythm and myocardial damage.

EMG (Electromyogram): A graphic record of the contraction of muscle tissue as a result of electrical stimulation.

Spina Bifida: A congenital defect in the walls of the spinal canal caused by a lack of union between the laminae of the vertebrae. As a result of this deficiency, the membranes of the spinal cord are pushed through the opening, forming a tumor known as spina bifida.

CHAPTER II

LITERATURE REVIEW

Pesticides are considered indispensable in our society, contributing to human welfare, industrial and agricultural development, and the worldwide economy. The use of pesticides is directed toward increasing food production, pest control, and control of disease transmission by insects and other parasites, but at the same time their use has been shown to result in population and environmental pollution. Of the one billion pounds of pesticides used annually in agriculture in the United States, 800 million pounds are applied to the approximately 20 percent of the total crop acreage farmed largely with the use of seasonal field labor (Pimentel, 1980). More than 50 percent of the seasonal workers are hired for harvesting operations, which involves contact with foliage during or shortly after pesticide application periods. Of the 27 percent who work in the cultivation of crops, more than one-third work in cotton, a crop requiring a very high rate of pesticide application (Task Group on Occupational Exposure to Pesticide, 1974).

Pesticides have strong links with land utilization both through their effects on the production of food and other commodities. Through their application in public health, pesticides provide security for the control of vector born diseases and the pursuit of enjoyable human activities. The Food and Agricultural Organization (FAO) has estimated that food supplies must expand 4 percent per year in order to keep pace with population growth and to compensate for existing deficiencies. Whereas the modernization of agriculture by the introduction of improved crop varieties, the extension of irrigation, and the wider application of fertilizers and pesticides offer significant hope for increased agricultural productivity, the doubling of the world food production would require a more than three-fold increment in the annual use of fertilizers and far more extensive use of pesticides (World Health Organization, 1979).

Physiological Health Effects of Pesticides

Classification of Pesticides

There are four major categories of pesticides: (1) heavy metal containing substances, (2) chlorinated hydrocarbons, (3) carbamates, and (4) organophosphates. The organophosphate group is perhaps the most important in relation to its effect upon farmworkers and its ability to depress cholinesterase enzyme activity. Of this group, Parathion is the most widely used and Aldicarb is the most toxic pesticidal chemical, with a very low median lethal dose (LD50) in modern agriculture. The measurement of cholinesterase activity is the most useful tool which can be applied in order to understand the nature of farmworker exposure to pesticides.

Toxicity of Pesticides

Toxicology is the division of medical and biological science concerned with the identification and detection of toxic substances, including the study of their chemistry and pharmacological action and the establishment of antidotes and the treatment of toxic manifestations, the prevention of poisoning, and methods for controlling exposure to harmful substances. Generally, toxicology is the study of the injurious effects of chemicals upon living organisms. Toxicity, on the other hand, is the extent, quality, or degree of being poisonous. The toxicity of pesticides is determined by their LD50 and a dose-response relationship. It can be demonstrated by a dose-response curve.

The measurement used as an indicator of toxicity is the median lethal dose or LD50, the dose necessary to kill 50 percent of a given population within a given parameter of exposure. The lethal dose may be introduced through the mouth (oral LD50), through the skin (dermal LD50) or through the respiratory system (inhalation LD50). When an indicator of the toxic effects of a pesticide on humans is needed, the oral LD50 is normally used; the lower the LD50, the more dangerous the pesticide.

The general use of both pre-emergent and post-emergent pesticides and herbicides is now routine in grain farming and other crops throughout the United States and Canada. Every year millions of pounds of these chemicals are used in agriculture. Weed control with herbicides, on the other hand, has been stimulated by the urgent need for food production as well as the drastic shortage of farm labor. The economic importance of weed control is apparent when it is estimated that weeds yearly rob farmers in the United States of $3 billion, according to Helderbrand (1964). Despite the millions of pounds of pesticides and herbicides that are used annually, little has been written about their toxicology. Much of the toxicological data assaying the risk involved in their practical use originates from confidential, unpublished reports for use of the authorities concerned (Poulsen, 1968). Instructions for the safe use of pesticides are stressed on manufacturers' labeling, as well by various farm agencies. This has reduced the incidence of severe poisoning and allergic reactions. Yet, every year in rural medical practices, cases of contact dermatitis due to herbicides and pesticides are recorded. These have usually occurred in connection with farmers who have been negligent in carrying out a protective program, in general not because of unawareness of the dangers of these chemicals, but because of the need to get crops planted as quickly as possible to avoid delays due to changes in weather.

A large number of deaths attributable to pesticides is due to accidental or intentional (i.e., suicidal) exposures to chemicals used in the control of weeds, insects, and plant diseases in agricultural production. The last agricultural fatality due to pesticide use in the field was reported in 1972, occurring as a result of exposure to Parathion, Propargite, and potassium nitrite. Other deaths due to fumigation of buildings with cyanide and due to handling and storage of ethylene dibromide have been reported since that time (California, Department of Food and Agriculture, 1983).

The main group of pesticides used in agricultural activities are chlorinated hydrocarbon, organophosphate, or carbamate substances, or such herbicides such 2,4-D and 2,4,5-T. The three major categories of chlorinated hydrocarbon insecticides include DDT and its analogs, Bezen hexachloride isomers, and Cyclodiene compounds. DDT is one of the oldest and most effective synthetic pesticides. Its action affects the nervous system. Acute poisoning cause tremors, paralysis and eventual death, usually attributed to respiratory arrest. In man, acute poisoning at a dose level of 10 mg/kg or higher may be expected to produce illness, although higher doses (285 mg/kg) have been reported which can cause muscle weakness, numbness, and eventually, convulsions (Hayes, 1982). Toxicity through dermal exposure is less important than ingestion because dermal absorption is poor. Therefore, DDT has been used for treatment of human body lice and scabies (Simmons, 1959). DDT was commercially produced in substantial quantities and was in use until the 1960s, when three factors contributed to its decline: pest resistance to its chemical effect, increasing concern that humans were being exposed through foods and the environment causing DDT to accumulate in human adipose tissue, and finally developing concerns about the effect of DDT upon the ecosystem. These factors contributed to restrictions of the use of DDT and other chlorinated hydrocarbons as well.

The gamma-isomer of hexachlorocyclohexan, often referred to as Lindane is the most important representative of the benzen hexachloride isomers. Lindane poisonings are similar to those of DDT, except for tremors and the more severe manifestations of central nervous system toxicity which occur in Lindane poisoning (Cameron, 1945). However, beta and delta isomers can also produce depression (McNamara & Crop, 1947). The chlorinated cyclodine insecticides are among the most toxic and environmentally persistent pesticides. Like DDT, this group is capable of hepatic microsomal enzyme induction and liver toxicity. The evidence for carcinogenicity is equivocal.

In the case of organophosphate pesticides, the two most important aspects of toxicity are cholinesterase inhibition and delayed neurotoxicity. Although the principal mechanism of carbamate pesticide toxicity is the inhibition of cholinesterase activity, the inhibition produced by the carbamates involves carbamylation of the esteratic site of the acetylcholine enzyme rather than phosphorylation. The resulting accumulation of acetylcholine at the nerve synapses and myoneural junctions produces signs and toxicity similar to that produced by organophosphate agents. However, cholinesterase inhibition produced by carbamates is more labile and symptoms are typically shorter in duration (Hayes, 1982)

In the case of herbicides, 2,4-D is the most widely used and is moderately toxic to most animals. In man, toxic signs include profuse sweating, a burning sensation in the mouth, chest, and abdomen, and sore, stiff muscles; 2,4-D is not considered to be mutagenic or carcinogenic (Anderson, Leighty, & Takahashi, 1972; Hansen, Quaipe, & Habermann, 1971; Innes, Ulland, & Valerio, 1969). The other herbicide noted above, 2,4,5-trichlorophenoxy acetic acid (2,4,5-T), has an action mechanism very similar to that of 2,4-D. Much more attention has been focused on the health effect of 2,4,5-T since the 1960s. It is believed to be teratogenic, but its teratogenic effects have been criticized by several investigators (Poland, Smith, Metter, & Possik, 1971). It is a restricted use pesticide in the United States.

Physiology of Cholinesterase Activity

Organophosphate pesticides inhibit the enzyme acetylcholinesterase which is responsible for the breakdown of the neurotransmitter acetylcholine at the nerve synapses. Three types of effects result from exposure to cholinesterase-inhibiting chemicals: (1) muscarinic, (2) nicotinic, and (3) central nervous system effects (Hayes 1982). Major effects are noted when cholinesterase is inactivated, and acetylcholine builds up at cholinergic nerve synapses, first causing excitation and then depression of the parasympathetic nervous system (Miller & Shah 1982). Cholinesterase activity levels at the cholinergic nerve synapses are the true and meaningful effects of exposure to cholinesterase-inhibiting chemicals; however, these levels cannot be measured easily. Monitoring organophosphate exposure is usually accomplished through an examination of the activity of cholinesterase present in the blood in erythrocytes and in the plasma. Of these two, the red blood cell cholinesterase is believed to be chemically identical to the cholinesterase found at the cholinergic nerve synapses. There are indications that ethyl organophosphates, such as ethyl parathion, may depress plasma cholinesterase activity more than red blood cell cholinesterase activity. Conversely, methyl parathion inhibits RBC cholinesterase activity more than plasma cholinesterase activity (Gage, 1967; U.S. Department of Health, Education and Welfare, 1976). Carbamate pesticides produce cholinesterase inhibition which is rapidly reversed, usually within 24 hours (Vandekar, Plestina, & Wilhelm, 1971). Therefore, the level of cholinesterase activity depression may become very difficult to quantify (Vandekar, 1980).

Red blood cell cholinesterase depression is more likely to be due to exposure to cholinesterase inhibitors, although leukemia, multiple myeloma, and the use of quinine and echothionphate may also cause RBC cholinesterase activity depression (Wills 1972; U.S. Department of HEW, 1976). Anemia influences the hematocrit, which in turn affects the measurement of cholinesterase values. RBC cholinesterase activity levels have been reported to decrease with age (Gage, 1967), suggesting the need for periodic baseline reevaluation. In contrast, plasma cholinesterase activity levels are more likely to be influenced by factors other than pesticide exposure, including a individual's general nutritional level, the existence of liver damage, the use of foods containing xanthine-related compounds such as coffee, chocolate, or tea, and the use of such drugs as morphine, codeine, thiamine, ether, or chloroquine (Wills, 1972).

Red blood cell cholinesterase is believed to be chemically identical to cholinesterase present at the nerve synapses (Kaloyanova, 1982). Red blood cell cholinesterase activity is therefore generally considered to be a better indicator of cholinesterase activity levels at the neural synapses than plasma cholinesterase activity levels (Vandekar, 1980; Wills, 1972). Thus, it provides a more accurate picture of the danger of impending illness than cholinesterase activity levels in plasma (Muller & Hundt, 1980; U.S. Department of HEW, 1976; World Health Organization, 1972). Butyrylchloinesterase, present in the plasma and liver, has also been called plasma cholinesterase or pseudocholinesterase (Department of HEW, 1976).

Following exposure to cholinesterase inhibiting compounds, plasma cholinesterase activity levels depress more rapidly than red blood cell cholinesterase activity levels. Therefore, some authorities consider plasma cholinesterase activity levels to be a more sensitive indicator of exposure to cholinesterase-inhibitors (Areekul, Srichairat, & Kirdudom, 1981; Namba, Jackrel, & Grob, 1971; U.S. Department of HEW, 1976; Wills, 1972). Burgess and Roberts (1980) have suggested that RBC cholinesterase values should be interpreted with caution since workers with chronic low-level exposure to cholinesterase-inhibiting pesticides have shown a 10 percent elevation of RBC cholinesterase activity levels above the observed controls values. Many researchers argue that both RBC and plasma cholinesterase activity values provide information necessary for effective cholinesterase monitoring (Gage, 1967; Hayes, Wise, & Weir, 980; Richter, Kaspi, Bordon, Levy, & Gruener, 1984; Wolfies 1957). It is argued that the two cholinesterase activity level values, in combination, can provide information on pesticide exposure that either alone could not provide.

In illness episodes, individual cholinesterase activity level baselines are not available unless the person's cholinesterase enzyme activity is monitored. Even then a baseline computed by a different laboratory or using a different measurement technique may not be applicable because of differences between techniques applies in the different laboratories. In cases where applicable individual baselines are available, the patient's cholinesterase activity level value must be compared against the laboratory norms. However, normal cholinesterase activity levels vary widely. For example, Midtling and Velasco (1985) reported an episode where 29 ill field workers, each of whom had experienced a single exposure, whose RBC and plasma cholinesterase activity values remained within normal laboratory limits. Due to the wide range of laboratory norms, and findings with respect to workers who become ill within these norms, effective monitoring requires pre-exposure baseline cholinesterase activity level values, which may then be used as benchmarks to assess the degree of cholinesterase depression (Vandekar, 1980; Wolfies, 1957). There are indications that certain clinically significant effects of organophosphate and carbamate pesticides may be present without cholinesterase activity depression. The effects of local exposure, including eye irritation, increased bronchial depression, and skin reddening, may exist without cholinesterase activity depression (U.S. Department of HEW, 1976).

Neuropathology, including neurotoxicity, paralysis, and disturbances in the electroencephalogram (EEG) and electromyography (EMG) tests, have been reported in cases where no cholinesterase activity depression was observed, leading researchers to speculate that these disorders may be due to effects on body chemistry other than effects on cholinesterase enzyme

(Jager, Roberts, & Wilson, 1970; Metcalf & Holmes, 1969; Richter et al., 1984). Delayed neurotoxic effects are due to inhibition of "neurotoxic esterase," accompanied by axonal degeneration and demyelination of the peripheral nerves (Alderge & Johnson 1971; Kaloyanova, 1982).

Cholinesterase Activity in Populations

Cholinesterase activity measurements offer the advantage of testing the ultimate physiological consequence of exposure, revealing a number of physiological and kinetic variables as well as effects from pesticide chemical absorption. Although measurement of cholinesterase enzyme is a good indicator for the measurement of exposure to organophosphate pesticides, its activity varies considerably.

Intra-Individual Variation

There is less variation between serially drawn samples from the same person than between samples taken from different persons. Normal workers who are not exposed to cholinesterase inhibitors may unpredictably show fluctuations varying as much as 13 to 25 percent for serum activity from one sample to the next (Hayes, 1982). Intra-individual variation over a period of time is not related to mean value, and there is no correlation between erythrocyte and serum enzyme activities in the absence of cholinesterase inhibition. Moreover, the laboratory which tests the samples may be responsible for a significant proportion of the measured intra-individual variation in the cholinesterase activity.

Inter-Individual Variation

Because of the wide range of activity levels among normal subjects, obtaining a pre-exposure baseline is important to the accurate surveillance of potentially exposed workers. With baseline values, the decline in cholinesterase activity needed for the diagnosis of inhibition is more dependable. For example, with a baseline or pre-exposure value of 10, a 15 percent decline in plasma and 11 percent decline in erythrocytes activity is significant. However, many applicators and most field workers do not have predetermined baseline cholinesterase measurements. In the absence of a baseline, the interpretation of the reported cholinesterase activity is difficult. According to Hayes (1982), plasma cholinesterase levels 30 percent or more below the laboratory normal range are required for a diagnosis of cholinesterase inhibition. However, the upper normal limit for a laboratory may be as much as 225 percent of the lower limit value, and workers suffering substantial declines from their individual baseline may still have cholinesterase levels well within the laboratory normal range. Moreover, a recent investigation conducted by the National Institute for Occupational Safety and Health (NIOSH) (Coye, Lowe, & Maddy, 1986), of workers exposed to the organophosphate pesticide Diazinon in a mushroom farm in California, indicated that there are potential difficulties in the evaluation of post exposure cholinesterase activity without a baseline value for comparison. Therefore, having a baseline for farmworkers, mixers, loaders, and pesticide applicators prior to starting to work in the fields is very important.

There are alternative methods for the measurement of cholinestease activity. It has been argued that urine testing for alkylphosphate metabolites of organophosphate pesticides may be effective for monitoring pesticide exposure (Richter et al., 1984; Roan, Morgan, Cook, & Paschal, 1969). Monitoring these metabolites presents the advantage of being less invasive than blood testing. However, while urine metabolites indicate exposure and are useful in the assessment of industrial hygiene practices, they do not indicate biological response effects per se, as is the case with the measurement of cholinesterase activity depression.

Screening for neuropsychological effects by the use of a questionnaire may also be possible (Gupta, Jani, Saiyed, & Kashyap, 1984). The inclusion of neuropsychological effects as well as EMG testing are also possible as an addition to cholinesterase monitoring (Roberts 1977). A comprehensive program of monitoring including urine and cholinesterase tests, and physical exams including examination for nerve damage, has been advocated for pesticide monitoring (Hayes, 1980). Nonetheless, alternative tests to the measurement of cholinesterase activity, which is sensitive, specific, and reliable, have not been developed to the same degree of capability or their acceptability in an agricultural work setting has not been sufficiently confirmed by testing.

Laboratory Methods of Cholinesterase Determination

In the comparative evaluation of laboratory methods for cholinesterase activity measurements, researchers are concerned with the characteristics of each method that determine the settings in which it is most useful. The current methods in use may be divided into two general groups: (1) The electrometric (Michel) method and the colorimetric (Ellman) method, each of which is useful in surveillance and field research within developed countries or for laboratories in developing countries; and (2) tintometric and field spectrophotometric methods, which are useful in surveillance and field research within developing countries and potentially useful for field worker surveillance in developed countries.

Dose-Response Relationship

A fundamental principle in the study of chemical action based upon classic toxicologic methods is the demonstration of what is known as the dose-response relationship. This is a graph illustrating what is known to be the most common and established method of biological response, i.e., the chemical reaction is dependent upon amount of chemical in use and it is a predictable relationship. By application of this method, toxicologists are able to compare chemical actions, regardless of the type, among different animals (Wagner, 1981). Though the dose may be construed to indicate an absolute amount, e.g., 1 or 10 mg, in the field of toxicology it is actually defined as a ratio rather than in such absolute terms as mg per kg of body weight. The response is simply a measurement of some end point in an experience situation. In this context, this requires an easily measured phenomenon in the laboratory, the most simple of which is the death of the animal following a single dosage of the chemical. There are a variety of factors that can change the response to a pesticide chemical, including changes in the physical environment of the animal, biochemical changes such blood sugar levels, enzyme changes, dietary changes, or even changes in social or physiological behavior.

Nutritional Influence on the Toxicity of Pesticides

In the area of nutritional influence on pesticide toxicity, the primary concern is the role of dietary protein as well as other nutrients. The type of dietary protein and the quality of protein affects pesticide toxicity. Inadequate protein in the diet increases the toxicity of most pesticides, but decreases or fails to alter the toxicity of a few others. Most of the findings in this area are results of experiments in laboratory animals. Human studies are unavailable because of ethical considerations. With the exception of epidemiological research, this is likely to remain true.

According to Shakman (1974), multiple factors are involved in explaining the variation in pesticide toxicity in relation to diet. These factors include liver microsomal enzyme induction, the amount of body fat, and the availability of amino acid methionine, carbohydrate, fat, magnesium, calcium, and ascorbic acid in the diet. Microsomal enzymes metabolize foreign substances, including pesticides. They catabolize oxidations, reductions, hydrolysis, and glucurnic acid conjugations. Microsomal enzyme activity may be induced or stimulated to a higher level by a variety of chemicals and with a range of specificity. Organochlorine insecticides decrease microsomal enzyme inducers, and organophosphorus compounds inhibit drug metabolizing enzymes, providing further reason why a pesticide may be an active toxin in itself, or it may be metabolized to a toxic metabolite in the presence of a low level dietary protein. There are other dietary factors which independently or with protein affect pesticide toxicity. For example, both DDT and Dildeirin can produce a deficiency in the liver storage of vitamin A. Vitamin A deficiency then can produce disease or increase the toxicity of other chemicals (Tinsley, 1969).

Diets lacking in methionin amino acid, which is an essential amino acid, provide another good example. The amino acids reach the body through a diet rich in animal protein. Lack of amino acid depresses growth and liver vitamin storage. This could be an important factor among low economic status migrant farmworkers or farmers exposed to pesticides in developing countries who do not consume enough protein in their diet. Dietary carbohydrate is another variable in determining the toxicity of pesticides. Completeness of digestion and absorption of amino acids are diminished by the amount of non-utilizable carbohydrates, such as sucrose in food. For this reason the effect of carbohydrates on pesticidal toxicity can provide an indirect effect through differences in protein availability and the avoidance of protein catabolism as a source of energy. On the other hand, dietary fat plays a large direct role in the toxicity of chlorinated hydrocarbons. Because fat stores organochlorine material when there is food deprivation, it will lead to metabolism of the stored fat deposit, and subsequently to the release of pesticides in the blood. Other relevant factors are calcium and magnesium. Without the production of deficiency states, the alteration of dietary magnesium and calcium levels alters enzyme activity under conditions of pesticide exposure. The interactions however are not clear (Casterline & Williams, 1969). It is important to note that in many developing countries DDT is still used heavily. It constitutes a contaminant of breast milk. In those countries where weaning is accomplished late, the effect of DDT on the calcium metabolism along with vitamin D could be quite deleterious.

Therefore, exposure to such pesticides near children and lactating women should be strictly limited.

According to Shakman (1974), the dietary effects of pesticide toxicity is a long term problem. With an increasing world population and universal demands for a better life, the use of pesticides must increase greatly as marginal land is cultivated and present agricultural lands are more intensively cultivated. Therefore, the issue is the wise and rational use of pesticides.

Carcinogenicity, Mutagenicity, and Teratogenicity

Carcinogenic pesticides may pose one of the greatest occupational dangers, but the extent of this effect is difficult to document. Clinical evidence of the carcinogenicity of pesticides has so far been demonstrated in only a few epidemiologic studies, although a considerable number of such products have been shown to be carcinogenic in animals (Durham, 1972). One reason for this may be that pesticide-exposed workers come into contact not only with active ingredients and their by-products, but also with solvents, carriers, emulsifiers, and other potentially hazardous pesticide components. Some of these, such as certain N-Nitroso compounds, chlorinated dibenzodioxins, and chlorinated dibenzofurans, have only recently been identified, following the development of new and highly complex analytical methods (International Agency for Research on Cancer, 1978). Chlorphenols and chlorophenoxy herbicides, or their CCD contaminants, as well as herbicides containing amitrole, were implicated as possible occupational carcinogens by recent epidemiologic studies in Sweden. Increased lung cancer incidence among certain groups of workers producing or using arsenical pesticides has been observed in the United States and Europe (Bleger & Wagner, 1976), and in a study in the Soviet Union, a correlation was found between lung cancer mortality and occupational exposure to dithiocarbamate pesticides (Sorokina, 1975).

In two epidemiologic studies carried out in the German Democratic Republic, Barthel (1976) showed that pesticide-exposed male agricultural workers experience significantly increased mortality from lung cancer, but without evidence to suggest that products such as DDT, HCH, or Toxaphone, which are tumorogenic in animals and have been used in the GDR since the 1950s, have contributed to the cancer incidence discussed in these epidemiologic studies. However, in a study of 2,650 exposed workers in the United States, Morgan, Lin, and Saikali (1986) found no significant differences between the mean serum DDT or DDT levels of subjects with and without cancer. They also found no significant differences between their study and the results of earlier epidemiologic studies examining the possible carcinogenicity of DDT, HCH, and Toxaphone. Some international agencies, including the WHO, the International Union Against Cancer, and the International Agency for Research on Cancer, have expressed the opinion that substances that have been shown to be carcinogenic in animal experiments can be considered a suspect carcinogen for humans. However, Schramm and Teichman (1977) have indicated that it is impossible to determine a threshold level for a chemical carcinogen below which there is no carcinogenic risk. This also applies to carcinogenic pesticides, some of which are or have been used in large amounts. According to Barthel (1981), in the near future the identification of carcinogens in pesticides by means of epidemiologic studies, and hence the imposition of corresponding legal restrictions on the production and use of these types of products, will continue to be problematic. The emphasis in cancer prevention will therefore have to be based on the improvement of the work environment and in the health protection of occupationally exposed members of the work force.

In the U.S. the use of pesticides has increased dramatically over the past years, and any number of new formulations have been introduced to the market. Of this large number, only about 100 brand names from the three major groups, fungicides, herbicides, and pesticides, are actively used in agriculture. Some of them have been related to carcinogenic effects in either animals or human beings.

In the case of fungicides, there are no published reports associated the use of agricultural fungicides with the induction of congenital abnormalities in the human. In chemical terms, the herbicide group includes chlorophenoxy, dinitrophenols, bipyridyls, carbamates, substituted ureas, triazines, and amide compounds. The most widely used herbicide in the United States is 2,4-dichlorophenoxyacetic acid (2,4-D), millions of tons of which are used on crops each year. The other widely used herbicide is 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). The use of both of these herbicides has been restricted by the EPA because of concern about their mutagenic, carcinogenic, and teratagenic effects. However, though they are on the EPA restricted list, they are still used in substantial amounts in agriculture. The use of these herbicides and their effect upon health, under the names "Agent Orange" and "Agent Purple," in the Vietnam War has been controversial and there are those who believe they have caused stillbirths among Vietnamese women. In February, 1979 the EPA halted most of the use of 2,4,5-T, the basis for which was a study which linked exposure to dioxin, an unavoidable contaminant of 2,4,5-T, and silvex herbicides with the increased risk of miscarriage. This occurred among women in Alsea, Oregon, a site where large areas had been sprayed with the herbicide by helicopter in an effort to increase the production of commercial forests. However, the results of the EPA study were critically examined by many investigators. As a group, the carcinogenic effects of insecticides have not been determined in humans and this effect has only been determined among animals.

Migrant Farmworkers and Pesticides Exposure

Farmworkers, many of them migrants, provide essential hand labor to agriculture in the United States. They thin apples among trees which have been sprayed with insecticides and they cut asparagus in morning fields still wet with herbicide sprays. Ralph M. Rodid, an industrial hygienist who has studied Oregon labor camps and workers' safety violations for 15 years, says that migrants have lived in a perennial cycle of "abuse, exposure and degradation" compared with consumers (Rosemary, 1989).

In most cases migrant farmworkers live in camp sites close to the farms at which they work and in some cases they live at the same farm. For example, in New Jersey they often live in the midst or on the fringe of vegetable fields. When airplanes spray the field with such toxic pesticides as the organophosphates, the farmworkers and their homes are almost unavoidably sprayed as well. Since the oral ingestion of pesticides is generally not an important route of exposure, in most cases pesticide dust or vapors and their accidental contact with clothing and skin, with subsequent absorption through the skin, is the source of migrant worker poisoning. Working continuously for long periods of time in treated fields also serves to expose migrant farmworkers to pesticides residues. Due to depressed enzyme cholinesterase activity, migrant workers may not be able to work many days of the year. Therefore, the development of a program whereby migrant farmworker and their families could continue to receive a living subsistence during these periods to supplement their already inadequate incomes would be useful.

Another factor which calls for serious attention is the diet of migrant farmworkers. In assessing the health of migrant farmworkers, the general health level for many of them may appear to be good. However, this type of finding must be interpreted with caution since most of the farmworkers are relatively young. According to Bogden (1975), migrant farmworkers stand at risk from the chronic effects of pesticide exposure because of their general lack of awareness of its danger and symptoms, as well as the lack of opportunity for treatment. In particular, there may be little opportunity for the improvement of the health of the individual migrant worker because the mobility inherent in this occupation prevents reception of continuing medical care from the same source. To date there has been little effort toward remedying the specific health problems of migrant populations in the United States. In effect, migrant workers have been given the lowest priority in terms of health and social services. Therefore, programs to improve this situation are desirable.

Routes of Entry

Given a chemical in the environment in terms of a given "dose," the presence of that chemical does not always mean exposure in the toxicological sense. It is simply not sufficient to state that because both chemicals and humans are present that some type of cause and effect relationship, or beneficial or detrimental situation may occur. For exposure to lead to significant biological action, a route of absorption must be supplied and available. There are three routes by which any chemical can get into the body: (1) dermal (skin), (2) the gastrointestinal system, and (3) the respiratory system. In occupational medicine, the skin and respiratory routes are the most important routes that have been assessed.

In the context of environmental medicine and incidental exposure, the gastrointestinal tract, or the ability of some chemicals to move through the food chain and finally become ingested, is the most significant route of entry (Wagner, 1982). In contrast, the skin is a barrier of considerable magnitude in its capability of protecting humans from exposure. However, there are a number of variables that can break down this barrier and which need to be considered when assessing possible pesticide chemical exposure.

In general, skin is very resistant to the absorption of water soluble chemicals and pesticide chemicals must be absorbable through the skin to cause injury. On the other hand, any dermatological disease will immediately provide an opening for pesticide chemical entry and should always be considered significant. However, the skin will absorb fat soluble chemicals without great difficulty, regardless of the condition of the epidermis. Thus, the nature of the chemical itself is important in the assessment of pesticide exposure problems. Heat may also play a role since as farmworkers sweat, dusty chemicals which normally would not be absorbed may become dissolved and may then be absorbed. Physicians and other observers in certain agricultural areas have frequently noted that poisoning from the organic phosphorous insecticides occurs more often in unusually hot weather than under cooler conditions; therefore, any valid conclusion, based on data relating to the effect of temperature on poisoning, must be taken to account during assessment of risk of exposure in population. There are also other factors which under certain circumstances may act to increase the rate of dermal absorption. One of these factors, according to Malkinson and Rothman (1962), is injury to the skin. In addition, there are other conditions that may modify the reaction of farmworkers to absorbed pesticide. One of the most common recognized conditions is prior exposure to an anticholinesterase compound.

The respiratory tract, particularly the lungs, represents an easy point of entry for chemicals which are presented in the form of a gas or an aerosol. It is important to distinguish between an aerosol and particulates since particulate matter is not absorbed into the terminal part of the airway and is generally much less dangerous than aerosols. The movement of chemicals into the lung does not necessarily mean that dangerous absorption has occurred. The nature of the chemical is important and certain chemicals may simply stay in the lung for years without significant impairment of lung functions. Finally, the respiratory rate of an individual farmworker is also important. The worker who breathes heavily due to physical exertion will obviously absorb considerably more chemical gas or aerosol than will the individual at rest because of the former's increased respiratory rate (Wagner, 1982). In comparison, the dermal route of exposure may represent a greater source of absorption than the respiratory route. According to Durham (1972), this does not mean that workers should neglect respiratory protection where there is respiratory exposure since in some circumstances respiratory exposure may be more dangerous. The reason is that the pesticide is more rapidly and more completely absorbed through this route. In the majority of occupational accidents and occupational exposures to pesticides, both the respiratory and dermal routes are involved in such a way that it is difficult to distinguish their relative importance.

Routes of Worker Exposure to Residues

When an agricultural worker enters a field or after an insecticide application has been made, three sources for exposure to toxic residues exist. One is insecticide vapor, aerosols, and fine toxicant-bearing particulate matter in the air, which can lead to inhalation and oral exposure. Airborne residues have now been generally discounted as a significant source of field exposure. The second source, which results in dermal exposure, is persisting residue which resides on the foliar surfaces of the sprayed crop and which can in part be transferred to the skin and clothing of workers. The third source is the residue on the mobile soil dust of the grove or field which results from off-target spray drift or runoff of insecticide spray from the target plant surfaces. The residue bearing dust can be stirred up by wind or mechanical action and settle on the skin and clothing of workers, thus serving as a second source of dermal exposure.

The current consensus is that the most important route of exposure is dermal and that toxic materials are transferred to workers by prolonged and extensive contact with foliar surfaces bearing toxicant-containing dust which may be present in dry, hot, and dusty agricultural climates. Both the nature of the soil dust and the amount of residues on foliage are important, as soil dust can retard insecticide dissipation or aid in the conversion of the parent insecticide to its more toxic oxygen analogues, often referred to as "oxons."

For example, it has been quantitatively demonstrated that the dust burden on citrus foliage in California increases throughout the growing season (Popendorf, Spear, & Selvin, 1975). It is believed that the oxons play an important role in worker poisonings due to their enhanced cholinesterase-inhibiting properties.

Chronic and Acute Exposure to Pesticide

Individuals exposed over long periods of time to low-dose levels of cholinesterase inhibitors develop a tolerance to higher than normal acetylcholine levels (Richter et al., 1979), and depression of cholinesterase activity can reach very low levels before clinical signs of poisoning are noted. Chronic cholinesterase activity depression, on the other hand, may increase sensitivity to challenge doses of cholinesterase-inhibiting compounds, thus resulting in illness (Hayes, 1982). The effect of chronic exposure to phosphate ester pesticides may be cumulative in the sense that repeated exposures closely following each other can reduce cholinesterase enzyme activity faster than it can be regenerated. For this reason, in states such as California, medical supervision is a legal requirement for agricultural workers who regularly apply the toxic phosphate ester group of pesticides. This monitoring takes the form of an erythrocyte or serum cholinesterase enzyme activity test performed before farmworkers enter the treated fields for the season. Decreases in the activity then can be monitored. In practice, this is difficult because most of time those who are dealing with highly toxic pesticide chemicals are migrant farmworkers who move from one location to another during the season, making pre-exposure testing difficult. A worker should be removed from any exposure when either plasma or red blood cell cholinesterase enzyme activity drops to below 50 percent of the individual workers' normal value. The worker can be returned to work when the level returns to 75 percent or more of this value.

<u>Symptoms of Poisoning Due to Exposure to Pesticides</u>

Symptoms of mild poisoning are reported to be non-specific, such as nausea, headaches, malaise, excessive sweating, constriction of the pupil of the eye, blurred vision, and asthma-like tightness in the chest. The association of these symptoms with pesticide exposure may be missed by medical personnel (Coye, Barnett, Midtling, & Lowry, 1984; Kahn, 1979). Psychological symptoms, including insomnia, nightmares, giddiness, disturbances of memory, difficulty in maintaining attention, and drowsiness, may be early signs of organophosphate or carbamate pesticide poisoning (Gupta et al., 1984; Kahn, 1976; Metcalf & Holmes, 1969; Misra, 1985), and there are indications that psychological impairment may persist after poisoning (Savage, Lewis, & Parks, 1982). Neurotoxic effects, including paralysis of the extremities and respiratory muscles, have been reported 24 to 96 hours after acute poisoning (Senanayake & Karalliedde, 1987). Delayed neurotoxicity appearing 2 to 5 weeks after acute poisoning has also been reported (Savage et al., 1982).

Cholinesterase activity depression below 60 percent of a person's cholinesterase activity baseline is reported to produce relatively mild symptoms, while depressions of 90 to 100 percent below a person's cholinesterase activity baseline may produce unconsciousness, pulmonary edema, respiratory difficulty, and even death (Kaloyanova, 1982). When death occurs, it is usually due to respiratory arrest (Namba et al., 1971).

Exposure to herbicides produces such symptoms as primary irritance and epidermal sensitization. The violaceous erythema and the associated edema are the most striking changes due to herbicide exposure. Organochlorine pesticides absorbed in sufficient doses may result in severe dysfunction of the central nervous system through interference with axonic transmission of nerve impulses. Symptoms include behavioral changes, sensory and equilibrium disturbances, involuntary muscle activity, and depression of vital centers, especially those controlling respiration. Sufficient dosage may also result in tissue damage of the liver and irritability of the myocardium of the heart muscle. Hayes (1982) suggested that the occurrence of three or more of the selected symptoms would be more representative of pesticide intoxication, since the individual symptoms commonly occur as a result of conditions other than organophosphate exposure.

Age, Sex, and Race

The pattern of erythrocytes and plasma cholinesterase activity among persons exposed to inhibitors have been studied extensively and reviewed by different investigators. Erythrocyte cholinesterase activity does not change with age in adults. Serum cholinesterase activity changes with age and it is different for both sexes, but the reported differences have been very small. There is no difference in red blood cell cholinesterase enzyme activity associated with sex, whereas serum cholinesterase activity is significantly higher in males than in females. According to Reinhold (1953), serum is lower in black persons than in white persons of the same sex. However, it is unknown whether this is the result of genetic or nutritional factors. The same is not true of red blood cell enzyme activity

Disease

The effects on serum cholinesterase of many diseases which affect hepatic function are well known. Neoplasms, parenchymal liver disease, malnutrition, acute infection, and some anemias all depress serum cholinesterase values. Most of these conditions also prevent the individual from working, so they are rarely responsible for depressed cholinesterase in occupationally exposed populations. Certain chemicals such as organic mercury compounds, carbon disulfide, and benzalkonium salts can depress serum cholinesterase activity (Hayes, 1982). In addition, Baetjer (1983) suggested that persons subjected to moderate nutritional or water deficiency, conditions frequently encountered by migrant and seasonal farmworkers, may be particularly susceptible to organophosphate and carbamate exposure.

Pregnancy

Pregnancy alters the concentration of many blood proteins. An acute drop in cholinesterase values was found in the first trimester, with a slightly apparent, but not significant rise in the third trimester. The lowest values were observed during the second to seventh days postpartum (Evans & Wore, 1980).

Reentry to Treated Fields

Determination of a time interval between the application of pesticides to agricultural fields and the safe reentrance of agricultural workers has been a subject of great concern to agricultural, industrial, health and political communities over the past few years. In 1970, as a means of reducing the exposure of workers to acceptable levels, field workers reentry intervals were instituted for various organophosphate and carbamate pesticides in California (California, Department of Food and Agriculture 1971). This strategy was adopted by the Environmental Protection Agency (EPA) and national reentry standards are now in force. However, the national standards are substantially less restrictive than those of California and reflect the generally held belief that the reentry problem is regional in character (U.S., Federal Rights, 1974). Most of the articles concerning reentry offer only suggested entry intervals based on the particular experiences described in individual studies directed at the effect of specific pesticides on the well-being of those who enter treated fields for thinning, harvesting, or the application of pesticides. In 1962, Baily suggested the following general criteria for establishing reentry into pesticide treated fields:

1) dermal toxicity of the pesticide,
2) worker characteristics,
3) the pesticide,
4) frequency of occupational poisoning cases,
5) formulation and concentration of the pesticide,
6) crop,
7) amount of active ingredient applied per acre, and
8) combination of pesticide chemicals used.

Baily suggested that the reentry interval must be sufficient in duration to protect the worker, but brief to be tenable with essential agriculture practices.

The use of organic phosphorus pesticides has been associated with many documented incidents of the poisoning of agricultural workers. In many cases, the workers have been sent into fields or orchards at a time when sufficient pesticide chemical residue still remained on the foliage to endanger persons either in contact with plants or who could inhale dislodged particulate matter. Attempts have been made to establish safe time intervals between the time of application of known amounts of pesticide and the time of entry into the fields (the "reentry" time), but these intervals have often been determined subjectively because well-designed, quantitative methods for their establishment have generally not been used (California, Department of Food and Agriculture, 1971). In establishing safe reentry times into pesticide treated fields, the goal is to limit exposure to pesticide chemical residues to levels beneath that found to cause a detrimental effect. According to Serat (1973), two points are implicit in this effort:

1) The detrimental effect must be known to be function of exposure; and
2) If any quantitative data are to be established in determining such reentry, some pertinent physiological function must be sensitive enough for measurement.

The enzyme cholinesterase level in red blood cells and plasma serum and its activity is a base line to determine the time intervals for reentering to treated fields with pesticide chemicals. This is done within the limits that any decrease in cholinesterase activity can be related quantitatively to pesticide chemical residue levels. It is a simple matter to establish reentry times from data such data as pesticide residue level on plant foliage (ppm), the plasma cholinesterase activity of workers (nanograms per milliliter of blood), the total pesticide residue to which workers were exposed (ppm), and the length of time following pesticide application (days). For example, if the plasma cholinesterase activity can allowed to decrease 30 percent from its limited value of 2.45 nanometers to 1.71 nanometers per milliliter of blood, a certain waiting period without exposure, the reentry time interval, is required to allow this level to return to normal value. On the other hand, there is a relationship between the worker's plasma cholinesterase activity and the total pesticide chemical residue on the foliage, i.e., as the level of pesticide chemical residue on the foliage increases, blood plasma cholinesterase activity decreases.

It should be noted that with the exposure of foliage pesticide chemical residue to sunlight and other environmental conditions, the toxicity of the residue decreases. For instance, when organophosphate pesticides are applied to orange trees, after three days the pesticide decreases to 74 ppm (Serat, 1973). Therefore, the third day after spraying would constitute a safe reentry time if workers were to be in the fields for only one day. However, if workers were to be there for more than one day, in order to sustain no more than a 30 percent enzyme loss of activity during this period, the total consecutive exposure to available residues must not exceed 74 ppm.

Reentry Intervals for Carbamates

At the present there are no reentry intervals specified for carbamates, other than the requirement that the sprays have dried and no dust is present. However, according to Kahn (1979), field worker poisonings have occurred after the application of carbamate pesticides. The problems of establishing reentry times for carbamate pesticides are quite different from those involved with organophosphates, chiefly because of the relatively transient and rapidly reversible nature of the cholinesterase inhibition produced by carbamates. For this reason, repeated exposure to a carbamate is not likely to produce the cumulative effect on cholinesterase levels that occurs with exposure to organophosphates. In one sense, this simplifies the nature of the reentry study design. The determination of pre-exposure baselines becomes less crucial since its importance is confined to insuring that the subjects are indeed in a nonexposed state. The only cholinesterase determinations required would be one prior to exposure and one immediately following exposure. An unexposed laboratory control group would still be needed. On the other hand, a carbamate study would present some special difficulties because of the need for great speed in laboratory procedures. The carbamate effect on cholinesterase activity is reversible both in vivo and in vitro. It would, therefore, be necessary to obtain blood samples promptly at the end of the exposure period and to determine the enzyme levels within a period of one to two hours.

Factors Affecting Reentry Problems

The term "reentry intervals" is the waiting period required to protect field workers from possible poisoning when they reenter pesticide treated fields. The establishment of reentry intervals is complicated by the number of parameters involved, which may be placed in three categories:

1) Crop:
    a) frequency and rate of required pesticide application,
    b) foliage characteristics,
    c) height,
    d) canopy density, and
    e) weather conditions ;

2) Pesticide chemicals:
   a) formulation (including combination),
   b) persistence,
   c) dermal penetrance characteristics for human, and
   d) toxicity for humans; and
3) Worker:
   a) contact with residues,
   b) length of exposure,
   c) clothing, and
   d) respiratory protection.

In conducting studies to gain sufficient information for setting safe reentry times into pesticide-treated orchards, it must be borne in mind that the rate of pesticide residue dissipation is constant. Thus, the decrease in cholinesterase activity is in accordance with the conditions of the individual study, the use of different crops, climatological conditions, or protections afforded to fieldworkers, and a number of other factors which may affect the results.

Regional Behavior of Pesticides in The United States

It is generally accepted that weather and other local conditions influence pesticide behavior. Climactical variables, including temperature, humidity, and solar radiation, which cause residue dissipation, make the evaluation of these conditions difficult. On the other hand, these conditions affect the disappearance and the toxicity of pesticides.

Variations in pesticide dissipation due to weather conditions have been observed in a number of studies over a period of years. Gunther, Iwata, Carman, and Smith (1977) found increased dissipation of organophosphate insecticides in warmer and wetter climates. Nigg, Henry, and Stamper (1979) found differences in organophosphate disappearance between wet, hot conditions and cool, dry conditions. Some organophosphates, however, do not fit this pattern. They may disappear rapidly or slowly in spite of wide variation in environmental conditions. For example, there is little difference in Parathion decay in Florida, California, and Arizona. In the dry regions of California, Parathion residue disappearance was best correlated with time, but was also significant in relation to the degree-days of heat (Nigg and Allen, 1979). For wet conditions in Florida, significant correlations exist between residue behavior and cumulative moisture. Nigg, Henry, and Stamper (1979) believe that if the United States were divided into weather regions, similarities in residue behavior could be determined. In addition, aside from variations in work practices, changes in residue behavior could be correlated with changes in the observed frequency of worker reentry incidents. The residue itself and their regional variation appear to be important factors in determining exposure to pesticides. However, it should be noted that differences in rates have their limits, regardless of climate. In other words, the disappearance of residues is neither instantaneous nor unending, but is strongly dependent upon the chemistry of the individual pesticide.

The regionality of worker reentry incidents has been reviewed by Gunther et al. (1977) and have been attributed primarily to weather, the use of organophosphate insecticides, and dusty field conditions. The parent pesticide chemical molecule has never been central to delayed acute fieldworker illnesses. Rather, the oxon metabolite of an organophosphate insecticide has been the causative agent. However, the quantity of oxon present is different and varies regionally. For example, paraxons (an oxygen analog of O-P pesticide parathion) behavior differs for Parathion treated citrus fields in Arizona, California, and Florid.

Pesticides Safety

The protection of agricultural labor from pesticides is important to United States agriculture. Current agricultural production levels assure an adequate food supply and are an asset to the general economy. Most of U.S. agriculture is dependent on the chemical control of pests and on a worker labor pool of low economic status. If the working conditions of this labor pool decline, a reduction in agricultural production could occur. Most of the poisonings happen when workers mix, load, or spray pesticides, as well as after application during harvesting periods.

The occurrence of pesticidal poisoning during spraying operation might not be due to the concentration of the pesticide in the air, but rather to the almost complete lack of adequate precautionary measures taken by some workers during spraying. The development of effective safety recommendations for workers using organophosphates and other highly toxic pesticides requires information on the relative importance of various possible routes of exposure which might be involved (Durham, 1972). Knaak et al. (1978) studied the effects of pesticide exposure on mixer-loaders, applicators, and flaggers in closed and open systems and found that mixers were the only agriculture workers exposed to sufficient pesticides to cause red blood cell cholinesterase inhibition. They also found that the toxicity of the pesticides used may be more important than the weather conditions or the amount of the pesticide used. The mixer-loader must be thoroughly trained in the use of closed-transfer systems, as opposed to the use of hand pouring procedures, if the equipment is to be more effective in preventing exposure.

Bathing after exposure to pesticides has been found to be associated with a rapid decrease in the excretion of absorbed pesticide or its metabolites from body by way of urination. Apparently, removal of excess pesticide from the skin through bathing limits further absorption of the pesticide.

Wolfe, Armstrong, Staiff, and Comer (1975) found that potential exposure to Parathion which might occur as a result of smoking during normal application operations or working in the fruit orchard was not particularly high where contact was with dilute spray or foliage residues. Smoking without washing hands should be of concern. A very important recommendation for pesticide applicators, and for workers whose hands come in contact with pesticide residues on crops or foliage, should be to protect their hands from exposure as much as possible and to wash hands before smoking. Moreover, cigarettes should not kept in open pockets where they may become exposed to spray drift. According to this study, two important points must be kept in mind with respect to pesticide exposure and smoking: (1) pesticide entry by the respiratory-oral route is practically 100 percent absorbed, and (2) there is no assurance that a more toxic oxidation product, such as Paraxon (the oxygen analog of Parathion) will not be formed and inhaled as the high temperature of burning cigarette reaches the contaminated areas.

Protective Clothing

Traditional engineering and administrative controls employed in industrial hygiene are often impractical for outdoor environments and may not be relevant to the dermal route of exposure. Controls, such as the closed cab system and closed mixing systems, have been demonstrated to reduce occupational exposure substantially (Lunchich, Nielsen, & Reinert, 1987). However, such systems are not possible for many pesticides application conditions. Current knowledge of the efficiency of protective clothing performance in agriculture is very limited, although research activity in this field has increased in recent years (Davies, Freed, & Enos, 1982). Much of this research has been directed at answering two very practical and critical questions:

1) What type clothing is appropriate during pesticide mixing and application?
2) How effective is the clothing in providing protection?.

Common field methods currently employed to evaluate protective clothing involve the adoption of traditional dermal patch technique. The use of fluorescent tracers in conjunction with video imaging offers an alternative method for determining dermal exposure beneath protective clothing. Using this method, Fenske (1988) found the following results in a comparative assessment of protective clothing performance by the measurement of dermal exposure during pesticide application:

1) A substantial portion of exposure beneath clothing occurred near the sleeves and neck openings of the garments;
2) Accumulation of deposition in the cavity between the breasts; and

3) All workers exhibited exposure to the hands despite the use of chemical protective gloves.

In this instance also, mixers had significantly higher mean exposure levels than applicators. Protective gloves are important in the prevention of dermal contamination due to exposure to pesticides. However, there are no differences between workers with gloves and without gloves in areas of low level exposure to pesticides, particularly for the organophosphate pesticide Parathion, either on red blood cells or plasma cholinesterase depression (Wicker, Williams, & Guthrie, 1979). In the case of high level exposures, such as the worker who loads or mixes the pesticides, there are significant differences between those who wear and those who do not wear protective gloves in red blood cell cholinesterase depression. Also, when workers wear the same gloves, unwashed and often torn, during work in the field, contaminated gloves may act as an occlusive dressing to increase absorption of pesticides. Thus, gloves may absorb more pesticide than would be retained on the skin. Since hand exposure is often such a large proportion of total exposure, excessive retention of residues by gloves may result in the gross overestimation of total potential exposure. Davies, Stevens, and Staiff (1983), comparing at a 95 percent level of confidence, monitored hand exposure by rinses or absorbent gloves and found that hand exposures obtained by rinsing were significantly lower than those obtained by using either type of cotton or rubber gloves. However, there was no significant differences between exposures obtained by using the different type of gloves. When mean exposures were compared, those obtained by using cotton and nylon gloves were approximately five and four times greater, respectively, than those obtained by using hand rinses.

Since exposure to insecticide residues appears to be predominantly dermal, one promising technique for the prevention of exposure would be the use of light-weight, disposable, protective clothing which would be comfortable, yet provide a barrier to the entry of toxicant-bearing particulate matter. This would protect workers from exposure not only to the cholinesterase inhibiting insecticides but also to other insecticides whose long-term effects, are not known.

The transportation of pesticides is also a major problem in the handling of pesticides. There are various international regulations to minimize the hazard of pesticide transportation by land, sea, or air, but accidents do occur and acute toxicity may be a hazard. For example, the contamination of flour transported in close proximity to the insecticide Endrin (Weeks, 1967) and cloth used for bedding and clothing contaminated with Parathion during transport have been reported (Anderson, Warner, Parker, Bullman, & Page, 1965). The enforcement of transport regulations is difficult and not always successful. Even when the law is complied with, accidents such as the sinking of ships, or road, rail, or airline accidents, can release toxicants into the environment with serious consequences.

First Aid in Pesticide Poisoning and Accidental Spillage

It is essential that pesticide poisoning incidents be recognized immediately because prompt treatment may mean the difference between life and death. First aid should not be a substitute for professional treatment because first aid can only relieve the patient before medical help can be received. The following information is adapted from *The New Pesticide User's Guide* (Bohmont, 1983).

If the first responder is alone with the victim, he should first check to be sure the victim is breathing; if he is not, give artificial respiration. Then, decontaminate the victim immediately by washing him thoroughly and call a physician or medical center. If another person is available, send him to activate the emergency medical service. If the pesticide chemical is spilled on the victim's clothing, the contaminated clothes must be removed immediately and skin should be washed with clean water thoroughly. Some of the pesticide chemical should be saved if any remains; the pesticide container and a readable label should be saved for the physician. Washing the victim's body and hair with water and soap, cleaning the finger nails, and speed in washing is very important in reducing the extent of injury. After washing, the victim should be dried and wrapped in a blanket.

If the poison is in the eye, hold the eyelids open, wash eyes with a gentle stream of running water immediately. Use large amounts of water. Delay of a few seconds greatly increases the extent of injury. Washing should be continued for 15 minutes or more, and chemicals or drugs should not be used in the wash water. They may increase the extent of injury.

Poisoning through inhalation of pesticide chemicals are rare, but very important because of the high rate of absorption via the lungs. However, if it happens due to dust from pesticides, or vapors and gaseous chemicals, and victim is in an enclosed space, the first responder should not go in after him without an air supplied respirator. The patient should be carried (not walked) to fresh air immediately. If breathing has stopped or is irregular, artificial respiration must be applied. Call a physician, prevent chilling, and do not give alcohol in any form. If the victim is convulsing, watch his breathing and protect him from falling and striking his head on the floor or wall.

In the case of swallowed poisons, call a physician immediately. Do not induce vomiting if the patient is in a coma or unconscious, or if the patient has swallowed a corrosive poison (strong acid or alkaline products). In the latter case, the victim will have a severe pain and a burning sensation in his mouth and throat. If the patient can swallow after ingesting a corrosive poison, milk, water, or milk of magnesia (1 tablespoon to 1 cup of water) in case of acids, and milk and water in the case of alkali could be given by mouth.

If the substance which has been swallowed is not a corrosive, vomiting can be induced by placing the blunt end of a spoon or a finger at the back of the patients throat, or by the use of two tablespoons of salt in a glass of warm water. Place the patient face down with his head lowered when vomiting, thus preventing vomitus from entering the lungs and causing further damage. If the poison is not known, a sample of vomitus should be saved. In the case of ingestion of pesticides, antidotes could be used. An antidote is a remedy to counteract the effect of a poison or prevent or relieve poisoning. They are two kinds: antidotes for external use and antidotes for internal use. There are medical antidotes for pesticide poisoning, which should be prescribed or given only by a qualified physician since they can be very dangerous if misused. For example, Pralidoxime chloride is generally used in the treatment of moderate or severe cases of organophosphate poisoning, when it is used in conjunction with atropine and is administered intravenously. It may also be used orally in mild cases in the absence of abdominal symptoms. Its use in the presence of vomiting or diarrhea not recommended, and its value in that clinical setting is unknown. Pralidoxiom will not haste the rate of recovery of red blood cells cholinesterase activity. This failure may be related to pralidoxims's relatively poor absorption from the intestinal tract. There are antidotes also to be used by non-medical people.

Container Disposal

Proper pesticide waste and container disposal is extremely important. It is the pesticide user's responsibility to see that unused chemicals and empty containers are disposed of properly. Improper disposal of pesticide waste and containers over the past few years has resulted in incidents involving animal poisoning and environmental contamination. Unfortunately, there are no easy or perfect means to dispose of excess pesticides and empty containers. Pesticide wastes may range in type from materials left after excess spray mixing, and accidental split, to pesticides left over from a warehouse fire. Pesticide containers vary from aerosol cans or paper bags to 1 and 5 gallon cans on up to 55 gallon drums, the disposal of which is sometimes difficult.

Supposedly empty pesticide containers are never really empty as several ounces of pesticide can generally be found in discarded containers. On many occasions the concentrations of the active ingredient in liquid formulations tends to increase in toxicity as the solvents evaporate from the discarded container. The National Agricultural Chemicals Association has suggested a procedure to use when rinsing containers prior to disposal that reduces their hazard potential. The procedure involves the triple rinse method described in the following steps:

1) When the container is being emptied, allow it to drain in a vertical position for thirty seconds;
2) Best results are obtained when the container is rinsed three times, allowing thirty seconds for draining after each rinse;
3) Water or other diluting materials being used as rinses in a spray program can be used to rinse the containers as follows: use one quart for each rinse of a 1-gallon can or jug; a gallon for each 5-gallon can; and 5 gallons for either 30- or 55-gallon drums; and
4) Each rinse should be drained into the spray tank before filling it to the desired level.

It makes good sense to empty and triple rinse pesticide containers because that will ensure that all chemicals are out of the container, as well as ensuring that there will be no residue left to contaminate the environment or injure someone (Bohmont, 1983). Laboratory tests show that even a good effort to empty a drum leaves about 6 ounces of pesticide in a 5-gallon container and 32 ounces in a 55-gallon drum. Each gallon of pesticide costs between $20 to $30, and each 6.5 ounce of pesticide costs one dollar. Therefore, with the large amounts of pesticides used in agriculture, it is obvious that considerable amounts of money could be saved by proper rinsing and disposal of pesticide containers, as well as preventing the environment from being contaminated by improper container disposal. Surplus or unwanted pesticide disposal can be kept at a minimum with some advanced planning. The safest means of disposal is to use the pesticide exactly as the label directs for the purpose for which it is intended. To do so requires some advanced planning to determine the kinds and amounts needed for the application in order to use all of the spray, dust, or granules prepared for the application.

Present methods of pesticide container and waste disposal include burial, incineration, degradation, soil injection, and in some instances permanent storage. From above methods, it is the user's responsibility to select the most feasible method. Every possible alternative should be considered in relation to the problem, giving consideration to the environment. The choice or selection of the disposal method will depend on several factors, including the pesticide type, the container type, facilities available for disposal, the nearness to communities, streams and crops, and any other geological or environmental considerations (Bohmont, 1983). The failure to consider any of these factors may result in more complex problems in the future.

The Resource Conservation Recovery Act (RCRA) governs larger accumulations of pesticide rinsings collected from aircraft, washing aprons and equipment, and the disposal of empty containers. Many states also have hazardous waste disposal laws. However, details of the state laws as well as interpretation of RCRA are complicated and difficult to understand in many cases. It is the responsibility of the pesticide applicator to ensure compliance with and understanding of legal requirements in order that they may be observed to the safest and fullest extent possible. Because of the complexity of pesticide waste and container disposal, as well storage of pesticides, the EPA has published detailed information in the *Federal Register* (Bohmont, 1983).

Legislative Approach to Pesticides In the U.S.

Standards to protect farm workers from the adverse effects of early reentry into pesticide-treated areas were first reported by the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor (DOL) on May 1, 1973 for 21 organophosphate insecticides (U.S. Department of Labor, 1973). These standards included five crops (citrus, peaches, grapes, tobacco, and apples) in wet and dry areas. Due to petitions filed by the Florida peach growers association and other associations, these standards were suspended after six weeks, and revised standards were proposed with less stringent requirements which covered only nine organophosphorus insecticides with intervals ranging from one to three for wet areas and up to 14 days for dry areas. Public hearings on the reentry issue were concurrently held in the late summer of 1973 by both the U.S. EPA and OSHA. There was a jurisdictional conflict over which agency would set and administer re-entry standards. The court of appeals held that EPA had ample authority to issue regulations concerning re-entry, and promulgation of regulations by the EPA precluded the Secretary of Labor from issuing regulations under the Occupational Safety and Health Act (Wasserstrom & Wiles, 1985).

The Wage-Hour Administration of the Department of Labor has recently set reentry standards for 10- and 11-year old children in strawberry fields and is considering similar standards for cane-berry crops. The EPA first published a detailed proposal for establishing health and safety standards for workers in the *Federal Register* on March 11, 1974 (Wasserstrom & Wiles, 1985). These standards proposed to establish postapplication limits during which time no person could enter a treated area without protective clothing. A reentry interval of 48 hours was set for 11 toxic organophosphorus insecticides, as well as for Edrine, an organochlorine compound, and Clodimeform, a formaidine-type compound. In addition, specific "harvest entry times" or preharvest intervals (PHI) were proposed for over 50 crops. It was recognized that in practice the establishment of PHIs, primarily designed to reduce food residues to acceptable levels for human consumption, were usually more than adequate to afford protection to farm workers harvesting crops. It was also recognized in the standards that many pesticide labels had specified enforceable reentry intervals, even before the standards were published in 1974.

Two months after the first publication of the proposed reentry standards, and following extensive public hearings and review of public comments, a revised and abbreviated list of reentry standards was published (Wasserstrom & Wiles, 1985). Some of the pesticides were deleted from the list and reentry intervals were shortened for four less toxic but more highly volatile organophosphorus insecticides, i.e., from 48 hours to 24 hours. The other regulations included the following provisions:

1) prohibition against applying pesticides when unprotected workers are in the area being treated,
2) requirement that unprotected workers not enter fields treated with pesticides until sprays are dried or dusts have settled,
3) description of protective clothing requirements for workers who must enter treated fields prior to the expiration of the designated reentry intervals,

4) labelling which is more restrictive than the standards set forth and which takes precedence over the requirements stated in the general regulations,

5) requirement that workers be given appropriate and timely warnings when working in fields treated with pesticides, and

6) recognition of state responsibility and authority to set additional restrictions to meet local problems as warranted and EPA sanction of such actions. For example, the California Department of Food and Agriculture has established reentry intervals and other requirements for certain pesticides used within that state.

The pesticide exposure of greenhouse applicators is another current regulatory interest of the U.S. EPA. The EPA is specifically faced with the task of assessing the pesticide exposure of greenhouse applicators, pesticide labeling requirements, and protective clothing which is both effective and comfortable (Stamper, Nigg, Mahon, Nielsen, & Royer, 1989).

CHAPTER III

SPECIFIC INSECTICIDES AND REENTRY TIMES

In the following sections the characteristics and major categories or classifications of three groups of pesticides (insecticides, herbicides, and fungicides) is briefly reviewed, and the conditions under which they have affected the heath status of farmworkers is noted.

Insecticides

Until 1940, the major insecticides were inorganic compounds, including as several arsenicals, petroleum oils, nicotine pyrethrum, rotenone sulfur, and cryolite. World War II and its aftermath opened a powerful new chemical era for the control of pests, beginning with the development of DDT by Dr. Paul Muller in Switzerland. The major classes of insecticides are considered in the following sections.

Organochlorines

DDT (dichloro-diphenyl-trichloroethane) is the most important member of this group of pesticides. This compound controls louse-borne typhus and is effective against malaria-carrying mosquitos. According to Woods (1974), DDT was first used during a potentially serious outbreak of typhus in Naples in 1944. One million people were dusted with DDT on this occasion and its later use in India and other Far East countries has decreased death from malaria. DDT soon became the most widely used pesticide in the world. It has a high LD50 (oral rat, 300 mg/kg) and the main advantages of DDT appears to be its stability, persistence of insecticidal action, cheapness of manufacture, low mammalian toxicity, and wide spectrum of insecticidal activity.

Although large amounts of DDT have been used since World War II, comparatively little is known about its mode of action; however, the general symptoms of DDT poisoning are tremors and loss of movement, followed by convulsions and death. These symptoms clearly indicate that DDT acts on the nervous system. Problems with the use of DDT and related organochlorine insecticides their ability to accumulate in animal fat tissue, their effect on the ecosystem through contamination of the environment, their effect on wild life, and rapidly developing insect resistance. For instance, after animals feed on foodstuffs treated with organochlorine insecticides, these compounds have appeared in milk .

The other major synthetic organochlorine insecticides are; Dieldrin, Enderin, Dicofol, Chlorobenzilate, Bromopropylate, Chlorbenside, Chlorofenson, Fenazaflor, Hlordimeferm, Hexachlorocyclobenzen (HCH), Heptachlor, and Bezoepin. The most widely used organochlorine pesticides and their LD 50 are listed in Table 3.1. Aldrin, Dieldrin, and Endrin have very low LD-50 values, in comparison to DDT and other insecticides in the group. They are some of the most active general contact insecticides and like DDT they are highly lipophilic and persistent, but offer little systemic action. According to Cremlyn (1979), the Cyclodiene group insecticides possesses significantly higher acute mammalian toxicities compared with DDT or Lindane (HCH).

Table 3.1 Organochlorine pesticides in wide-scale agricultural use.

Common Name	Acute Oral LD50 mg/kg bodyweight (rat)	Acute Dermal LD50 mg/kg bodyweight
DDT	250	
Aldrin*	38-67	98 (rat)
Dieldrin*	37-87	60-90 (rat)
Endrin*	7-15	15 (rat)
Chlorobenzilate	1800	10200 (rabbit)
Bromoproplate	5000	5000 (rabbit)
Chlorofenson	1520-2070	2000 (rat)
Chlodimeferm	340	640 (rat)
Heptachlor	147-220	2000 (rabbit)
Benzoepin	30-110	359 (rabbit)
HCH**	88-125	1000 (rat)
Dicofol	820-960	1000-1230 (rat)
Chlorbenside	discontinued	

*Cyclodiene group organochlorine insecticides.
**HCH: hexachlorocyclohexan.
Source: *Farm Chemicals Handbook*, 1988.

With the exception of a few of the organochlorine insecticides, those used in the United States are not considered dangerous pesticides. Nevertheless, they should be handled with caution during such farm operations as mixing-loading and application to farm lands and crops. In order to avoid contamination, they should not be stored near food stuffs or bodies of water. Although protective clothing is not recommended for all of the organochlorine insecticide chemicals, protective rubber or PVC gloves, rubber boots, and clean clothes should be worn daily. In addition, the skin should be washed after the use of these chemicals. The most hazardous brands for farmworkers who mix, load, apply, or are occupationally exposed to pesticide chemicals, are Dieldrin and Endrin (Table 3.1).

Organophosphates

During recent years the organophosphate pesticides (OP) have virtually replaced the use of the organochlorines. Organochlorine compounds have lower toxicity, but they are stable and thus pose environmental problems. In comparison, the organophosphorus compounds do not present this problem because of their rapid degradation in the environment. However, they are highly toxic and are hazardous to farmworkers who use them in farm operations or who enter to work in a field in which OPs have been applied, such as orchards or vineyards. According to an expert report prepared for a commission of the European Economic Community published in 1977, 92 of the 502 pesticides registered for use were organophosphorus compounds. Of this number, 20 of those most popularly used in agriculture were selected for the study of their health effects. These are listed in Table 3.2, with the approximate quantities of pesticide used and the route of exposure.

Many of the organophosphate compounds function as systemic insecticides, enabling the effective use of a small amount of ingredients while reducing harmful effects to natural predators. As may be noted from Table 3.2, the amounts of organophosphate pesticides, the chemical pesticides most widely used in agriculture, are applied in varying amounts. Since, in comparison to other insecticides, these compounds are highly toxic, particular concern has been directed toward their health effects upon mixers, loaders, and applicators, or harvesters who enter treated fields. Of the applica

Table 3.2 World usage, selected organophosphate pesticides.

Common Name	Approximate Amount Used*	Oral LD50 mg/kg (rat)	Dermal LD50 mg/kg
Azinophos	++	50-70	220
Bromophose	++	3750-8000	-
Chlofenphos	+	10-39	400-4700 (rab)
Demeton methyl	+	65-75	350 (rat)
Diazinon	+++	300-400	3600 (rab)
Dichlofos (DDVP)	+++	56-80	107 (rab)
Dimethoate	++	215	1000 (G.P)
Fenchlothion	+	1740	1000-2000 (rab)
Fenitrothion	+	800	1300 (rat)
Formothion	+	365-500	1000 (rat)
Malathion	+++	1375	1000 (rab)
Methidathion	+	44	200 (rab)
Mevinphos	++	2-12	16-33 (rab)
Parathion ethyl	++	3-13	55 (rat)
Parathion ethyl	++	9-25	300-400 (rat)
Phosalone	+++	120	1530 (rab)
Phosphamidon	++	17-30	267 (rab)
TEPP	+	1.2-2	-
Thiometon	+	120-130	1000 (rat)
Tichlorfon	+	150-400	2100 (rab)

* large (+++), medium (++), small quantities (+).
Source: *Farm Chemicals Handbook*, 1988.

tions applied in medium quantities, ethyl and methyl parathion (Table 3.2), are the most hazardous pesticide chemicals in this class. The problem with Parathion is that following field application under such environmental conditions as sunlight, it is converted to oxygen analogs of "oxon," which are more toxic than the parent compounds. It should be noted that the use of Paraxon, the oxygen analog of Parathion, has been banned for commercial use because of its extreme toxicity toward warm-blooded animals and man. Among the organophosphates used in lesser quantities, TEPP (tetraethylpyrophosphate) is the most hazardous of this class because of its low LD50 and high toxicity (Table 3.2), and the fact that it can be rapidly absorbed through skin. However, it presents a rapid hydrolysis process and ethyl and methyl Parathion continue to be a frequently used if hazardous agricultural pesticide .

Although the respiratory tract is an important route of exposure for most farmworkers, the absorption of pesticides of this class occurs mainly through skin absorption when farm workers reenter a field following application and are exposed to foliar residues. Those most easily absorbed in this class are Guthion, Azordin, Parathion, and Malathion. There is variation in the amount absorbed, depending upon the anatomic region which has been exposed (Maibach, Fieldman, Milby, & Serat, 1971). For instance, the areas of the skin which absorb most poorly include the palm and abdomen and the areas which absorb the most rapidly include the elbow, forearm, armpit, neck, and scrotum, as well as any areas in which the skin barrier has been broken, allowing the rapid penetration of chemicals.

Wearing protective clothing, including rubber gloves, coveralls, goggles, and a respirator mask, during application, and long sleeves during harvesting, are important to the prevention of farmworker exposure to pesticide chemicals, reducing the extent of exposure significantly. However, it has been recognized that under actual field conditions wearing cotton gloves significantly increases the penetration of organophosphorus compounds. It should be noted that following exposure, washing with soap and water is the best way to remove OP from the body surface reduce the extent of exposure significantly.

Organophosphates and the Reentry Problem

Generally, it has been demonstrated that with working conditions designed for the prevention of OP absorption, farmworkers can work safely with the organophosphate chemicals without the depression of cholinesterase enzyme activity or signs and symptoms of intoxication. Although there have been no reports of fatal cases of poisoning from organophosphate pesticide residues related to reentry time, there have been numerous non-fatal cases of intoxication in a variety of crops in a number of geographic areas. At present, the allowable reentry times vary from state to state, and differences exist between state and federal standards. There are many factors which affect the length of reentry time before a entering a field treated with OPs, including the nature of the crop and the pesticide chemical used. One of the most important factors is the amount of dislodgeable residue on the crop, which varies with climate and crop. Knaak et al. (1978), following a case study of 14 male farmworkers exposed to a group of organophosphate pesticides in citrus crops, have stated that following application the actual residue levels (dislodgeable) must be considered and measured in determining reentry interval before a reentry time can be set. The reason, depending on the chemical residue and a number of other factors, is that the toxicity level in the field is often lower after a shorter delay times than longer delay times. However, national reentry times have been set for most organophosphate pesticides by the EPA and other federal agencies, and they are in general shorter in length than the times set by various states. For instance, ethyl-parathion has a federal re-entry time of 48 hours for all crops, whereas it has a 30- day time for citrus, a 21-day time for peaches and grapes, and a 14-day time for apples in California. Table 3.3 includes a comparison between federal and California reentry intervals for different crops.

Carbamates

As noted in Table 3.4, most of the commercially used carbamates have low oral LD50s. In this class, Aldicarb (Temik), which reflects strong anticholinesterase activity, is the most toxic pesticide in the group.

The problem with Aldicarb is that it is an unusual insecticide which does not contain an aromatic moiety, and on the plants it is oxidized to the sulfoxide and then more slowly to sulfur. Sulfoxide is relatively stable and has a higher anticholinesterase activity than Aldicarb itself. On the other hand, Aldicarb is a suspected mutagen. According to Bleviens and Regan (1977), Aldicarb alone does not produce mutagenic effects, but when it is converted to a nitroso derivative, it causes breaks in DNA. However, it should be noted that the question of the mutagenicity of Aldicarb remains unclear. The best example of the toxicity of Aldicarb are provided by two outbreaks of illness which occurred in Nebraska in 1979, associated with the consumption of hydroponic cucumbers.

Other pesticide chemicals in this group are also cholinesterase inhibitors and a have possible occupational exposure problem. Cholinesterase inhibition by carbamates is quickly reversible, which makes the measurements for determining a reentry baseline difficult for farmworkers. Carbamates are easily degraded into a number of other by-products in the body

Table 3.3 Comparison of U.S. and California reentry intervals.

Pesticide	California (days) Citrus	Peaches	Grapes	Apples	Federal (hours) All Crops
Parathion	30 45 60	21	21	14	48
Dioxathion	30	30	30	-	none
Guthion	30	14	21	14	24
Ethion	30	14	14	-	24
Supracide	30	-	-	-	none
Parathion	-	21	14	14	48
EPN#	14	14	14	14	24
Trithion	14	14	14	14	48
Dimecron	14	-	-	-	none
Phosalon	7	7	7	-	24
Omite	-	-	7	-	none
Methiocrab	-	7	-	-	none
Imidan	-	5	5	-	none
Demeton	5	7	7	-	48
Diazinon	5	5	5	-	none
Mevinphos	4	4	4	-	none
Dimethoate	4	-	4	-	none
TEPP	4	4	-	-	none
Methomyl	2	2	2	2	none
Naled	1	1	1	-	none
Sulfur	1	1	1	-	none
Malathion	1	1	1	-	none
Torak	-	-	75	-	none
Endrin	48 hours all crops				48
Metasytrox-R	48 hours all crops				48
Azordin	48 hours all crops				48
Bidrin	48 hours all crops				48
Disulfoton	48 hours all crops				none
Endosulfan	48 hours all crops				none
Phorate	48 hours all crops				none

Source: *U.S. Farmworkers and Pesticide Safety*, 1985.

Table 3.4 Carbamates in wide-scale agricultural use.

Common Name	Acute Oral LD50 mg/kg bodyweight (rat)	Acute Dermal LD50 mg/kg bodyweight
Aldicarb	0.9	20 (rabbit)
Mevinphos	3-12	16-33 (rabbit)
Methomyl	17	5880 (rabbit)
Carbafuran	11	10200 (rabbit)
Carbaryl	246-283	
Avensex	395	

Source: *Farm Chemicals Handbook*, 1988.

and are excreted via the urine. However, since they have a low LD50, they pose a serious hazard to farmworkers, and if massive chemical overdoses occur, the pesticide or its residues should removed from body as quickly as possible. It is important to note that acute respiratory failure may occur as a result of the paralysis of the respiratory muscles.

With respect to reentry timed, there is a rapid disappearance of the less severe exposure effects of carbamate pesticide chemicals on farmworkers, and cholinesterase activity usually reverts to normal values within a few hours. This class of pesticide does not actually have a national reentry time interval following application. However, variations in field reentry time periods between the states and those standards set by the EPA exist. For example, Mevinphose or Methomyl, which do not have national standard reentry times, have 2- and 4-day re-entry times in California, dependent upon the crop.

Herbicides

Herbicides, or weed killers, have largely replaced mechanical methods of weed control in past 20 years, especially in countries such as the United States which practice intensive and highly mechanized agriculture. Herbicides are of two kinds: (1) Selective, which kill just the weeds without damage to the crop, and (2) non-selective, which kill all vegetation. Herbicides are either inorganic or organic and strict EPA regulations specify which of the inorganic herbicides can be used because of their persistence in the environment. Nonetheless, herbicides are a very useful means of weed control.

Organic herbicides include different chemical groups. Among them most widely used of all herbicides are those chemicals which fall into the class of chlorinated phenoxy compounds, including 2,4,5-T and 2,4-D. Both of these chemicals, and a number of others, are on the EPA restricted use list. Regardless of the restrictions, 2,4-D is widely used worldwide and in the United States. Its major application in the U.S., including the Pacific Northwest and other states, is for wheat production and forest crops. Therefore, it may be considered a representative organic herbicide. The major herbicides used in this country and their acute oral and dermal LD50 are listed in Table 3.5

The herbicide 2,4-D is not persistent in soil or water and is believed to break down within four to six weeks after application, so it does not pose an environmental problem. As may be seen from Table 3.5, it has a lower LD50 in comparison to other herbicides in its class, but compared to other pesticide chemicals, e.g., the organophosphates, it has a higher LD50.

Table 3.5 Major herbicides in wide-scale use in the U.S.

Common Name	Acute Oral LD50 mg/kg bodyweight (rat)	Acute Dermal LD50 mg/kg bodyweight
2,4,-D	375	-
2,4,5-T	5000	-
Dalapon	970	-
Asulam	5000	-
Atrazin	1780	2000 (rat)
Endothal	51	-
Bromoxynill	260	-
Dichloroprop	800	-
Silvex	650	-
Mapica	1160	-
Mecoprop	930	-

Source: *Farm Chemicals Handbook*, 1988.

According to Wagner (1982), like , there are no documented cases of intoxication from either 2,4-D or 2,4,5-T occurring as the result of accidental exposure. There are a number of cases of intoxication resulting from 2,4-D which have either occurred as the result of accidental ingestion or suicide attempts. Accidental exposure to 2,4-D herbicide, in addition to the involvement of the peripheral nervous system, results in such symptoms as headache, nausea, and vomiting, vertigo, fatigue, and diarrhea, which may last for up to 10 days. The majority of these symptoms are now believed to be produced by the dioxin secondary product, rather than the phenoxyacetic acids. Therefore, in spite of many cases of intoxication reported due to accidental or intentional exposure to 2,4-D, the risk of intoxication with 2,4-D and other herbicide chemicals in this class is low from the standpoint of occupational exposure.

Normally, the body does not contain a level of 2,4-D. Therefore, in the case of either occupational or other form of exposure, the appearance of 2,4-D in the urine would be the simplest procedure to measure the extent of the exposure. In most cases, farmworkers will not excrete 2,4-D in urine, even after a full working day of exposure, since minimal safety practices, including long-sleeved shirts, hat, and boots, are adequate protection from absorption. Again, according to Wagner (1982), even for the unprotected worker the safety factor is better than 1000:1. Since the level of 2,4-D normally does not exceed 1.0 ppm in urine, and there are no established levels for toxicity, it is difficult to indicate when intoxication is likely to be present for occupationally exposed individuals who enter a treated field.

Fungicides

Fungicides have an important role not only in American agriculture, but also in the economic status of developed and developing countries. From the economic standpoint, if fungicide chemicals were not available, the loss on grapes and peanuts would be as high as 100 or 75 percent, respectively. According to an official report, *Fungicides: An Overview of Their Significance to Agriculture and Their Regulatory Implications*, issued by the EPA, it has been estimated that 145 million pounds of fungicides were produced and used in 1974. Without treatment of seeds with these chemicals about 25 percent of the wheat and oat crop would be lost. Therefore, their importance in the protection of crops and feeding growing populations is obvious. Another advantage of the use of fungicidal chemicals is that they are most often not considered a major environmental concern to public health, or a hazard to the farmworkers and those individuals who are involved in fungicide applications. However, many questions have been raised about their chronic and long-term safety, especially with regard to possible biodegradation to potential carcinogens. In the Table 3.6 the most frequently used fungicides and their acute oral and dermal toxicity are listed.

Table 3.6 Fungicides in wide-scale use.

Common Name	Acute Oral LD50 mg/kg bodyweight (rat)	Acute Dermal LD50 mg/kg bodyweight
Captan	9000	-
Benomyl	10000	10000 (rabbit)
DBCP	170-300	1240 (rabbit)
Thiram	780	-
Zineb	5200	2500 (rat)
Dinocap	980	-
Avicol (PCNB)	1200	4000 (rat)

Source: *Farm Chemicals Handbook*, 1988.

As may be noted in Table 3.6, the most commonly used fungicides have high acute oral and dermal toxicity. This is the likely reason that fungicides do not pose acute occupational hazards, such as do other pesticide chemicals. In this group, the chemical Captan could be identified as the most toxic of the fungicides used in the United States. Not only does Captan have a high acute LD50, but large amounts are produced and used in a variety of formulations available to users (e.g., dust, wettable, granular), as well as in combination with other fungicides. It has been estimated by the EPA, that of the 17 million pounds of Captan produced in the United States in 1972, 16 million pounds were used in agriculture. Although it is used, limited data are available on its acute inhalation effects, or on the possible occupational hazard to workers who have been working with this chemical in industrial production or agricultural applications. However, there is concern about long-term effects of Captan because of their teratogenic, carcinogenic, and oncogenic effects on experimental animals. Captan is rapidly absorbed through the gastrointestinal tract, but is rapidly degraded in the blood and does not bioaccumulate in tissue. It is also readily degraded in the environment. No reentry times have been established for individuals who enter treated fields, but since most of the time fungicides are applied in spray form, wearing protective cloth, including a respirator, goggles, and gloves, are necessary because of inhalation and mild sensitization effects on the skin.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study reviewed the literature of injury and poisoning to farmworkers over the past 20 years which was due to exposure to insecticide chemicals (pesticides, herbicides, and fungicides) and their residues during harvesting, mixing, loading, and application, as well as other field activities, in agricultural crops in the United States. The objective of study was to determine which factors are associated with workers' injuries due to exposure to these chemicals.

Agricultural chemicals are a fact of modern life and benefits drawn from their use are undeniable. But at the same time their effect upon public health and the environment is both controversial and a worldwide problem. There are many issues of concern, centered upon the social, economic, health, and environmental problems related to pesticide use. In the broadest economic sense, the pesticide industry is part of the chemical industry, which is among the largest industries in the U.S. in terms of capital and equipment investment. It is also an industry which is heavily dependent on scientific knowledge and experience.

The most important group of pesticides, in terms of amounts used in U.S. agriculture, are insecticides and the second most important are the herbicides, followed by the fungicides. Although pesticides have been used heavily in agriculture, farmers continue to lose about 30 percent of their potential crop yield (i.e., about $20 billion) each year in the United States. Without the use of pesticides this annual crop loss would be closer to 50 percent, i.e., the use of pesticides and other methods of control has decreased by annual crop losses by 36 percent (Pimentel & Levitan, 1986). The benefits of pesticidal uses in the control of vectorborn human diseases can also be viewed positively.

Conclusions

It has been determined in the present study that there are many factors and different conditions which are associated with the extent of exposure, the severity of symptoms, and the short- and long-term effects of human pesticide exposure. Since exposure to pesticides and related health hazards are multidimensional, one of the factors associated with farmworkers' injuries or poisoning by pesticide residues is how the exposure can be determined and calculated. Data from skin, clothing, and other contamination exposures, which have been traditionally used to determination overall exposure, is not sufficiently adequate to establish a base for the evaluation of the likelihood of poisoning. For example, the entrance of a foreman into a field 10 minutes following application for 30 minutes does not necessarily mean that the foreman is not exposed because of the short stay in the field. However, if the same foreman enters 10 fields a day, this person would be exposed to toxicants for 300 minutes, which is of sufficient duration to cause an effect. The overall length of time exposed is one of the associated factors in the extent of poisoning.

Another important exposure factor is the route of entry. Dermal absorption is the main route of entry for most organophosphates and carbamates, while organochlorines, in particular DDT, do not have high dermal absorption levels. Another confounding factor in determining the extent of exposure in the case of cholinesterase depressing pesticides is that some of them do not reduce the blood cholinesterase value below normal values, and depression will likely go unnoticed for a long time prior to the appearance of overt symptoms. This emphasizes the necessity of using more sensitive equipment in determining cholinesterase values, particularly with reference to the determination of baselines prior to re-entry into treated fields. One other major factor with regard to cholinesterase depressing organophosphate pesticides is their conversion to more toxic residue substances than the parent compounds. The production of paraxon from Parathion is a good example (i.e., paroxon is much more toxic than Parathion). This can cause problems in the calculation of re-entry intervals. The reason is that since reentry intervals have been based on the assumption that, as time passes, the pesticide's active ingredient or residues become less toxic, conversion of these residues to more toxic materials with time will put the reentry concept, insofar as it is the sole means of prevention, in some jeopardy. In addition, there are a number of other factors, including the level of foliar dust, sunlight, and dry conditions, which can increase this conversion.

Although poisoning can happen at any age and chloinesterase enzyme activity does not change with age, age could be an indirect factor in the establishment of reentry intervals and subsequent farmworkers' injuries due to exposure to pesticides residues. The reason is that migrant farmworkers who come to the United States to work on farms as labor are young and are generally in good health. Since they are not trained or educated in how to handle highly toxic chemicals, nor do they generally wear protective clothing, these workers may develop the symptoms of intoxication. Since they are young and healthy and, for the most part, have been exposed to residues over long periods of time, their reaction could be different than those more representative of the median population. Therefore, data from the exposure of migrant farmworkers cannot be extrapolated to the general population and the measurement of cholinesterase activity may not give the true value of this enzyme activity to be used in the establishment of reentry intervals.

The nutritional status of farmworkers, especially their dietary protein intake, is another factor which must be considered. This is particularly true in cases of chronic exposure to pesticides due to the low socioeconomic level of the labor force in agriculture industry, especially in the instance of migrant farmworkers. This also applies to developing countries, for example, India where religious faith does not allow consumption of animal protein, and where pesticides are extensively used in patterns of intensive cultivation.

The amount of the pesticide used and its toxicity are two important factors in the poisoning of farmworkers. Sufficient amounts of pesticide must be available to cause acute adverse health effects, dependent upon the toxicity of the individual chemical in use. Some of them which have low LD50s, such as Parathion, can cause effects in small amounts, while others, such as DDT can be directly applied on the skin because of its high dermal LD50 value.

Sometimes the crop itself can decrease or increase pesticide absorption. For example, during the harvest of tobacco the plant's juice (gum) accumulates on the hands and prevents skin absorption of the residue through the skin by adhering. There are many other factors which can reduce the extent of exposure that should be considered, including wearing protective clothing, the climactic condition of the area in which the pesticides are used, application methods, and even the behavior of farmworkers in such matters as personnel hygiene and good housekeeping.

As was noted in several different investigations reviewed in this study, factors associated with farmworkers' injuries due to exposure to pesticides chemicals and their residue is multidimensional, and there are many factors which affect their toxicity and the severity of symptoms. Moreover, for the forseeable future, the use of pesticides in order to assure adequate food production for the increasing populations leaves few options other than the continued use of millions of pounds of pesticides as a means of increasing crops and decreasing damage to crops by pests. At the same time, it seems clear that increasingly huge amounts of pesticide applications have caused environmental health problems, leading to the conclusion that a rational plan must be developed for the use of pesticides. The wise use of pesticides, including the use of protective clothing, the use of the right equipment for applications, the establishment of proper reentry intervals, the education of farmers and involved individuals, and the selection of the least hazardous and most effective pesticides could be effective in reducing farmworkers' acute intoxication and injuries. Nonetheless, even this solution leaves us with the problem of chronic effects and environmental pollution.

Documentation could be the most valuable tool for implementing changes both in the diagnosis and management of exposure by medical professionals and in safety regulations for pesticides usage. States vary in their requirements for notification and reporting of pesticide-related illness and California is the only state that has mandatory reporting which places a legal responsibility on physicians and other health personnel to report all cases of pesticide poisoning.

The documentation of pesticidal exposures to farmworkers can be difficult, if not impossible. The only group which can document the extent of poisoning or pesticide-related illnesses are the physicians and clinicians who provide health care after exposure. This will entail a number of difficult problems, including the questions of how to accomplish the task, the determination of when a level of poisoning constitutes a diagnosis of pesticidal exposure, the extent to which local and state health departments will be able to assist physicians and clinicians, and the degree to which these efforts will be supported by legislative action and law enforcement. Answers to these questions are not clear, though necessary regulations have been established in many states. One of the difficulties in documenting pesticide-related injuries is the degree of responsibility felt by health care personnel and the accuracy of the diagnosis and reporting system. For example, if cholinesterase enzyme activity is the basis for assessment of exposure, having a baseline for the accuracy of measurement is important since, due to low level and long-term exposure to cholinesterase depressing pesticides, farmworkers manifest depressed enzyme activity. One other factor affecting the accuracy of documentation is the existence of other cholinesterase depressing conditions, such as disease. According to Moses (1987), symptoms of pesticide poisoning could be confused with the symptoms of flu or gastroenteritis.

One other problem with the documentation of farmworkers injuries, especially for migrant farmworkers, is their movement from state to state. For example, a migrant worker registered in Arizona comes to Oregon and works in the state, though he is not legally allowed to work in Oregon. This causes fear of complaint and works against seeking medical care when poisoning occurs. We can add to this problem the language deficiency of migrant farmworkers, who are not always able to describe their exposure symptoms to growers or farm owners. The hiring of health personnel with Hispanic backgrounds would elevate the accuracy of cases reported and should result in more accurate documentation.

Except for California and a few other states in which farmworkers are employed year around, harvesting is mostly seasonal and intensive in nature. For many migrant farmworkers, complaints about symptoms of mild exposures, such as headache or dizziness, could place their jobs in hazard. Since these workers are often "illegals," reporting sickness could result in their deportation. To this factor we can add that there are many states in which farm owners are not legally obligated to provide the information in cases of acute exposure resulting in illness and injury, which also causes problems to investigators who try to document cases of intoxication.

Many investigators have stated that the education of farmworkers and the institution of proper training and labeling programs will decrease the number and extent of exposure. Education and training have reduced the number of exposures, as evidenced by the increased number of cases reported, but labeling will not reduce workers' injuries because the farmworkers who are in direct contact with the pesticide residues usually do not have access to the containers or are not able to read it in the English language.

Due to low socioeconomic status of farm workers families in many developing countries, and migrant farmworkers in this country in particular, children offer a significant contribution to the workforce and family income. This is one of the situations which causes major health problem among children. Aside from acute health effects, the relation of cancer in children and pesticidal exposure is another problem. In Ohio, five children were diagnosed with neuroblastoma when their mother had been exposed to Chlordane (Infante, Epstein, & Newton, 1978). Nine cases of colorectal cancer connected with pesticide exposure were diagnosed within a two-year period in rural areas in Mississippi, Arkansas, and Tennessee (Pratt, Rivera, & Shanks, 1977).

One of the problem factors is that the number of workers injured by pesticides each year is not known, but can only be estimated at 300,000 farmworkers' poisonings each year (Wasserstrom & Wiles, 1985). Of more than one billion pounds of pesticides used in the U.S. (U.S. Environmental Protection Agency, 1986), organophosphates are responsible for 25 percent of the injuries each year (Retting, Klein, & Sniezek, 1987). There have been many cases of worker poisoning reported by investigators which occurred due to direct contact with residues on crops during harvesting (Hayes, 1982, Midtling & Coye, 1984; Morgan, 1982; Namba et al., 1971; Peoples & Maddy, 1987; Tafuri & Robert, 1987). With good record keeping and mandatory reporting, such as required in California, it would be easier to document the acute health effects of pesticides poisoning. Problems would still remain with documenting chronic effects.

Although investigations of chronic health problems related to occupational exposure to pesticides have been undertaken, little information has been derived. In case of malignant lymphoma, leukemia, and multiple myeloma, the increased risk of cancer has been documented (Blair & Tomas, 1979; Blair & White, 1985; Burmeister, 1981; Cantor & Blair, 1984; Everett, Blair, Cantor, 1985; Milham, 1971; Saftlas, Blair, & Cantor, 1987; Stubbs, Hams, & Spear, 1984). This includes testicular cancer (McDowall & Balarajan, 1984; Mills, Newell, & Johnson, 1984), liver cancer in agricultural workers in New Jersey (Stemhagen, Slade, & Altman, 1983), and increased risk of stomach cancer in Iowa (Burmiester, Everett, & Van Lier, 1983), Wisconsin (Saftlas et al., 1987), and California (Stubbs et al., 1984). Also excess mortality from lung cancer has been reported in Florida and Maryland (Mabuchi, Lilienfeld, & Snell, 1980).

There are several other limitations to drawing conclusions from the studies cited on the chronic effects of pesticidal poisoning. One of these limitations is the small number of deaths that have been reported. Simply enough, we cannot know how many people have died due to chronic pesticidal exposures. Except for a few epidemiological studies, the small sample size is another limitation which biases the result of these studies and makes it difficult to extrapolate these results for the general population. Another limitation in determining chronic health effects from farmworkers' exposure to pesticides is the long period of time needed to observe effects between the last exposure and the development of a disease. In addition, one of the biases in long-term, low level exposure could be selection bias. Most studies have been completed on farmers or farm owners, and not on the farmworkers who are in direct contact with pesticides or their residues.

Current policies by official organizations such as the EPA are directed at the establishment and enforcement of reentry times in order to prevent further farmworker poisoning. Although reentry intervals are effective in the prevention of acute exposures, these intervals do not always protect workers due to the lack of consistent law enforcement. The recent death of a 32-year old farmworker, who died approximately six hours after he was sent into a treated field that had been sprayed one hour before with the organophosphate Monitore (Moses, 1988), indicates a possible failing of the selected time intervals. In addition, reentry intervals also fail to protect workers from long-term, low level exposure.

Furthermore, based on animal studies, a large percentage of pesticides used in agriculture are carcinogenic or teratogenic. According to Begley (1983), there are deficiencies in the toxicology submitted to the EPA by agrichemical companies on the acute and chronic toxicity of their products. Agrichemical companies claim that there is no evidence of increased risk of chronic effects, including cancer, from pesticidal exposures by humans. They state that their products can be safely used and pose no carcinogenic risk to general populations, who are exposed to much lower levels.

In summary, the factors associated with farmworkers' injuries due to exposure to pesticidal chemicals and their residue is multidimensional, and there are many factors which affect their toxicity and the severity of symptoms. On the other hand, the use of pesticides in order to assure adequate food production increasing populations leaves few options, other than the continued application of millions of pounds of pesticides as a means to control crop loss factors. Increasingly large pesticide applications have caused environmental health problems and a rational plan for the safe use of pesticides is strongly recommended.

Recommendations

It is widely accepted that precaution can and should be taken to avoid personal contamination by farmworkers involved in pesticide application, harvesting, or any other type of agricultural field activity. Suitable precautions have been advocated by a number of investigators, as well as by federal and state authorities. However, the same investigators and agencies state that the existing regulations are neither consistent, fully adequate, nor fully enforced and they fail to protect all farmworkers in direct contact with pesticides or those who are subject to low level pesticidal chronic exposure effects through food and water contamination. In most reported instances of farmworker poisoning or illness, the affected worker(s) has not been supplied with items of protective clothing or equipment and have not been instructed in how to handle and work safely with pesticides. Most farmworkers, particularly the migrant workers, are not even aware of the name of the pesticide they are handling or to which they are exposed. Therefore, the development of adequate and consistent education and training programs for these workers is strongly recommended. What this implies is the institution of both widespread and uniform educational programs which provide up-to-date information encompassing changes in governmental regulations at all levels, changes in the types of crops to which pesticides are applied, and changes in the behavior patterns of farmers and farmworkers who use the pesticides, as well as any other factors which may have changed at the times particular pesticides are placed in use. In addition, since existing state and federal regulations have failed to provide uniform protection for farmworkers, a stronger and more consistent enforcement effort is required in order to provide safe work places for farmworkers in the U.S., or residences for those whose live adjacent to agricultural worksites using pesticides. Moreover, it does not appear that it is sufficient to merely require farmowners and managers to provide the means of protection for the use of farmworkers--regulatory agencies should ensure that the wearing of protective clothing and the observation of protective regulations is also the responsibility of individual farmworkers, no matter the difficulties this may pose in some climates.

From this study it is clear that additional education and training for farmers, farmowners, and farmworkers and the consistent use of safety equipment would do much to reduce the acute effects of pesticide exposure. With respect to the chronic and long-term effects of pesticide exposure, although the assessment of the results of epidemiological studies are difficult to interpret and there are any number of biases which can affect the results of these studies, the message to parties concerned with public health is quite clear. Research priority and support should be given to further epidemiological studies aimed at the biological assessment of long-term, low level exposure to pesticides and their potential residues which can affect human populations.

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