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Introduction and Overview

Farming has the allure of a healthy lifestyle. Farmers usually live far from congested and polluted urban areas and are generally healthier than urban counterparts. Farmers have lower mortality rates from ischemic heart disease and cancer as compared to other occupations of the same age and sex.[1] Despite this seemingly idylic life style, there are health risks associated with farming that underscore the serious nature of the labor endured by those in agribusiness. Estimates from the United States Department of Agriculture (USDA) indicate that 3.7 million people are employed in farming in the United States.[2] The Office of Migrant Health, of the Department of Health and Human Services, estimates that between 2.7 and 5 million hired employees in the agribusiness are seasonal and migrant workers with, approximately 30% being migrant.[2] Farming remains dependent on seasonal and migrant workforces in most areas of the country.

Prominent health and safety isssues in agriculture involve exposure to a variety of chemicals and pesticides, trauma, respiratory disease and cancer. Agriculture production is one of the most accident prone occupations in the United States.[1] Farmers have higher incidences of certain types of cancer as well as higher incidences of morbidity and mortality from respiratory disease.[1] As contrasted with other industries, there has been a paucity of organized occupational safety and health programs dedicated to disease prevention, health promotion, and medical care of the farm worker. In addition to the injuries and illnesses sustained by farm workers, broader public health issues have also come to attention in the form of the spread of pesticide and chemical residues from the farm land into grounwater, air and soil. The contamination of rural groundwater with pesticides and other chemicals is just being recognized as a potential health problem.

In developing countries, more than 50% of the population is involved in agriculture and farming whereas in industrialized nations less than 5% of the population are involved in agicultural business.[3] Since food must be provided to the world's population of 5 billion, agriculture remains an

important contributor to the world economy. Despite this economic importance, farming as a business and way of life has faced financial and political hardships.[4] American farmers produce enough food to feed the population of the United States and export $40 billion in produce annually.[5] Despite the fact that the family farm is the single most common unit for the production of the agriculture economy, the family members who work on farms are not protected by state or federal labor regulations.[5] All age groups work on farms, and thus injuries and illnesses are common to those under 18 as well as over 65 years of age.

Overall mortality for common diseases in farmers appears to be less than the general population, however, injuries and illness related to farming continues to rank as high as mining and construction industries. Strategies to improve the delivery of occupational and environmental health services to farming communities are needed.[6] Such health programs must focus on critical areas with regards to the business of farming:

(1) Injury prevention
(2) Prevention of respiratory disease.
(3) Medical surveillance for health effects from exposure to pesticides.
(4) The increasing incidence of certain forms of cancer in farm workers.
(5) Prevention of toxic effects from chemicals
(6) Environmental chemical pollution of soil and water
(7) Exposure of the public to pesticides.
(8) Education and health surveillance programs.

Rural healthcare has always been a difficult service to deliver and occupational healthcare delivery to farming communities is no better. There continues to be a decline in the availability of healthcare to rural populations. Rural hospitals continue to close at a rate higher than urban hospitals. Physicians have little incentive to practice in these underserved areas and if they do, they are usually not trained in occupational and environmental health. During the 1980-1987 period, 161 rural hospitals located mainly in farming states (Minnesota, Wisconsin, Illinois, Texas, Oklahoma, and Louisiana) closed.[5] These closures followed the implementation of Medicare's Prospective Payment System, which pays

rural hospitals 36% less than urban counterparts for same services.[5] Physician to population ratios in rural areas continues to be less than in urban areas. Recruitment of physicians is hampered by attractive urban reimbursement standards and lifestyle [7].

Research into novel healthcare delivery programs to farming communities is occurring in some states, but more is needed [7]. State and federal regulations to protect farmers and farm workers are also needed. the National Association of Community Health Centers and the National Rural Health Association have pointed out that the United States Spends 42% less on funding of rural healthcare versus urban healthcare despite the fact that rural populations have higher rates of chronic disease.

Epidemiology of Injuries and Illness

The National Safety Council ranks agriculture as the nation's most dangerous industry with the highest annual work death rate of all industries (Table 1, Figures 1 and 2).[8] Tractor related accidents are the leading cause of fatal injuries.[4,8] Machinery, animals and trucks are the leading causes of non-fatal injuries .[4,8] These figures may actually be underestimates since agricultural facilities with less than eleven employees are exempt from the Occupational Safety and Health Administration's (OSHA) legal injury and illness reporting requirements and more than 95% of farms have less than this number of employees.[9] Estimations of work-related deaths and serious injuries are based on multiple sources such as the National Safety Council, Department of Labor, and the Center for Disease Control. Data on accidents and injuries is frequently difficult to collect.[8,9]

To help correct the problems associated with multiple federal agencies collecting data on mortality statistics from accidents and injuries, the National Institute of Occupational Safety and Health recently created the National Traumatic Occupational Fatalities data base (NTOF) which provides a uniform approach of work-related health surveillance for trauma linked mortality.[10] In addition, the NTOF includes agriculture in its surveillnace

program. However, the NTOF only uses infromation from death certificates and can miss fatalities.

The accident suveillance program of OSHA covers less than 11% of farming business due to the small number of employees per business in the farming industry.[10] In contrast, NTOF has no exclusions for certain worker groups. The NTOF data base shows that the overall agribusiness, which included production, services, forestry, and fishing) had an annual mean mortality rate of 20.7 deaths per 100,000 workers from 1980 to 1985 compared to a mean of 7.9 deaths per 100,000 workers in the general workforce.[10] If agriculture production is separated out from services, and forestry and fishing are excluded, the producing agribusiness has a mortality per 100,000 three times that of general industry (figure 3). Age specific mortality rates are highest in the 55-64 year old group (figure 4).

National Safety Council statistics from 1989 show that there were 40 deaths per 100,000 population in the agriculture industry compared with 9 per 100,000 in all other industries [8]. Mining in 1989 had 43 deaths per 100,000 (Table 1). However, these statitistics do not include anyone under the age of 14. Some states have data on children under the age of 14: Indiana,14% of fatal farm injuries involved children under 15 years; Wisconsin, 24%, and Pennsylvania, 19%.[8,9]

Despite the difficulty in obtaining accurate health surveillance data a pattern of disease and injury linked to farming as an occupation has been identified [4]. Most fatalities in farming are due to trauma secondary to machinary and tractors (Figures 5a and 5b). Other causes of fatalities include animals, electricity, drowning, trauma from objects, and toxic exposures.[4,8] The majority of those injured are males between the ages of 20 and 60.[4] If the statistics are arranged to look at those injured with the most hours worked, children and older males, ages 14-20, have the highest injury and mortality rate.[4] More accidents and injuries occur in farming than in any other business, yet there is a distinct lack of organized comprehensive health and safety programs that address the problems unique to this business.

The type of labor involved in farming gives rise to other sorts of injuries that are more chronic, such as muscle, joint, and bone injuries secondary to repetive motion or vibration. Noise and hearing constitute another problem. The type of farm labor and associated illness and injury also varies depending on the developing status of a country. Physical activity and manual labor are characteristics of third world agribusiness. Developed countries use more mechanized approaches to labor. Exposures to toxic chemicals are more common among laborers in developing countries.

Fatal agriculture-related accidents far exceeds the number of work related deaths in other industries. Workers are potentially exposed to a tremendous variety and quantity of synthetic chemicals used as fertilizers, pesticides and fumigants. These chemicals pose both acute and chronic health hazards. Exposure to organic materials and microorganisms from plant and animal origin have also been shown to have detrimental effects on the respiratory system. Organic Dust Toxic Syndrome and Farmer's Lung Disease, an allergic alveolitis, are well known agricultural occupational diseases. Farmers have also been shown to have increased incidence of lymphatic and hemopoietic, stomach, brain, prostate, lip, skin and connective tissues cancers than do other occupational groups. Exposure to dust and molds from grain and hay is attributed to an excess mortality rate due to respiratory disorders. Skin disease in the form of mechanical trauma, over exposure to sunlight and chemicals, and dermatitis are commonly seen occupational hazards of the industry.

The aggressive use of chemicals, pesticides, fumigants, and fertilizers has resulted in a variety of health concerns to both the individual laborer as well as to the public. The use of pesticides is both an emotional and political issue as well as an economic conern. Aerial spraying and crop dusting can expose both workers as well as members of the public. In addition, the widespread contamination of groundwater and soil beyond the point of pesticide and chemical application raises concerns of larger environmental pollution and public exposure to low levels of pesticides, nitrates, and other chemicals.

Health problems of farming can be ordered in nine general categories:

1. Trauma and injury- acute and chronic
2. Respiratory disease
3. Toxic exposures to chemicals
4. Cancer
5. Skin disease
6. Infections
7. Hearing loss
8. Neurological disorders
9. Muscle and joint disorders

The extent to which occupational related exposures are associated with various health disorders is difficult to accurately assess. Unlike other industries which have access to specialized occupational medicine programs and physicians, the agriculture industry has traditionally lacked the dedicated and organized health and safety approach common to other industries. This is especially true in third world countries or in the case of migrant farm workers. The lack of uniformity in diagnosis, testing and evaluation of occupational factors makes it difficult to perform effective epidemiological evaluations. Worker compensation data is also inconsistent due to various exclusions, exemptions and loopholes in state laws.

Agriculture is a unique industry because people of all ages are at risk. Farms are often both work sites and homes so that even non-workers can be exposed to hazards. Thus, it can not be assumed that the majority of farm injuries and illnesses occur with full-time farmers since hired workers, spouses, young children, retired and part-time farms are also at risk. The diversity of the workers differs from one are of the country to the other and within each area agriculture workers differ from the work force in other industries.[11] For example, each year over 300,000 agricultural laborers work in the state of California. These workers differ from the rest of the work force in the state in the nature of their work,

ethnic and cultural make-up, and in their socioeconomic and employment relationships. A significant portion are Mexican nationals who work transiently, moving to a new location as work becomes available.[11] The great diversity of crops cultivated in California create a multitude of job tasks each of which may entail its own particular risk. Workers in southwestern states share these characteristics. The workforce in the southeastern states differs in ethnic make-up and sociological factors. Workers are often informally recruited by labor contractors and have no idea whose field they are working in. These factors combine to make it difficult to obtain valid data to ascertain the extent to which occupational health problems exist among migrant agricultural workers.

Agriculture workers in other regions have their own set of occupational exposures varying with the type of crops and animal production carried out. In the midwestern and north central United States, where crops and harvesting practices differ, automated farm equipment is extensively used in the harvest of grains and cereals. Animal confinement systems, grain silos and hay storage each have characteristic hazards and associated health effects.

Comparisons of respiratory disease rates for farmers and farm laborers show regional differences between Iowa and California:. California showed an elevated rate relative to Iowa. Although the reason for this difference is not fully understood, the differences in the mobility and the socioeconomic and ethnic backgrounds of the worker populations and difference between crops and work practices are cited as potential explanations.[12] For example, pesticide usage is high in both areas; however the crop mix is substantially different between the two states. Iowa has greater acreage of corn while California has substantial commercial vegetable acreage. Thus while California requires intensive applications of halocarbon fumigants for controlling nematodes, in Iowa this problem is typically controlled by granule-formulated organophosphates. Fumigant gases may be widely used in warehouses containing perishable crops, elemental sulfur dusts are used as miticides and fungicides, and large quantities of Organophosphate and carbamates are applied to orchards, vinyards and row crops.

Comprehensive Occupational and Environmental Health Programs for the Farming Business

Recognition of the unique problems related to occupational and environmental health of the farmer and farm workers has led to the call for improved medical surveillance and health services in the United States and other developed nations. Policies and strategies for future disease prevention have been the focus of conferences at the university and government level.[6] Despite the fact that farming is one of the top three hazardous occupations ranked with mining and construction, there is no industry specific comprehensive occupational health and safety services established in the United States. Whereas mining and the construction industry are regulated by the Mining Safety and Health Administration (MSHA) and OSHA respectively and served by existing occupational health and safety programs, farming has not enjoyed this integrative medical and technical approach. Industrial hygienists, safety specialists, engineers, and specialized health care providers have not been available to meet the needs of the agribusiness in an organized and comprehensive fashion.

Model farmer health and safety programs have been functioning in Sweden and Finland.[3,13,14] Many of these programs may serve as models for future program development by other countries. Sweden provides occupational health services to farmers in all regions of the country through 33 specialized occupational health centers.[15] Comprehensive health services are provided by a team of physicians, occupational health nurses, safety engineers, and other related health and safety specialists. This provides a dual medical-technical approach that can address farming issues ranging from clinical treatment and prevention services to medical surveillance and industrial hygiene.[15] At the governmental level, there is a regional director for each of six regions in Sweden which coordinates the activities of the local health centers in their region. A central office in Stockholm administrates these six regions.

In the U.S., Iowa has implemented a model community-based health and safety program which targets the family farm and small agribusiness using local community health care facilities to deliver services while the University of Iowa acts as an overall management center.[14] Eighty percent of the economy of Iowa is dependent either directly or indirectly on agriculture; thus illness and injury in the farming community can have tremendous impact.[14] The Iowa Agricultural Health and Safety Service Program was a two year study funded by the State legislature in 1987 in an effort to develop a model program for disease prevention. It used existing health services within communities to deliver sophisticated occupational health and safety programs. Its organizational structure (Figure 6) is dependent on the University of Iowa, College of Medicine to manage the project, train physicians and staff, develop educational programs, provide medical consultation, serve as a tertiary care referral resource, and provide consultation in industrial hygiene and environmental health. The community hospital, in conjunction with local clinics provide the direct services. A multidisciplinary approach is used at the clinic level by a staff of specially trained physicians and nurses. Safety specialists and industrial hygienists are available from the University. Telephone consultation and basic educational programs are provided free or at low costs to all farmers. On site industrial hygiene consultation is also available if an accident or injury occurs.

Colorado has had successful experience with an agriculture safety and health program since the late 1970s.[16] Based and managed from Colorado State University, the program was funded by a W.K. Kellogg Foundation grant and initially provided workplace health and safety consultation to small business throughout the state and the Rocky Mountain region, including farmers. The success of this venture led to stable funding of the program now named the Colorado Occupational Safety and Health Consultation Program. However, it was recognized that direct consultative services were not utilized as much by the small farmers as they were by other non-agiculture based businesses. A re-direction of this effort created the Workplace Health in Agriculture Program (WHIAP) which sought to educate farmers and ranchers with respect to the relationship of health hazards to the agribusiness using a variety of educational media and

techniques. An essential feature of the project was the addition of expertise in toxicology and occupational health that could address issues of chemicals and pesticides. In addition to educating the individual farmer, educational forums were held for the medical community to make physicians and other healthcare providers aware of the unique work-related accidents, illness, and injuries associated with the agribusiness. [16]

Another unique healthcare delivery network was initiated in Wisconsin by the Marshfield Clinic in 1979.[5] This system utilized existing rural medical facilities and practicioners and linked them to the Marshfield Clinic via telecommunications and transport systems. Primary care was provided locally and the Clinic served as a resource center for consultation, diagnostic services, tertiary care referal, and continuing medical education.

Overall, healthcare delivery to farming communities has begun in a variety of countries and states, new policies and strategies. The needs of agricultural workers can be met when new policies and approaches are adopted.

Respiratory Health Hazards in Agribusiness

Farmers are subject to develop a variety of pulmonary diseases identified as occupational hazards: chronic bronchitis, abnormal pulmonary functions with limited airflow, emphysema, allergic alveolitis, asthma, Farmer's Lung Disease, Silo Filler's Disease, and Organic Dust Toxic Syndrome. The increase in respiratory disease in farmers is concerning and prevention can play a role in decresing morbidity and mortality.[1]

Chronic Bronchitis and Respiratory Disorders

Farmers have a high incidence of pulmonary symptoms which are attributed to exposure to dusty environments. The ambient air in and around various agricultural production, storage and transportation facilities is laden with a variety of gases, dusts, suspended particles, and bioaerosols which pose a risk to the respiratory system. These include

organic antigens such as pollen, fungal spores, animal danders, grain dust and mites; synthetic chemicals such as fertilizers, insecticides and herbicides; and toxic gases released from decomposing plant or animal material. It has long been noted that farm workers are at risk of developing respiratory health disorders, however, limited information is available on the prevalence and specific causes of lung dysfunction in this segment of the work force. Although the reason for excess mortality from respiratory disease is not known, it is suspected that exposure to organic dusts, exposure to endotoxins, and exposure to thermophilic fungi are primary factors in the production of pulmonary diseases.

Studies have shown that organic dust and tobacco smoke are independent and additive causes of chronic bronchitis.[17] Only 6% of non-smoking farmers compared to 10-14% of smoking farmers have chronic bronchitis.[17] Table 2 outlines the physiological responses to commonly encountered causative agents characteristic to particular respiratory disorders.

Agricultural lung diseases can be divided into immunologic and nonimmunologic:[18]

Immunologic Type I: Acute or chronic Asthma

Immunologic types III-IV: Acute, chronic, subacute
Hypersensitivity Pneumonitis
Allergic Alveolitis

Nonimmunologic: Acute, chronic, subacute

Irritant Pulmonary Response
Reactive Airway Dysfunction
Pulmonary Fibrosis
Granulomatous Disease
Chronic Bronchitis

Immunologic or hypersensitivity pneumonitis, is best represented by a condition termed Farmers Lung Disease (FLD) and the nonimmunological condition is best represented by Organic Dust Toxic Syndrome (ODTS).

Farmer's Lung Disease

Inhalation of material from mouldy forage containing thermophilic spores is most commonly associated with a syndrome known as "Farmer's Lung Disease". After handling moldy crops, workers may experience symptoms such as cough, dyspnea and fever. In acute cases, symptoms are manifested 3-4 hours after exposure and may resemble viral or bacterial pneumonitis. Fatigue, fever, weight loss, malaise and a nonproductive cough may be the major complaints. However, the disease may be develop gradually producing permanent dyspnea and pulmonary impairment.[19] The chest x-ray may show bilateral reticular patterns. Recurrence of symptoms when the worker returns to the job and to exposure to moldy hay or grain would indicate the possibility of Farmer's Lung Disease. Pulmonary function tests may show a loss of FVC and $FEV_{1.0}$ as well as ventilation-perfusion imbalance which may produce hypoxemia.

In the United States, case reports of farmer's lung have centered in the Wisconsin area where climatic conditions are conducive for the development of mold.[20] The prevalence of the disease is directly related to the rainfall in the area. Medical surveillnace programs for farmers conducted at the Marshfield Clinic have monitored pulmonary problems of the agricultural work force in the Wisconsin area since 1963.[21] Seological monitoring for Famer's Lung Disease in more than 1000 blood samples per year at the Clinic have shown that 8-10% of farmers are serologically positive for antigens thought to produce the disease. The Clinic has not been able to establish any causative relationship between seopositivity and the subsequent development of the disease; however, seropositivity for antigens dose correlate with pulmonary symptoms.[21] An increase in chronic cough, bronchitis, and decreased pulmonary functions has been seen in workers seologically positive to Farmer's Lung Disease antigens. The most common seropositive response in one study group was to *Micropolyspora faeni*..[18]

Chronic pulmonary symptoms have been positively correlated with the presence of positive antibody serology.[18]

Cases of FLD in rural cattle and dairy communities in Maryland and Wyoming have also been reported. The prevalence of farmer's lung in epidemiologic studies of farming and dairy production workers in Wisconsin was 3% and 9% in Wyoming. Prevalence rates in Scotland have been reported at 2-9%, and 12% in England and Wales.[19]

Organic Dust Toxic Syndrome

Exposure to respirable organic dust can occur in removing layers of silage and in other dusty processess. Exposure to farm dusts is associated with a pulmonary syndrome known as Organic Dust Toxic Syndrome (ODTS).[18, 22] The syndrome is noninfectious and presents with fever, chills, malaise, cough, myalgias, headache and dyspnea soon after heavy exposure to dust.[22] ODTS is thought to be non-immunological in origin, and due to a direct inflammatory response of the lungs to respirable particles of organic material. Agricultural dust is composed of a wide variety of organic materials in addition to inorganic materials (Table 3). These wide variety of dust components are all implicated as etiologic agents in ODTS. The composition of the dust depends on the type of operation or farm environment in which the dust is produced. High concentrations of gram negative bacteria, endotoxin, and mold such as actinomycetes occurs in operations involving moldy grains and silage.[18] Cotton dusts have a higher concentration of endotoxin containing gram negative bacteria.[18]

Exposure to 90-100 mg/M^3 of respirable grain dust for one to two hours provoked the syndrome in 2 out of 6 controls.[1] Symptoms include productive cough, facial warmth, headache, throat irritation, chest tightness, burning chest pain, and dyspnea.[1] These symptoms may be followed several hours later by myalgias, fever, chills, and elevated white blood cell counts.[1] Organic dusts containing endotoxin, mold, spores, and bacteria can produce an acute pulmonary inflammatory response with a predominance of polymorphonuclear leukocytes in the lungs. The disease is usually self

limited without permanent sequelae. Therapy is symptomatic and supportive.

It is now thought that exposure to organic dusts causes a cascading effect to occur (Figure 7) involving pulmonary macrophages.[21] The activated pulmonary macrophages triggers phagocytic responses in the lungs with an infiltration of polymorphonuclear leukocytes. In addition, complement activity may be triggered, T-cells activated to respond to these antigens. and inflammatory mediators released.[21]

Despite the different pathogenesis between OTDS and FLD, it is difficult to separate these two syndromes by clinical symptoms and physical examination on all occasions (Table 4). Both FLD and ODTS can present with cough, leucocytosis, fever, dyspnea, chills, malaise, myalgia, and pulmonary function decrement.[21] ODTS is characterized by a history of high level dust exposure acutely with negative serology for FLD antigens. The cause of ODTS is an acute inflammatory pulmonary response to inhaled dusts and there are usually no long term sequelae.[21] FLD has a higher incidence in late winter and early spring. ODTS has a higher incidence in late summer and early fall.[21] The prevalence rate for FLD has been calulated to be 4.2/1000.[21] The incidence of ODTS versus FLD is difficult to ascertain given the common symptoms of both diseases. The incidence of ODTS is estimated to vary from 10 to 190 per 10,000 population at risk. [22]

Animal Confinement Areas

Animal confinement areas represent a distinct pulmonary health hazard. This method of production, where a large number of animals are raised in an enclosed structure with a limited amount of area provided per animal has brought about a tremendous increase in productivity. The increased use of confinement systems has been associated with an increase in physical, chemical and biological health hazards to the agriculture worker. An estimated 500,000 workers are employed in swine confinement operations and an additional 500,000 work in poultry, veal, beef or dairy confinement operations.

Exposed production workers show a high prevalence of respiratory symptoms including cough, excess sputum and phlegm production, wheezing and irritation to the nose and throat. Feeds and particulates of animal origin are the greatest contributors to the total dust load which reaches excessively high levels during feeding.[23] Human antibodies found specific for feed dusts suggest an immunological basis for the respiratory symptoms observed. Biological materials also contributes adversely to the effects on the respiratory tract. Since a single antigen has not been identified as the primary source of sensitization, in order to test for sensitization it would be necessary to use a large antigen panel to assess the many types of dust present in barns and confinement systems.

Symptoms in swine confinement workers can be grouped to include the following:[24] (1) Upper and lower airway irritation and inflammation. (2) Chronic bronchitis. (3) Rhinitis and sinusitis. (4) hyperactive airways. A summary of the symptoms reported by swine confinement workers includes cough with sputum production, chest tightness, dyspnea, wheezing, malaise, fever, dizziness, myalgias and arthralgia, fatigue, and throat irritation.[23] Pulmonary function studies have shown decrements in flow volumes as well as in the paramaters of $FEV_{1.0}$ and $FEV_{1.0}/FVC$.[24]

The incentive for energy production from methane released by anaerobic decomposition of wastes from animal confinement units has made liquid manure storage a common component of confinement systems. The uncontrolled activity of anaerobic and facultative microbes in stored manure produces metabolic by-products including as many as 150 different gases, many of which are known to be toxic.[25] Ambient concentrations of methane, ammonia, carbon dioxide and hydrogen sulfide can easily exceed chronic and short-term exposure limits if proper controls are not practiced and maintained. In addition to respiratory symptoms, workers are also subject to the central nervous system depressant effects of carbon dioxide and the metabolic effects of hydrogen sulfide and carbon monoxide. Displacement of atmospheric oxygen by the mixture of gases has lead to asphyxiation especially among workers entering confirned spaces within the production facility.

The development of allergic alveolitis (hypersensitivity pneumonitis) has been shown to be a risk from exposure to airborne microorganisms. Significant amounts of suspended endotoxins from gram-negative bacteria have been found in swine confinement units, poultry production and processing facilities and in airborne grain dust.[26] Similar endotoxins have been thought to be responsible for pulmonary reactions in persons exposed to cotton dust and are also associated with headache, diarrhea and other symptoms in compost workers.

An immunoglobin-E-mediated asthmatic response can be precipitated by the exposure to a variety of organic agents. Pollen from cereal grains, dander from livestock, fungal antigens in grain dust and on live crops or dust mites in organic dusts are among the most common causative agents for this type of response.[27] Non-immunologic asthmatic responses can also be elicited from exposure to various agents such as organic dust, organophosphate pesticides and irritant dusts fumes and gases.

Grain Dust

Grain dust is a product of the handling of grain. There are several process in which workers are exposed ranging from grain elevators to transporting, milling, and baking.[28] Grain elevators are sources of high particulate pollutants both inside the elvator and outside. Dust levels vary, depending on ventilator effectiveness, between 5-50 mg/M^3. Air particulates as high as 1000 mg/M^3 have been recorded.[28] Particles less than and equal to 10 micrometers are considered respirable and up to 10% of grain dust would fit this size.[28] The components of grain dust will vary with the grain and location. Common constituents of grain dusts are:[28]

Grain kernel pieces
pieces of seeds
Trichome particles
Insect parts
Allergans

Silica
Mite parts
Bacteria
Mold and Fungi
Residues of pesticides, fungicides, and herbicides

Clinical symptoms following exposure may vary depending on the composition of the grain dusts inhaled. Skin irritation and pruritis are common complaints following exposure to oat and barley dusts due to the trichome partices that penetrate the skin.[28] a syndrome known as "grain itch" is caused by a mite.[28] Irritation of the eyes, nose, and upper airway are common complaints following grain dust exposure.

Respiratory diseases following exposure to garin dusts vary from hypersensitivity pneumonitis to asthma and Grain Fever. Chronic exposure results in airflow limitations evident on pulmonary function testing. Grain Fever is an acute febrile illness occuring after exposure to dusts and is reported to occur in up to 30% of farmers.[28] Symptoms of Grain Fever include malaise, cough, dyspnea, chills, and fever. Grain Fever is actually classified as an Organic Dust disease and is probably nonimmunologic.[28] Symptoms may last from hours to days.

Hypersensitivity pneumonitis (allergic alveolitis or FLD) is associated with the handling of moldy materials. This is not commonly associated with handling dry grain.[28] Asthmatic reactions can be induced by both allergic and non-allergic causes. Overall, grain dust exposure can produce symptoms associated with chronic bronchitis, asthma, allergic alveolits, and chronic airflow limitations.

Cotton Dust

Symptoms of exposure to cotton dusts are similar to those caused by other organic dusts. Pulmonary disease caused by chronic exposure to cotton dust has been known as *byssinosis*. Workers exposed to cotton dust would slowly develop a chronic cough that would be particularly worse on returning to work on Monday, with improvement over the weekend. Over

time, the cough became worse and relenting with no weekend improvement.[29] The term *byssinosis* traditionally is reserved for symptoms related to chest discomfort experienced by workers returning to work on Monday.[29] Overall, respiratory symptoms experienced by cotton workers include low grade fever, wheezing, chest tightness, initially a dry cough followed by productive cough with longer exposure, and asthma.[29]

The pathophysiology of cotton dust exposure is an inflammatory response in the lungs due to responses of pulmonary macrophages and the release of mediators of inflammation. The causative agents in cotton dust are thought to be products of the plant as well as endotoxin, molds, and gram negative bacteria. Plant products include: histamine, phenols, epoxides,terpenoids, tannin, lacinilene C7-methyl ether. [29]

Mycotoxicosis and Silo Fillers's Disease

Pulmonary mycotoxicosis can be caused by exotoxins of fungal spores in moldy grain or hay. This condition is more commonly known to grain handlers as "grain fever", an acute febrile pulmonary illness that may develop into fibrosis of the lung.[27] This condition is not to be confused with "silo fillers disease" a condition which results from nitrogen dioxide release from decaying fodder in silos.[20,30,31] The nitrogen dioxide is released as a product of the oxidation of nitrate groups in silage and nitrogen-rich soils. As the fodder decays in this manner, the silos in which it it stored begin to fill with the gas. Sufficient concentrations can produce resiratory irritation. Higher concentrations can precipitate acute pulmonary edema. If the worker survives this event, the condition may relapse within a few weeks. Survival after relapse is less likely. Without relapse, complete recovery can be expected.[31] Gases released from decomposing fodder and other chemical agents used in agricultural practice pose a significant hazard to pulmonary function. Chlorine, sulfur dioxide, ozone, phosgene, herbicides such as paraquat and fertilizers such as anhydrous ammonia produce immediate irritation of the mucous membranes of the upper respiratory track. If the exposure is great enough delayed pulmonary edema may develop.

Endotoxin Exposure

Gram negative bacteria and endotoxin are found in many farming environments.[32] Endotoxin is a heat stable, lipopolysaccharide-protein complex derived from the cell wall of gram negative bacteria.[32] Endotoxin contaminated dusts are encountered in harvesting, transport, processing, and storage of agriculture products as well as in livestock production areas.[32] The target organ for endotoxin induced injury is the lung and in particular, the pulmonary macrophage, which is very sensitive to inhaled endotoxin. Dusty farming operations are a prime source of endotoxin pulmonary exposure and calculated levels can exceed the airborne threshold of 90 endotoxin units per cubic meter (90 EU/M^3). This threshold is set for a zero mean $FEV_{1.0}$ response following exposure to endotoxin containing dusts of a respirable size. Some environments have recorded endotoxin air concentrations as high as 13, 210 EU/M^3 in respirable dust.[32] Other studies have confirmed these airborne concentrations of endotoxins well beyond the 90 EU/M^3 threshold limit and that these high concentrations can vary in different locations of a processing area. [32]

Green Tobacco Sickness

Green tobacco sickness is an occupational illness occuring among workers who crop or harvest tobacco leaves which are damp from rain or dew. The incidence of the illness is regularly noted in the tobacco fields of North Carolina where workers complain of headache, pallor, nausea, vomiting and prostration after handling wet tobacco leaves. Symptoms resemble nicotine poisoning and may simulate organophosphate poisoning and heat exhaustion and thus may be treated inappropriately. The moisture on the tobacco leaves probably acts as a solvent for the nicotine facilitating dermal absorption especially as work clothing becomes wet.[33] Sufficient urinary excretion of nicotine and it's major metabolite cotinine have been observed in conjunction with the the symptoms of green tobacco sickness. Cigarette smokers rarely experience symptoms. This is probably due to the fact that smokers are more tolerant to the amount of nicotine they absorb while working on the harvest.[34]

Clinical Evaluation of Respiratory Diseases

Distinguishing among the various respiratory disorders that occur in farm workers can be difficult because the symptoms of each disease process are quite similar. Also, the combination of smoking and agricultural exposure can be additive. The duration and amount of exposure to certain dusts and environmental contaminants is also important to consider in evaluating symptoms.[35] In evaluating exposure to dusts, the dose, length of exposure, type of dusts, dust components, and size are all factors that contribute in different ways to produce different disease processes.

Clinical sysmptoms of cough, fever, fatigue, dyspnea, and $FEV_{1.0}$ declines can occur with both acute as well as chronic exposures. Thus, symptoms alone, without a historical time course of the exposure, and an understanding of the true nature of the exposure, may not be helpful in disease differentiation. Immediate pulmonary responses may or may not be predictable of the development of chronic or future pulmonary disease.[35]

The disease process and syndromes that require differentiation are: pulmonary hypersensitivity, Organic Dust Toxic Syndrome, Mucous membrane irritation, chronic bronchitis, byssinosis, and occupational asthma. Clinical evaluation should focus on questions about smoking history, allergies, personnel protection methods, previous work and exposures, prior cardiac and pulmonary disease.[36] A useful guide to the clinical evaluation of some of the more common pulmonary diseases of farmers is presnted in table 5: [36]

Agricultural Chemical Exposures

Agriculture remains the largest business in the United States and the use of chemicals, particularly fertilizers, pesticides, fumigants and herbicides is pervasive. Approximately 65% of the registered pesticides in the United States are used in agriculture. The primary use of these and other insecticides is control of insect vectors to reduce crop loss. Insecticides have

helped reduce disease in our environment through control of insects as well as improving living conditions by increasing the amount of available food. Pesticides include organophosphates, carbamates, rodenticides, herbicides, and fungicides. Additional agents found to be useful include food preservatives and seed dressings. Human exposure to insecticides and pesticides is widespread in developing countries as well as in more industrialized nations. Agricultural workers represent approximately 52% of the occupational labor force in developing countries.[37] In 1984, insecticides made up 32% of the world's market of pesticide sales.[37] There are more than 900 different pesticides registered for use by the Environmental Protection Agency in the United States which compose more than 25,000 brand names of agrochemicals and pest control agents. [37]

The use of pesticides in agriculture has produced an improvement in the financial investment of the farmer.[38] To improve crop production, losses to insects and pests must be minimized. Third World Countries especially have a need to improve agriculture production. This poses health problems since these countries make extensive use of pesticide application and workers in developing nations are generally unaware of safety aspects in the distribution and application of pesticides.

Insecticides can be classified into four main chemical groups:[37]

1.Synthetic Organic Chemicals: Organochlorines, Organophosphates, Carbamates
2. Inorganic Chemicals: Metals (Arsenic, thallium, cyanaide)
3. Biologicals: Pheromones, Bacteria, Viruses
4. Botanicals: Pyrethrins

A more extensive classification of pesticides is presented in table 6.

There are two categories of workers who are occupationally exposed to pesticides. The first group consists of those workers described as mixers, loaders and applicators of pesticide formulations. A high rate of occupational injury in these workers is due to their acute exposure to high concentrations of pesticides at full strength. Illnesses usually evolve from accidental spills.

The second category consists of a much larger number of field workers who are exposed to pesticide residues on the foliage of crops and in soils of the treated fields in which they harvest or otherwise do work. The exposure of this group differs from that of the mixer-loader, applicator group in that it is a more chronic, low-dose exposure primarily involving dermal absorption.[39-41]

The pesticides which are most frequently implicated in acute field exposures have been the organophosphates and carbamates. These pesticides exert their primary and acute toxic effects by inhibiting acetylcholinesterase by phosphorylation of the enzyme. A 60% depression in cholinesterase activity can produce relatively mild non-specific symptoms such as nausea, headaches, malaise, constriction of pupils, and an asthma-like tightness of the chest. Greater depressions of cholinesterase activity may produce pulmonary edema, unconsciousness, respiratory failure and even death. Depressions resulting from carbamate exposures are usually reversed more rapidly than those resulting from organophosphate exposure. Depression in plasma cholinesterase can also occur from pregnancy and birth control pills, which can make interpretation difficult if there are no symptoms associated with exposure.

Symptoms of organophosphate and/or carbamate poisoning can range from mild to severe. The degree of symptoms is dependent on the nature of the pesticide and its toxicity, absorbed dose, and prior level of cholinesterase activity. Weakness, abdominal pain, nausea, diarrhea, vomiting, visual changes are associated with mild toxicity. Workers who are chronically exposed to organophosphate and carbamate insecticides, without proper protection, can deplete their cholinesterase activity to seriously low levels and be at an increased risk for developing poisoning even following a mild exposure which would normally not be serious. These individuals are at an increased risk for other work-related accidents and injuries also. Workers can be posioned from crop residues as well as from direct contact during application.[41-45] The rationale behind the legal reentry intervals has been to prohibit entry into treated fields to allow sufficient decay of the pesticide such that potential health risks should be mitigated.

Pesticide related illness in agricultural production workers is an occupational hazard. A study of Nebraska farmers and pesticide appicators discovered that 30% of these individuals had significant reductions in serum cholinesterase activity and 22% had pesticide poisoning symptoms.[46] These types of exposures could certainly be an important variable contributing to the high incidence of accidents in this population. One example occured in the Salinas Valley when a field crew bagan harvesting in a mevinphos (Phosdrin^{R}) treated field two hours after the pesticide was applied. Members of the crew sought medical treatment for a variety of symptoms ranging from nausea and visual disturbances to chest pain and shortness of breath. Plasma cholinesterase levels were depressed 15% and RBC cholinesterase depressed almost 6%. Symptoms persisted for up to 10 weeks after exposure which was longer than the 14 days it took for cholinesterase levels to normalize.[42]

In response to serious illnesses and deaths among agricultural pesticide applicators, the state of California introduced a medical surveillance requirement in 1974.[47] The primary goal of medical surveillance is to prevent the development of profound cholinesterase depression and pesticide toxicity. California employers are required to provide wash and change facilities, clean work clothing and the use of closed mixing and loading systems for the most toxic pesticides. Medical surveillance is also required for all agricultural pesticide applicators whose exposure cholinesterase-inhibiting pesticides in toxicity category I or II (Table 7) is expected to reach 30 hours in any 30-day period. Mixer and loaders exclusively using closed systems are exempt from this requirement. Workers are referred to a physician medical supervisor for baseline red blood cell and plasma cholinesterase determination not less than 30 days after the last exposure to a cholinesterase-inhibiting pesticide. Workers are retested during their exposure period to detect any probable pesticide overexposure. If red blood cell cholinesterase activity is depressed to 60% or below baseline or plasma cholinesterase to 50% or below, the worker must be removed from all exposure to organophosphate or carbamate pesticides. Removed workers may not resume handling cholinesterase-inhibiting pesticides until their cholinesterase activity levels have returned to at least 80% of baseline values. However, although the regulations also require

enclosed mixing and loading systems or enclosed cabs and industrial hygiene measures in conjunction with medical supervision, surveys of workers demonstrate that cholinesterase depression exceeding the state's requirements for removal still exist.[43] This suggests that the present regulatory mechanism is inadequate to control occupational pesticide exposures and reevaluation of the individual components of the system is necessary to determine where improvements can be made.

The Federal Food, Drug and Cosmetic Act originally established harvest intervals restricting the time between pesticide application and harvest based upon pesticide residue levels on foodstuffs for the purpose of consumer protection. Today, it is the Environmental Protection Agency (EPA) which lists tolerance levels of residues on food under Toxic Substances Control Act (TOSCA). The intervals themselves, however, are established by the individual states.[48] Reentry intervals for the purpose of worker safety did not become a regulatory issue until the passage of the Occupational Safety and Health Act of 1970 creating the Occupational Safety and Health Administration (OSHA), and the passage of the1972 amendments to the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). OSHA became the first federal agency to propose pesticide reentry standards to protect the health of fieldworkers. The first standards included 21 organophosphorous insecticides and five crops (citrus, peaches, grapes, tobacco, and apples). After protest from several agricultural groups, these standards were replaced within 6 weeks with less stringent standards covering only nine organophosphates with intervals ranging from 1 to 3 days for wet areas and 14 days for dry areas (based on average rainfall greater or less than 25 inches).[49] In 1973 the Federal Court gave jurisdiction to set and administer reentry standards to the EPA. Final EPA reentry standards, published in the Federal Register in 1974, required 48-hour reentry intervals for 11 organophosphate pesticides, endrin, and endosulfan.[50]

States were given the responsibility and authority to set additional restrictions to address local problems. California has been the only state to establish it's own reentry standards which require longer intervals of between 5 to 30 days.[51] Even with these longer intervals, there have still

been numerous cases of illnesses among field worker crews that were induced by contact to residues on leaf surfaces.[41,42,52]

The extent to which field workers are adversely affected by contact exposure to pesticide residues is a controversial subject. Many factors or combination of factors may be necessary to produce an actual episode of poisoning by residues. Also the dose response mechanisms are difficult to assess because of the great variation in the types of pesticides used, work rate, and quantity of pesticide contacted and individual metabolism. The use of biological markers such as pesticide metabolites have been attempeted as a means of determining absorption. However, biological monitoring is costly and as noted earlier, the agricultural work force does not lend itself well to any long-term survailance. In an effort to overcome this obstacle, exposure assessment models have been attempted for individual types of crops which involve similar maintainance and harvest so as to have similar exposure patterns. These models correlate the dislodgeable foliar residues (DFR) available for contact with daily dermal dose rates of an average harvester. The result is an emperical transfer factor expressed in terms of quantity of residue per unit of body surface area.[40,41] Thus far transfer factors for tree fruits such as citrus and peaches is in the range of 4,000 to 30,000 cm^2/ hour. A substantial amount of data needs to be amassed under varying climatic conditions in order for the transfer factor to be a effective method of quantifying exposure without the use of biological monitoring.

The number of officially reported cases of residue-related illness is estimated to be only 1-2% of the actual number. Epidemiological evidence backs this up. Considerable indirect evidence suggests that farm workers are adversely affected by pesticide residues but the true magnitude of the problem is uncertain because cases are largely undetected and grossly under-reported. There are important socio-economic and cultural factors which must be understood and carefully evaluated in any attempt to study this problem.

Pesticide Related Dermatitis

Other pestcide related exposue health problems include contact and allergic dermatitis. Chlorinated compounds, organophosphates, sulfur compounds, fumigants, herbicides, and fungicides may cause dermatitis in exposed individuals. Some pesticides are known to be potent skin sensitizers. These include dithiocarbamates, thioates, thiurams, parathion, and malathion.[53,54] Contact dermatitis is also common following exposures to animal hair and some plants. Contact dermatitis may also be related to the solvent used to dilute certain pesticides for application.

Cancer Risk, Pesticide Exposure, and Agriculture

Overall incidence of cancer in agricultural workers is lower than the general population. However, there is concern over the widespraed exposure and longterm exposure of farm workers to the myriad pesticides and other agricultural chemicals. Agricultural works tend to have a decreased risk for cancers of the lung, colon, bladder, nose, rectum, and liver.[55,56] There is an increased risk for certain other types of cancer. Increased risk is established for hematologic malignancies, brain cancer, lip cancer, stomach cancer, and prostate cancer.[55] Mortality from multiple myeloma, leukemia, non-Hodgkin's lymphoma, brain cancer, and connective tissue cancer has been increasing in the farming communities more than in the general population over the period from 1950-1980.[55] The question is whether or not chemical exposure is associated with this increased cancer risk. Groundwater and soil contamination with pesticides, nitrates, and nitrosamines is increasing in rural communities from the extensive use of chemicals. In Nebraska farming areas alone there were an estimated 30 million pounds of pesticides and two million tons of fertilizer used in 1982.[46] Mortality studies published in 1985 looked at the years 1950-1979 and revealed an excess mortality from lymphoma and leukemia in Nebraska.[46] Case-control studies from Iowa farming communities in the 1980's do not indicate that the occupation of farming itself is a risk for increased lymphocytic leukemia; however, this study does point toward pesticide use as a risk factor in multiple myeloma.[57]

Investigations into the possible etiologies or associated risks have focused on chemicals and animal viruses.[57] An elevated risk for lymphosarcoma and reticulosarcoma and other lymphomas in areas with heavy insecticide, herbicide and fertilizer use has been noted.[58] These cancers may also be related however to dietary factors, sun exposure, the handling of synthetic chemicals or inhalation of mycotoxins.[59] An identifiable risk pattern in association with chemical exposure has not yet been established.

To evaluate the potential carcinogenic risk of pesticides the National Cancer Institute developed a large-scale routine bioassay in 1960 as a preliminary means of testing pesticides and other chemicals.[56] This program is now being conducted by the National Toxicology Program. Criteria were established to ensure the validity of animal tests as a qualitative predictor of human effects. For example, a test using the maximum tolerated dose of a pesticide would require that it induce cancer in at least 7-10% of the animals being tested to be a statistically significant risk. Various federal and state agencies use this data in their regulatory decision-making process. In addition to the EPA, The U.S. Department of Agriculture, The Food and Drug Administration and the Consumer product Safety Commission are also authorized to exercise specific controls for limiting human exposure.[56]

Arsenic exposure is associated with human lung cancer and hematologic malignancies.[55] Exposure of Egyptian farmers to organophosphates, vynl chloride, and arsenical pesticides has been noted to be associated with a higher incidence of hepatic angiosarcoma.[56] Arsenic compounds are used still as wood preservatives but the use of arsenical compounds as pesticides has greatly declined.

Many studies have examined the suspected link between cancers and pesticide exposure in farmers. Using death certificates for for Nebraska farmers from 1957 to 1974, one study found a statistically significant increase in chronic myelogenous leukemia.[59]

Many pesticides have been demonstrated to have carcinogenic and genotoxic properties in animals (Table 9). Only a few of these have been demonstrated to be human carcinogens (arsenic and vinyl chloride). The organochlorine pesticides such as chlordane, heptochlor, dieldrin, aldrin, lindane, and DDT have been scrutinized as potential causes of increased risk of cancer. However, reviews of most of the significant studies performed through the years show inconclusive evidence of the carcinogenicity of the organochlorine pesticides.[55,56]

Certain cancers have been found to be in an excess in agricultural workers, especially for hematologic malignancies.[55] Similar cancer patterns have been observed in other countries in farm workers. The reasons for this increased risk of cancer remain unknown. Studies have been focusing on the exposures to pesticides and to animal viruses.[55] Multiple epidemiologic studies examining the relationship of chemical exposures and cancers in agricultural workers have been performed. As would be expected, acute and chronic exposures to multiple chemicals occur.

Difficulties are encountered in trying to assess the exposure to pesticides and determine any increases in relative cancer risks. Phenoxy herbicides such as 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 2, 4-dichlorophenoxyacetic acid (2,4-D) have been extensively studied with respects to potential carcinogenesis.[55] These herbicides had been contaminated with 2,3,7,8-terachlorodibenzo-*p*-dioxins (TCDD), a known animal carcinogen.

Multiple case control and cohort studies of phenoxy herbicide exposed agriculture workers have been published since 1979.[59-68] The major case control studies performed in Sweden, New Zealand, and the United States can be questioned with respect to the reliability of data collection and exposure assessment.[60] These studies, published between 1979 and 1988, demonstrated widely ranging relative risks.[55]

Swedish case control studies published in 1979 and 1981 indicated an increase in soft tissue sarcoma and lymphoma in exposed workers.[55,61-64] Studies in New Zealand and the United States published between 1986 and

1988 as well as a newer Swedish study in 1988 and 1989 have demonstrated varying relative risks.[55,65-69] Swedish case-control studies of 1979 and 1981 showed a five to six fold relative risk for soft tissue sarcomas in workers exposed to these herbicides[55,61-64] whereas more recent Swedish studies (1988) showed only a 3.3 relative risk for sarcoma.[55] A two-fold relative risk for soft tissue sarcoma was found in Italian rice field workers in a 1987 study.[55,66] However, U.S. studies published in 1986 and 1987 along with a New Zealand studies in 1984 and 1986 demonstrated a relative risk of only 1.0.[55,65-67] Swedish cohort studies differed from case-control studies and found a relative risk of only 0.9 for soft tissue sarcomas compared to the 5-6 fold relative risk in earlier swedish studies involving herbicide exposure.[55]

Case control studies in 1981 showed an increased relative risk of 6 for non-Hodgkin's lymphomas in phenoxy herbicide exposed workers but a 1989 swedish study found a relative risk of only 1.6.[55,62] A Kansas study in 1986 found a risk of 2.0 which increased to 7 fold if workers had used the herbicides for more than twenty days.[55] Other studies from New Zealand in 1987 and from Washington,1987, failed to show an increased risk for lymphomas in persons exposed to phenoxy herbicides.[55,65,67]

Definite conclusions from all of these cohort and case control studies cannot be reached. All of these studies suffer from lack of variables control: methods of herbicide application, dose absorbed, length of exposure, route of exposure, cofactors such as presence of other chemicals or potential carcinogens, and genetic background. The increase in certain cancers in agricultural workers appears real; however, the etiology remain unknown.

Regulation of Pesticides

The primary federal statute for the regulation of manufacturing, use, and distribution of pesticides is the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) which was enacted in 1947. Since then, FIFRA has been amended in 1972, 1975, and in 1978. The Environmental Protection Agency has had the responsibility to to regulate pesticide use since 1970.

Pesticide regulation first occurred under the Insecticide Act of 1910 which was a consumer protection measure against mislabeling and distribution of ineffective pesticicdes. FIFRA replaced this act. Pesticides are also regulated by the Environmental Protection Agency under the following acts:

(1) Federal Environmental Pesticide Control Act
(2) Resource Conservation Recovery Act of 1972 (RCRA)
(3) Comprehensive Environmental Response, Compensation, and Liability Act(Superfund)
(4) Toxic Substances Control Act (TSCA)
(5) Clean Water Act
(6) Safe Drinking Water Act

A pesticide is defined under FIFRA as, "any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, and... any substance or mixture of substances intended for use as a plant regulator, defoliant, or dessican."[70] Pesticides thus include insecticides, fungicides, herbicides, rodenticides, dessicants, disinfectants,defoliants, and nematocides.[70] FIFRA requires all pesticides sold or distributed to be registered with the EPA. Once registered, FIFRA classifies the pesticide as general or restricted in use. The application and use of pesticides is tightly controlled by the EPA under FIFRA.

FIFRA prohibits the sale of unregistered pesticides, the production of pesticides by unregistered mnufacturers, the use of adulterated pesticides, and the use of a pesticide in amanner inconsistent with its labeling. The EPA has the authority to enforce FIFRA by legal sanctions including civil penalties, criminal fines, injunctions, product seizure, termination of product sales, or recalls.[70] When evidence indicates that a particular pesticide may be a significant health hazard, the appropriate regulatory agency or agencies can take any of the following actions:[56]

(1) Issue permissible exposure limits for the work place.

(2) Cancel registration and order withdrawal of the product from the market.
(3) Place restrictions on use or application of the compound.
(4) Set tolerance limits for pesticide residues on foodstuffs.
(5) Cancel registration.
(6) Establish maximum permissible contamination levels for the pesticides in drinking water.

In addition to the regulation of pesticide use and application, FIFRA requires the pesticide manufacturer to be registered with the EPA. The EPA, under agreement with the Food and Drug Administration, establishes pesticide tolerances for raw foods and produce.[70] Pesticides that might be considered food additives are controlled by the EPA under the Food, Drug and Cosmetic Act.[70] It is of interest that once a pesticide is discarded, it becomes a hazardous waste and is then under regulation by RCRA and not FIFRA.

The 1978 amendment to FIFRA allows manufacturers of pesticides to have a waiver on submission of data demonstrating efficacy of their product, except where the product has a direct relation to or effect on public health. In addition the 1978 amendment allows for public disclosure of the safety and health data regarding pesticide regulation.[70] The 1978 amendment also transfers to states the responsibility to enforce pesticide use regulations if they can demonstrate that they possess the means to do so. The EPA reserves the right to revoke any state's responsibility for pesticide regulation if that state is unable or unwilling to enforce the regulations.[70]

Regulation of a pesticide suspected to be a carcinogen is not uniformly applied by all federal agencies.[56] However, these agencies have been consistent in regulating a substance when it is expected to cause an increase of more than four cases of cancer per 1000 persons.[56] If the expected increase in cancer is less than one in a million, then regulation is unlikely.[56] Cost-effectiveness of regulation is also considered. If the cost of regulation is anticipated to be less than $2 million per life saved, then it is called for.[56]

Environmental Concerns Regarding Chemicals and Pesticides

Soil, Air, and Groundwater Contamination

There are approximately 1 billion pounds of pesticides applied to crops in the United States annually.[71] The main route of application is spraying and its is estimated that only 1-3% of these pesticides reach their point of action.[71] Application via spraying covers wide agricultural areas as well as potentially exposing workers and the public.

Since World War II, the widespread and intensive use of pesticides has been associated with persistent and broad spectrum agents such as DDT. DDT and its related chlorinated compounds have been associated with residues throughout the environment, including accumulation in both the food chain and living systems. Although DDT was banned in the U.S. in 1972, it continues to be used widely outside North America. However, new nonresidual chemicals and agents that can be specifically targeted to certain pests have been developed in response to environmental concerns. These newer chemical agents, despite substantial improvements, still generate concern because of their potential impacts on soil fertility and their long term effects on ground and surface water (Figure 8).

Chemical pesticides reach the soil by direct application and from aerial and ground sprays. Overall, there are three main processes which affect the efficiency and ultimate fate of pesticides in soil:

(1) absorption-desorption.

(2) transformation via biological and chemical degradation.

(3) transport into the soil, atmosphere, surface water, and ground water.

Investigations have demonstrated that ground water can suffer contamination attributable to the widespread application of agricultural chemicals. Specific chemicals, such as atrazine, can now be measured in aquafiers and wells. The problem is to determine the origin of these chemicals, which have been widely applied over periods of decades.

This non-point source problem involves both time sequence and location. Recent work by the Tennessee Valley Authority involving stereoscopic infrared color aerial photography has begun to demonstrate that source and time sequence problems may no longer be insurmountable.[72] Computer databases can be constructed that include land use category, site number, surface area and topography, and hydrogeologic codes for both aquafier and stream systems. As this technology becomes more sophisticated, the quality and specificity of the data base will improve such that the term "agricultural non-point source pollution" may become an anachronism.

Contamination of groundwater, well water, and soil by in farm chemicals occurs due to water runoff, drainage, seepage, and spraying. Environmental contamination by nitrates, pesticides, halogenated hydrocarbons, and other toxic chemicals are now recognized as a health risk.

Nitrate contamination of well water and groundwater in rural areas has been a source of methemaglobinemia in infants and children and in some occasions even adults.[73] Nitrates from fertilizer and livestock excretement are the main sources of this type of water contamination. Water contamination with nitrates and nitrites is common and illness and death secondary to methemoglobinemia was recognized as early as 1947 and as late as 1987 from ingestion of contaminated water sources.[74,75] Well water surveys in South Dakota revealed that up to 39% of dug or bored wells contained nitrates at unsafe concentrations.[73]

The E.P.A. defines the acceptable limit of nitrates (NO_3-N) as 10 milligarms per liter of water (10 parts per million). Most cases of methemoglobinemia involve water concentrations above 100mg/liter.[73] It should be noted that the production of methemoglobinemia is not always associated with symptoms. Ilness is associated with the amount of hemaglobin available as

well as the percent oxidized to methemaglobin. Rural children and adults who have relatively lower levels of hemoglobin will tend to manifest illness more easily.

An additional potential health concern involves the conversion of nitro containing compounds to potentially carcinogenic nitrosamines that can be consumed. Aldicarb, atrazine, carbaryl, simazine, and carbofuran can react with nitites at acidic pH's to form nitrsos compounds.[73] Aldicarb, a highly toxic carbamate has been detected in groundwater samples.[76] The degradation and persistance of aldicarb in soil and water are influenced by the type of soil, pH, plant application, and moisture.[76]

Volatilization of pesticides into the air is determined by the vapor pressure of the active ingredient.[71] Pesticide loss into the air occurs during application of vapors, aerosols, and dusts as well as from retained crop residues. The transport of pesticides beyond the sites of application into nearby homes, public roadways, water, and nonagricultural land is a realistic concern.

The legal, economic, regulatory, political and social forces directed at the agriculture business are growing. Practices that will reduce pesticide loss from point of application, increase the effectiveness of pesticides thereby reducing the amount needed, reduce volatilization and runoff by changing pesticide formulations, make available improved biodegradable pesticides, and improve application methods are strategies being explored.[77,78] Innovative changes include improving chemical formulations to prevent release into the atmosphere as well as reducing soil and groundwater release and the use of recombinant DNA biotechnology to provide biological pesticides such as viruses and bacteria.[78]

An Agricultural Superfund

The agricultural sector as a whole is increasingly under fire as a source of pollution. Extending the "polluter pays principle" to agriculture and to individual farmers, based on an agricultural "superfund" is a novel idea with

technical, health and public policy implicatons. The superfund concept arises from P.L. 94-580, which effectively spreads the costs of industrial pollution by imposing fees on industry, the proceeds of which are available to pay for hazardous waste cleanup at "superfund sites".[79]

If agriculture were to be included in the superfund, or a separate such fund were established for the agricultural sector, the costs of agricultural pollution would effectively be spread to all those paying into the fund. Who will pay, of course, is an issue likely to prompt debate, as is the magnitude of the problem itself. Regardless of who pays and how much, such cost spreading may be preferable to allowing full liability to be borne in agriculture by a few companies producing chemicals found to have adverse effects, or by farmers found to have used these chemicals over time.

Based on methods currently in use in connection with the superfund, the type of informaton that will be demanded in characterizing the risks associated with agricultural pollution can be explored. These risks are at present largely unknown. If the public increasingly demands information on the human health impacts of agricultural pollution, the framework developed under superfund legislation in the non-agricultural sector can be useful in agriculture as well. After considering this information, what would be the implications of public policy issues involved in implementing an agricultural superfund?

Chemicals and fertilizers used in crop production have, until recently, been regarded as less significant causes of pollution than more localized hazards resulting from landfills, industrial disposal and other "point sources". Yet recent evidence implicates agricultural contributions over wide areas as significant "non-point sources" of pollution, which despite the lack of a single source, are nonetheless identifiable. Broadly speaking, the two main sources are pesticides and fertilizers.

Pesticides are generally synthetic organic chemicals used to kill or inhibit the growth and reproduction of species viewed as pests. Crop fertilizers encompass a broad range of commercially available and indigenous sources, including animal wastes and plant nutrients (nitrogen, potassium,

phosphorus). Both pesticides and fertilizers can have impacts on distant non-target organisms. Pesticides, because of their pervasive use and negative public perception, provide a focal point for an analysis of the linkage between potential adverse health effects associated with agriculture-induced by environmental pollution.

In pollution control technology, agricultural businesses can be viewed as "source generators" that either continuously or intermittently release contaminant material into both air and water. Traditionally, these releases have been viewed as non-point source pollution, as opposed to industrial point source pollution. This non-point versus point source distinction provides a partial basis for the exemption from the Clean Water Act currently enjoyed by the U.S. agriculture. Yet, increasing analytic and environmental engineering sophistication coupled with changing public perception may blur the distinction between point and non-point source contaminants. Sites polluted with by-products of agricultural land-use such as California's Kesterson Reservoir and Italy's Bay of Venice have focused national and international attention on the agricultural industry. As the ability to track the fate and transport of agricultural chemicals improves, it is reasonable to foresee a superfund process specifically directed toward agriculture.

Obviously, such an "agricultural superfund" program would have long-term economic impacts on agricultural policy, land valuation, property transfers and farmland conversion associated with urban development. For example, lending institutions are already beginning to consider potential and existing environmental liabilities associated with agricultural properties. Under an agricultural superfund, this practice would become a normal part of doing business in agriculture, similar to the current scrutiny applied to the industrial and commercial sectors.

Although no "agricultural superfund" exists, it is appropriate to consider how such a fund might be constructed and what type of information might be demanded of the agricultural sector, specifically concerning the fate, transport, and health risks of agricultural practices. The Superfund Human Health Evaluation process provides a framework for developing the risk

information necessary to assist in this process[80]. There are four primary objectives of this assessment:

1. to provide an analysis of baseline risks;

2. to generate data which provides a basis for determining what levels of chemicals are environmentally acceptable;

3. to provide a basis for comparing potential health impacts of various remediation strategies;

4. to provide a consistent process for evaluating and documenting public health threats associated with a given pollution source.

The analysis of agricultural use of pesticides fits well into this overall framework. Typically, the baseline risk assessment of potentially widespread contamination utilizes a four part approach:

1. Historical overview, data collection and evaluation
2. Exposure assessment
3. Toxicity assessment
4. Risk characterization

Each of these categories is further subdivided into specific tasks (Figure 9) which will produce an overall conceptual evaluation model (Figure 10). Pesticides can be considered in terms of this four-part process.

Exposure Assessment

Exposure assessment is the determiantion or estimation of the magnitude, frequency, duration and route of exposure to a particular chemical pollutant. These estimations can be based on long duration real-time measurement or a variety of mathematical models. Typically, these "fate and transport" models provide conservative estimates of the amount of chemical available at the human exchange boundaries (lungs, gastrointestinal tract, skin) during a specified time period. There are several specific instances where

real-time monitoring data is not adequate and fate-transport models must be utilized. These include:

1. Cases in which potential exposure points are spatially separate from the monitoring point. Examples of this situation include ground water transport and air dispersion of chemicals.

2. Cases in which time-series data is lacking. Long term site specific data is generally unavailable; therefore, even though there may be situations where it is reasonable to assume constant conditions, it is necessary to predict future exposure employing a model.

3. Cases in which monitoring data are difficult to quantify. Examples are the case of a ground water plume discharging into a river or other surface water body. The dilution in the river water can result in concentration of the chemical below limits of detection, despite the fact that the chemical can bioaccumulate and ultimately raise health concerns.

Fortunately, while much could be done to improve our knowledge of agricultural chemical use, a reasonably large and well-documented data base exists for the environmental fate and transport of pesticides in soil. Soils possess a large and physio-chemically active surface area. This surface area provides a site for mutliple surface reactions and a reservoir for the retention of pesticides; in addition, the chemical character of pesticides affects the extent and nature of pesticide absorption by soils. The overall distribution of pesticides in soil phases is influenced not only by intrinsic soil properties, but also by external factors, including climactic conditions and agricultural practices.[81]

Fate-transport models have been devised to incorporate both these external factors and various physio-chemical factors to address the following fundamental questions:

(1) What are the principal mechanisms for change or removal in each soil type and horizon?

(2) How does the chemical degrade or accumulate in air, water, soil, and other biological material?

(3) Does the agent react with other compounds in the soil environment?

(4) Is there transfer from the soil surface to ground water, and if so, what are the mechanisms, rates and reactions of this process?

(5) What is the long-term (air, water, soil) environmental persistence of each chemical?

(6) Are potentially toxic by-products produced, and if so, how are they to be analyzed?

(7) Is a steady-state concentration distribution achieved?

Each of these questions is applicable to the general transport of chemicals in ground and surface water, air, soil and the food chain.

The Superfund Exposure Assessment Manual provides specific guidance for the selection of contaminant release and fate analysis models; in addition, there is a large selection of situation specific models.[82] Two particularly well-documented models relevant to pesticide fate and transport are the Pesticide Root Zone Model (PRZM, Figure 11) and the Seasonal Soil Compartment Model (*SeSoil*) (Figure 12.[83,84]

PRZM simulates the vertical movement of pesticides in the unsaturated soil and within and below the plant root zone. Simulations can also be extended to the water table where ground water models can be utilized. The PRZM model analyzes runoff, erosion, plant uptake, leaching, decay, foliar washoff/volatilization, vertical movement, dispersion and retardation (Figure 11). Predictions can be made daily, monthly or annually. The cumulative frequency distribution wave of a given pesticide leaving the root zone is illustrated in Figure 13. Extensive documentation including modeling specifics and limitations are available for PRZM and other pesticide models from the EPA.[82]

SeSoil is a general water and sediment transport model that allows specific analysis of pesticide and sediment transport on water sheds (Figure 12). This model has particular utility because it merges with pre-existing long-term climate files and it is integrated into the Graphical Exposure Modeling System (GEMS) family of air and water models. GEMS is user friendly and allows the complete fate and transport analysis of most chemicals. There are, of course, many limitations to these models; however, they are increasingly improved, and provide an initial screening tool with wide applicability to pesticide use in agriculture.

Toxicity Assessment

The primary hazard of pesticide exposure is the development of acute toxic effects associated with dermal contact or inhalation. The medical literature is replete with studies of pesticide related illness.[52] The health effects of low-level or prolonged pesticide exposures via drinking water is less clear. Controlled epidemiologic studies of long-term exposure to pesticides has generally been focused on farmers and pesticide production workers. Qualitative and quantitative risk assessment suggests the possibility of incremental increased cancer risk although human epidemiologic data is less clear. Specific health based recommendations for acceptable pesticide levels in ground water have been formulated. The ability to recommend no adverse effects levels for pesticides in ground water is controversial, although the limit setting process and methodology is well established by the EPA. Risk based toxicity assessments for pesticides are common despite the lack of strong evidence to support or negate a causal relationship between low-level exposure and disease. This scientific uncertainty does not effect the increasing public pressure to monitor and regulate low doses of pesticide exposure in food and water.

Risk Characterization

Risk characterization combines toxicity and exposure assessments into quantitative and qualitative expressions of risk. Risks are estimated as

projected excess rates of cancer for chronic disease associated with a set of chemical exposures. Risk characterization also provides key information for policy makers. Pesticide risk methodology involves the same assumptions and calculations as for other chemical exposures. Those are (1) standard intake assumptions; (2) EPA potency factors (carcinogenic risk) and reference doses (non-carcinogenic); (3) risks combined across exposure pathways; (4) carcinogenic risk is assessed and analyzed; (5) non-cancer hazard quotients are calculated; and, (6) sensitivity and uncertainty analysis of all assumptions are performed. The current risk assessment guidance manual for Superfund,[80] provides further detail and documentation of the entire process.

Implications for Policy

Overall, traditional non-point source pollution problems such as agriculture, in fact appear highly amenable to the Superfund Risk Evaluation process. As the distinction between point and non-point source pollution becomes harder to sustain, non-point source pollution in agriculture may well become subject to regulations under existing superfund laws, or through creation of a separate agricultural superfund. An agricultural superfund would, no doubt, be controversial since it would involve major shifts in liability assignment for farmers and suppliers of farm chemicals. Yet, members of the U.S. Committee on Irrigation and Drainage (USCID) have suggested that some members of industry might be happy to see the focus and costs for cleanup of contaminated water shifted in part to an additional sector of the economy that has heretofore escaped responsibility.[79] As the technology of chemical detection and fate-transport improves, agriculture may well become exposed and vulnerable to the increasing regulatory and financial pressure associated with environmental contamination.

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Table 1

National Safety Council's Work Accidents Per 100,000, 1989

	Workers	Deaths	Death Rates	Disabling Injuries
Agriculture	3,200	1,300	40	120,000
Mining, Quarrying	700	300	43	30,000
Construction	6,500	2,100	32	190,000
Manufacturing	19,500	1,100	6	340,000
Transportation & Public Utilities	5,900	1,400	24	140,000
Sevices	36,200	1,500	4	300,000
Government	17,300	1,600	9	240,000
Trade	27,400	1,100	4	340,000

National Safety Council, Accident Facts, 1990, Edition, Chicago, Illinois

Table 2

RESPIRATORY HEALTH RISKS

ASTHMA

a) Immunoglobin-E-mediated

Causative agents	Health Effects
pollen from cereal grains dander from livestock fungal antigens in grain dust and on live crops dust mites in organic dusts	Early asthmatic response within 10-20 minutes after exposure caused or associated with allergen-induced nonspecific bronchial reactivity Late asthmatic response 3-8 hours after exposure with recurrent nocturnal asthma several days post-exposure

b) Nonimmunologic Asthma

Causative agents	Health Effects
Organic Dusts obstruction	"Grain Dust Asthma" cough, chest tightness, fever, immediate - 4 hr onset, hyperinflation, airway stimulates release of histamine from mast cells
Organic Phosphate Insecticides	cholinesterase inhibition of acetylcholinesterase
Irritant Dust, Fumes and Gases bronchial	bronchospasm with preexisting non-specific hyperreactivity

HYPERSENSITIVITY PNEUMONITIS (extrinsic allergic alveolitis)

Causative Agents	Health Effects
fungal spores of thermophilic and/or cell actinomycetes released from moldy hay or grain	local formation of immune complexes mediated immunity IgE precipitation of antibodies, specific lymphocyte stimulation
Aspergillus and Micropolyspora fungal spores	"Farmer's Lung ": chronic cough, dyspnea, with onset 3-4 hr post-exposure.
Antigen of less than 5 uM in diameter	Cellular infiltration of alveolar and bronchiolar walls with formations of granulomas and giant cells. Progressive interstitial pulmonary fibrosis.
Penicillium fungal spores or proteins in bird droppings	"Bird Fancier's Lung"

Table 2 Continued

PULMONARY MYCOTOXICOSIS

Causative Agents	Health Effects
Toxins released from fungal spores moldy grain or hay	Acute febrile pulmonary illness lasting several days or weeks. chest radiograph: interstitial or alveolar infiltrate pattern infiltrates or both "Grain Fever": fibrosis of the lung, rhinitis, conjunctivitis, or allergic alveolitis

RESPIRATORY INFECTIONS

Conditions which constitute definite risk		Conditions which constitute possible risk
brucellosis	staphylococcal infection	psudotuberculosis
leptosporosis	echinococcosis	psittacossis
toxoplasmosis	collibacillosis	salmonellosis
rabies	Rocky Mountain spotted fever	listerosis
tetanus	tularemia	tuberculosis
anthrax	sporotrichosis	
erysipeloid	ascariosis	
Q-fever	pasteurellosis	
histoplasmosis	balantidiasis	
blastomycosis	contagious acthyma	
ring-matitis		

RESPIRATORY EFFECTS OF GASES AND CHEMICALS

Causative Agents	Health Effects
gases from decomposing materials manure: ammonia, hydrogen sulfide, carbon dioxide, carbon monoxide, methane	acute pulmonary inflammation from inhalation of H_2S, acute asthma-like illness,bronchitis, delayed hypersensitivity pneumonitis-like illness
gases formed from decomposing fodder and other chemical agents phosgene, chlorine, sulfur dioxide, ozone paraquat (herbicide), anhydrous ammonia (fertilizer)	immediate irritation of the mucous membranes of the eyes, nose, mouth, larynx, trachea and bronchi delayed pulmonary edema (12-24 hrs) caused by damage to alveolar capillary membrane
nitrogen dioxide released from decaying fodder in silos	"Silo fillers disease", cough, dyspnea, delayed pulmonary edema
other oxides of nitrogen	acute respiratory distress, delayed febrile respiratory illness leading to adult respiratory distress syndrome and death, survivors have fivrosing bronchiolitis and/or interstitial pulmonary fibrosis

adapted from: Cockcroft DW, Dosman JA, Respiratory Health Risks in Farmers, Ann Internal Med, 1981, 95(3):380-382. Lowry T, Schuman LM. "Silo-filler's disease" - a syndrome caused by nitrogen dioxide. JAMA, 1956; 162:153-160. Madsen D, Klock LE, Wenzel FJ, et al. The Prevalence of Farmer's Lung in an Agricultural Population, Am Rev Respiratory Disease, 1976, 113:171-174. Warren CPW, Lung disease in Farmers, CMA Journal, 1977, 1977, 116:391-394.

Table 3

Contents of Organic Dusts

Plant debris
Starch granules
Molds
Endotoxins
Mycotoxins
Spores
Fungi
Gram Negative Bacteria
Enzymes
Grain extracts
Allergans
Insect parts
Silica
Soil particles
Chemical residues

Table 4

Organic Dust Toxic Syndrome	Farmer's Lung Disease
Onset in 4-12 hours	Onset 4-8 hours
Fever, chills, dyspnea, myalgias, headache, nonproductive cough, malaise	Fever, chills, malaise nonproductive cough, dyspnea
Duration of 12-24 hours may last up to 5-7 days	Duration 12-36 hours and disease may progress with permanent damage
Rales on examination	Rales on examination
Leukocytosis with predominance of neutrophils	Leukocytosis with lymphocytosis and eosinophils
Mild hypoxemia with alveolar-arterial gradient	Mild to severe hypoxemia with an increased gradient
Negative serology to antigens	Positive antigen serology
Lung lavage cells are PMNs	Lung lavage cells are lymphocytes
Chest x-ray is normal or shows only mild interstitial infiltrate	Chest x-ray may show more dense infiltrates

Biopsy shows acute inflammation	Biopsy shows mononuclear cells or granulomas
Pulmonary function tests demonstrate mild restriction and decreased diffusion of Co (DLCO)	Pulmonary function tests show severe restriction, obstruction, and decreased DLCO
Non-immunologic etiology	Immunologic etiology

Table 5

Clinical Evaluations of Respiratory Disorders in Agricultural Workers

Chronic Bronchitis

History: Consider exposure history, amount of sputum produced, duration of symptoms, time of day that cough is worse and sputum production is the most. Any symptom change away from work should be noted. Inquire about night sweats, fatigue, and other vague symptoms.

Physical Examination: Ausultation of lungs for diminished breath sounds, presence of ronchi or rales, and quality of breath sounds. Respiratory effort and respiratory rate should be noted. General condition and level of physical activity should be noted. Note temperature patterns during day and night.

Ancillary Testing: Chest x-ray with a PA and lateral view should be obtrained. Look for absence of hilar adenopathy or other lesions. Pulmonary function testing should include $FEV_{1.0}$, FVC, and $FEV_{1.0}$/FVC ratio. Sputum should be examined to for types of inflmmatory cells and can be cultured if necessary. A complete blood count (CBC) with differential should be obtained. Appropriate skin test can be applied and serology may be considered for common fungal infections such as coccidiomycosis and histoplasmosis.

Assessment: Exclude asthma, bronchiectais infections, neoplasms and other causes of chronic cough.

Occupational Asthma

History: Occupational history and exposures are important. Asthma can be caused by a wide variety of exposures, chemical as well as biological. Astmatic like syndromes can be allergic or non-allergic in nature. Evaluate hereditary predisposition. Seek presence of work-related wheezing. Define the times of onset and the activity engaged in at the time of onset.

Physical Examination: Pulmonary auscultation may reveal inspiratory as well as expiratory wheezes. Note respiratory rate and effort. Note temperature. Look for use of accessory muscles.

Ancillary testing: Chest x-ray, PA and lateral, should be obtained. Chest x-ray may reveal signs of hyperaertion. Pulmonary function testing should include $FEV_{1.0}$, FVC, and $FEV_{1.0}$/FVC ratio. Reversible airway obstruction with beta adrenergic agonists. Peak flow recordings during the week may indicate times of airway obstruction.

Assessment: Exclude reactive airway disease process. Bronchodilators are usually helpful. Referal to a pulmonary specialist.

Hypersensitivity Pneumonitis

History: Explore symptom onset in relation to certain types of exposures. Define the exposure in terms of location and nature. Inquire about cough, sputum production, myalgias, fever, chills, malaise, dyspnea.

Physical Examination: May reveal rales and ronchi. May note increased respiratory effort and rate.

Ancillary testing: Chest x-ray, PA and lateral, may reveal reticulonodular pattern bilaterally. Absence of hilar adenopathy. Pulmonary function testing should include $FEV_{1.0}$, FVC, and $FEV_{1.0}$/FVC ratio looking for restrictive airway defects. Positive

serology for fungal antigens. CBC with differential may reveal a leukocytosis with increased lymphocytes.

Assessment: Referral to pulmonary specialist if suspected.

Organic Dust Toxic Syndrome

History: Symptoms usually occur a few hours after a high leevel dust exposure. Consider the nature of the dust. Symptoms include cough, fever, chills, myalgias, dyspnea and are usually self limited to hours or days.

Physical Examination: Auscultation of the chest is usually normal. Note respiratory effort and rate. Note temperature.

Ancillary testing: Chest x-ray with Pa and lateral is usually normal.Pulmonary function testing should include $FEV_{1.0}$, FVC, and $FEV_{1.0}$/FVC ratio and are usually normal. CBC with differential may reveal a leukocytosis. Examen sputum for microorganisms and cell types.

Assessment: Refer to pulmonary specialists if no improvement in seven days. Rule out pneumonias and other causes.

Adapted from doPico:American Journal of Industrial Medicine. 17:132-135. 1990

Table 6

INORGANIC AND ORGANOMETAL PESTICIDES

Barium carbonate
Sodium dichromate
Copper sulfate
Zinc chloride
Zinc phosphide
Cadmium chloride
Elemental mercury
Mercuric chloride
Thallium sulfate
Lead arsenate
Fentin acetate
Ethyltin and related compounds
Bismugh subcarbonate
Bismuth subsalicylate
Antimony potassium tartrate
Arsenical pesticides
Phosphorus
Elemental sulfur
Sodium selenate
Sodium fluoride
Sulfuryl fluoride
Zinc hexafluorosilicate
Sodium chlorate
Boric acid

PESTICIDES DERIVED FROM PLANTS AND OTHER ORGANISMS

Pyrethrum
Barthrin
Decamethrin
Permethrin
Rotenone
Nicotine
Anabasine
Sabadilla and related compounds
Strychnine
Ricin
Blasticidin-S

PROPELLANTS, SOLVENTS, AND OIL INSECTICIDES

Dichlorodifluoromethane
Kerosene
Tetralin
Xylene

FUMIGANTS AND NEMATOCIDES

Hydrogen cyanide and the cyanide ion
Acrylonitrile
Isobornyl thiocyanoacetate
Carbon disulfide
Phosphine
Naphthalene
Epoxyethane
Methyl bromide
Dichloromethane
Chloropicrin
Carbon tetrachloride
1,2-Dibromoethane
1,2-Dichloroethane
1,1,1-Trichloroethane
Trichloroethylene
Tetrachloroethylene
Dibromochloropropane
1,3-Dichloropropene
p-Dichlorobenzene

CHLORINATED HYDROCARBON INSECTICIDES

DDT
TDE
Ethylan
Methoxychlor
Benzene hexachloride and lindane
Chlordane
Heptachlor
Aldrin
Dieldrin
Endrin
Isobenzan
Endosulfan
Mirex
Chlordecone
Toxaphene

ORGANIC PHOSPHORUS PESTICIDES

Mipafox
Dimefox
DFP
Malathion
Parathion-methyl
Demeton-methyl
Oxydemeton-methyl
Dichlorvos
Trichlorfon

Jodfenfos
Methidathion
Naled
Phenthoate
Phosphamidon
Pirimiphos-methyl
Temephos
Thiometon

Propaphos
Schradan
Merphos
EPN
Leptophos
Carejin
Edifenphos
Fonofos

Mevinphos
Azinphos-methyl
Bromophos
Dicapthon
Monocrotophos
Dicrotophos
Dimethoate
Endothion
Fenitrothion
Fenthion
Formothion

Parathion
Diazinon
Demeton
Phorate
TEPP
Carbophenothion
Chlorfenvinphos
Chlorphoxim
Chlorpyrifos
Dialifos
Dichlofenthion
dioxathion
Fensulfothion
Phosalone
Phoxim

CARBAMATE PESTICIDES

Carbaryl
Aldocarb
Propoxur
3-Isopropylphenyl-N-methylcarbamate
4-Benziothielyn-N-methylcarbamate
Bufencarb
Carbofuran
Dioxacarb
Isolan
Landrin
Methomyl
Mexacarbate
Oxamyl
Phencyclocarb
Promecarb

NITRO COMPOUNDS AND RELATED PHENOLIC PESTICIDES

2,4-Dinitrophenol
DNOC
Binapacryl
Dinocap
Dinoseb
Pentachlorophenol
TCDD

SYNTHETIC ORGANIC RODENTICIDES

Sodium fluoroacetate
Fluoroacetamide
Fluoroethanol
Gliftor
MNFA
Pyriminil
ANTU
Warfarin
Coumafuryl
Diphacinone
Chloralose
Norbormide

HERBICIDES

2,4-D
2,4,5-T
MCPA
Silvex
Dicamba
TCA
Propanil
Phenmedipham
Cycloate
Molinate
Diuron
Dichlobenil
Ioxynil
Paraquat
Diquat
Atrazine
Propazine
Simazine
Amitrole
Pyrazon

FUNGICIDES AND RELATED COMPOUNDS

Captan
Captafol
Tetrachlorophthalide
Dichloran
Quinotozene
1-Chlorodinitrobenzene
Hexachlorobenzene
Diphenyl
Thiram
Ziram
Maneb
Zineb
Benomyl
Thiabendazole
Thiophanate-methyl

MISCELLANEOUS PESTICIDES

Chlorfenxon
Propargite
Azoxybenzene
Chlordimeform
Metaldehyde
Deet

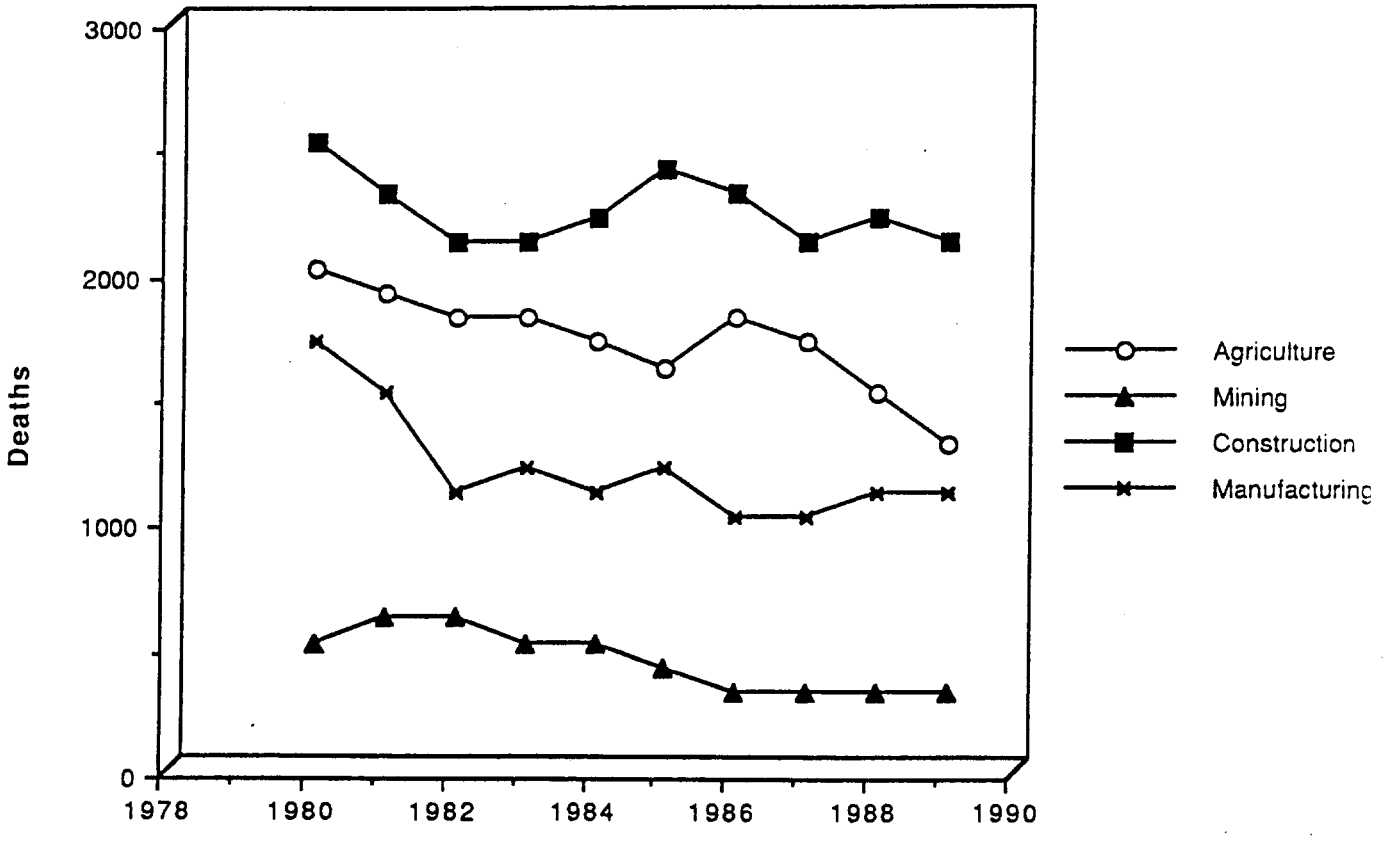
Busulfan
Chlorambucil
Thiotepa
Hexamethylmelamine
5-Fluorouracil
Methotrexate
Porfirmycin

Table 7

U.S. Environmental Protection Agency's Toxicity Categories for Pesticides

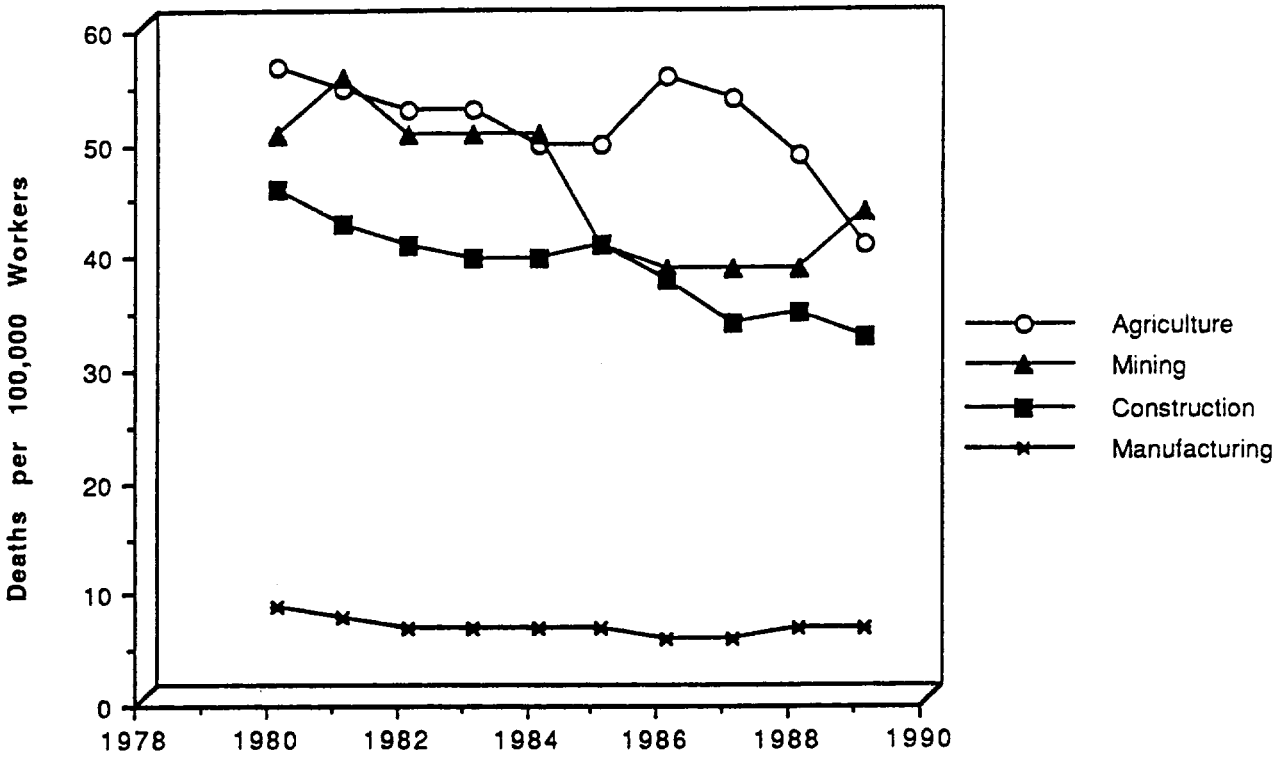
Category	LD_{50}*
I	< = (less than or equal to) 50 mgs/kg
II	51-500 mg/kg
III	>500 mg/kg

*animal oral and dermal median lethal dose



Work Deaths by Industry Division, 1980-1989, National Safety Council

National Safety Council, Accident Facts, 1990, Edition, Chicago, Illinois

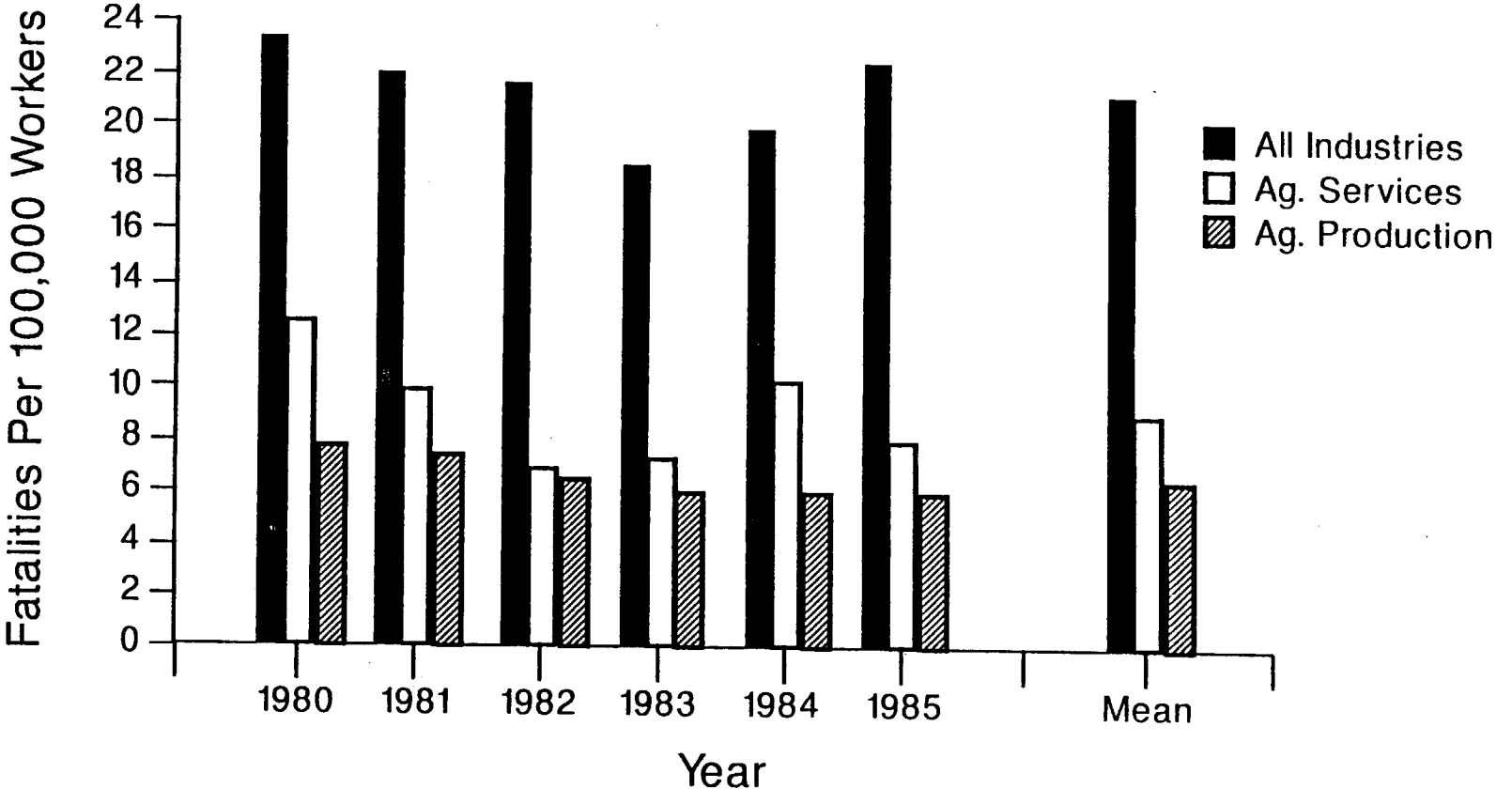


Death Rate by Industry Division, 1980-1989, National Safety Council

National Safety Council, Accident Facts, 1990, Edition, Chicago, Illinois

Fatality Rates per 100,000 Workers for All Industries, Agricultural Services, and Agricultural Production, 1980-1985

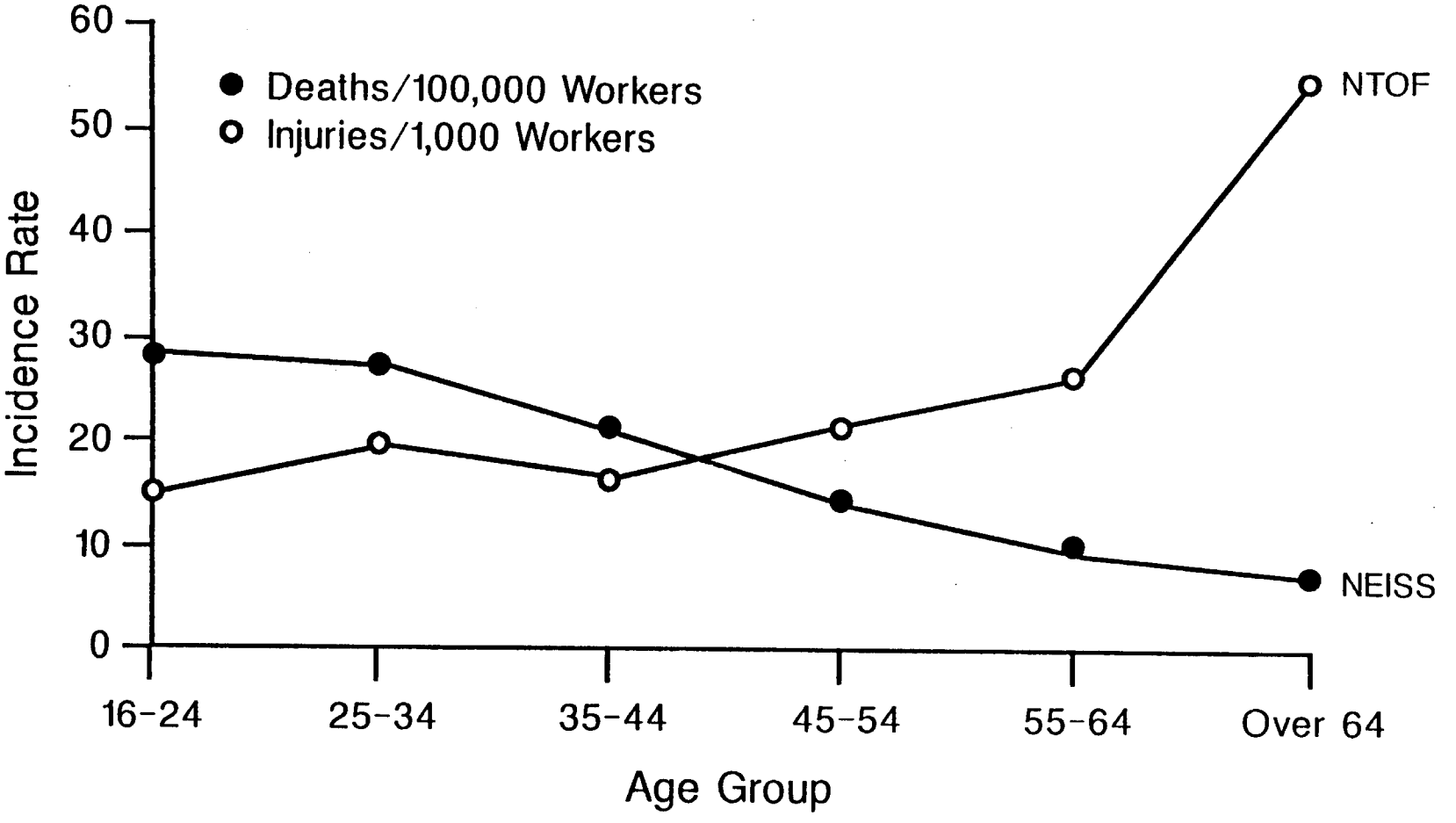
(Centers for Disease Control, 1980-85)



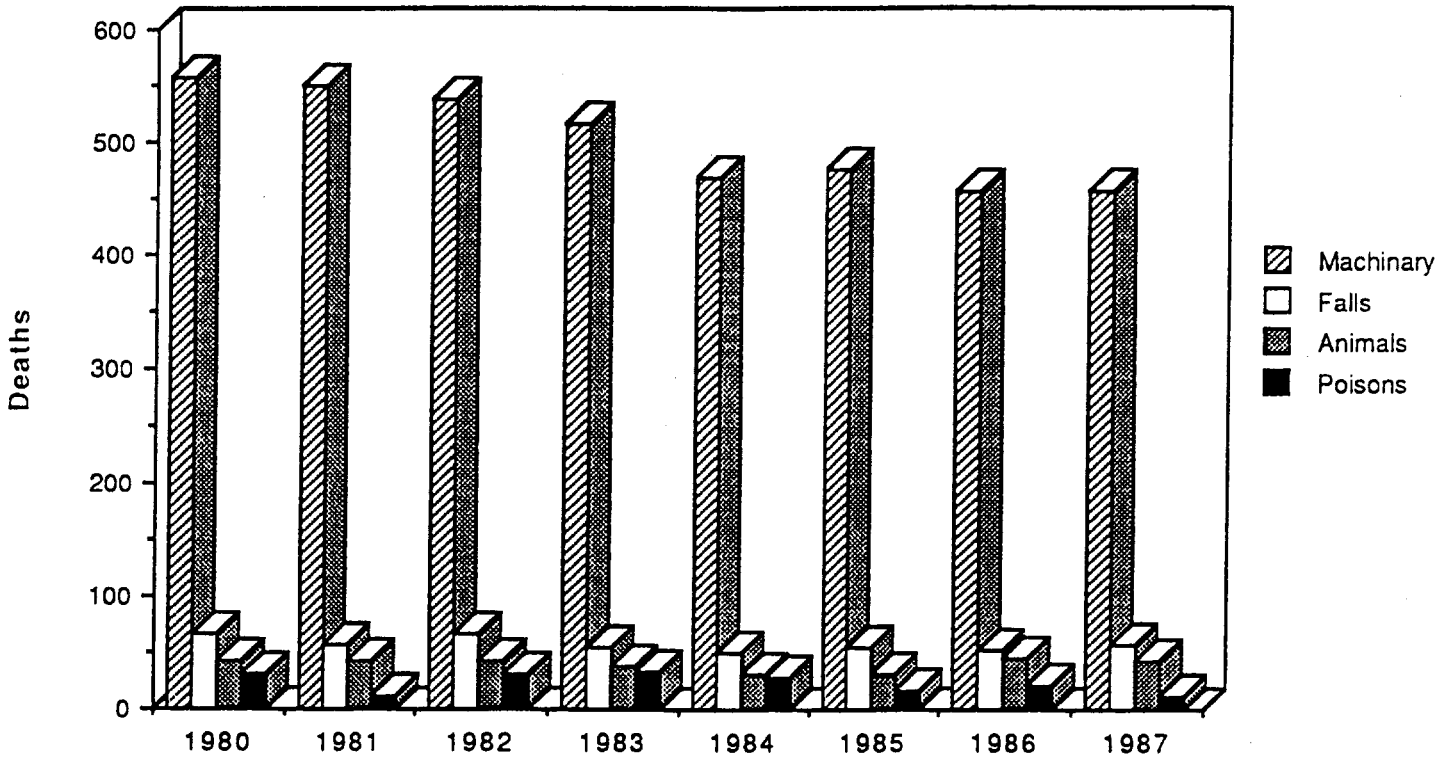
National Safety Council, Accident Facts, 1990, Edition, Chicago, Illinois

Mortality and Injury Rates for the Agricultural Industry

(Centers for Disease Control, 1980-85;
U.S. Consumer Products Safety Commission, May 1981-April 1987)

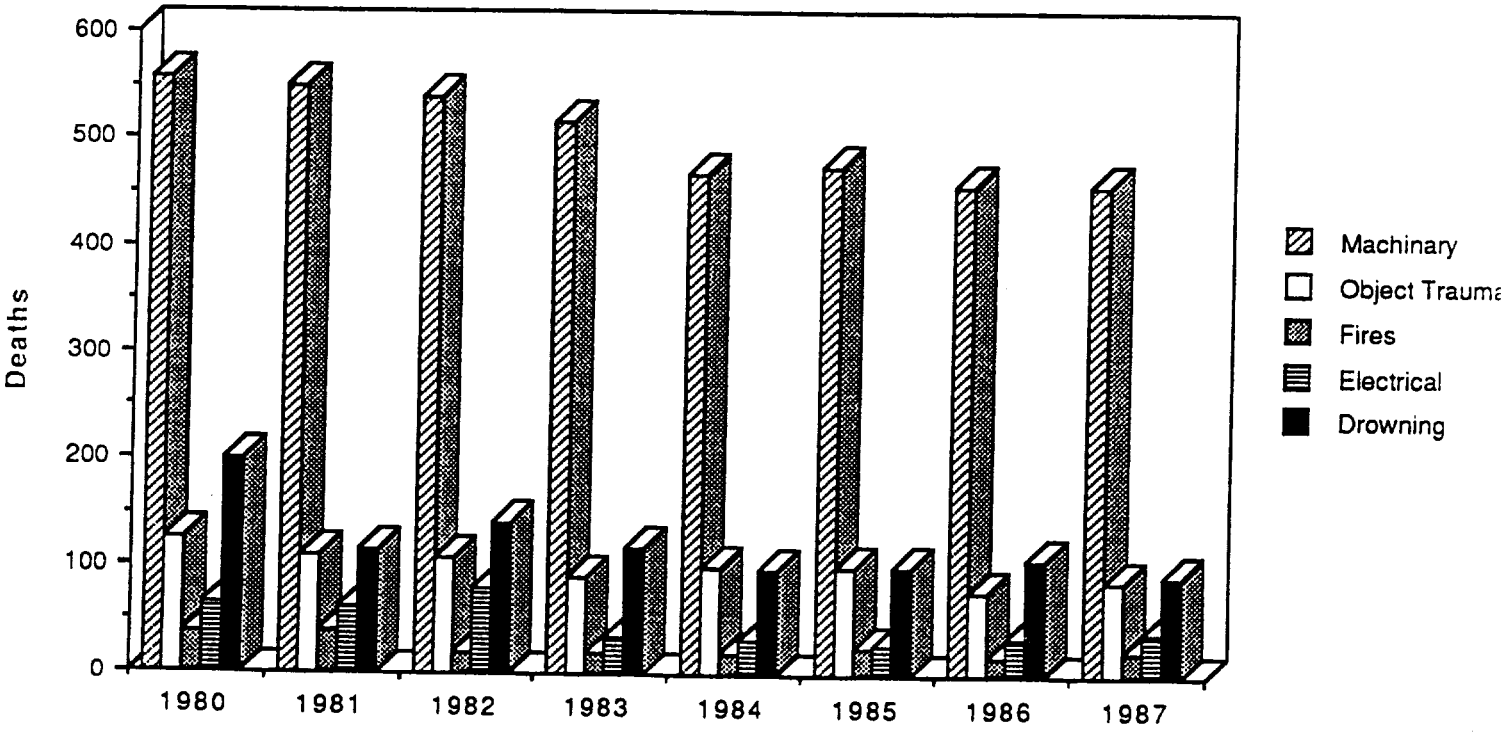


National Safety Council, Accident Facts, 1990, Edition, Chicago, Illinois



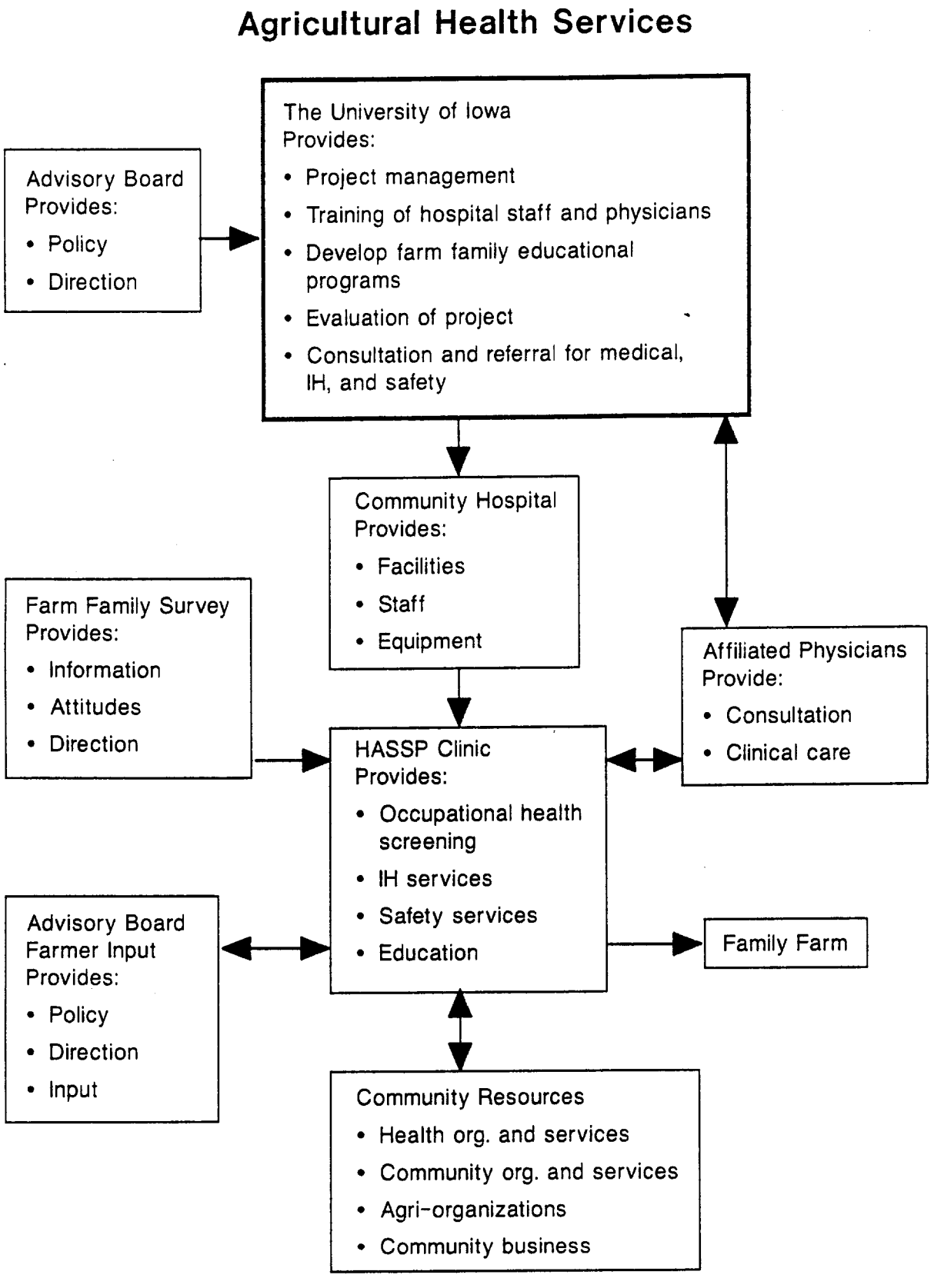
Deaths from Farm Accidents, 1980-1987, National safety Council

National Safety Council, Accident Facts, 1990, Edition, Chicago, Illinois



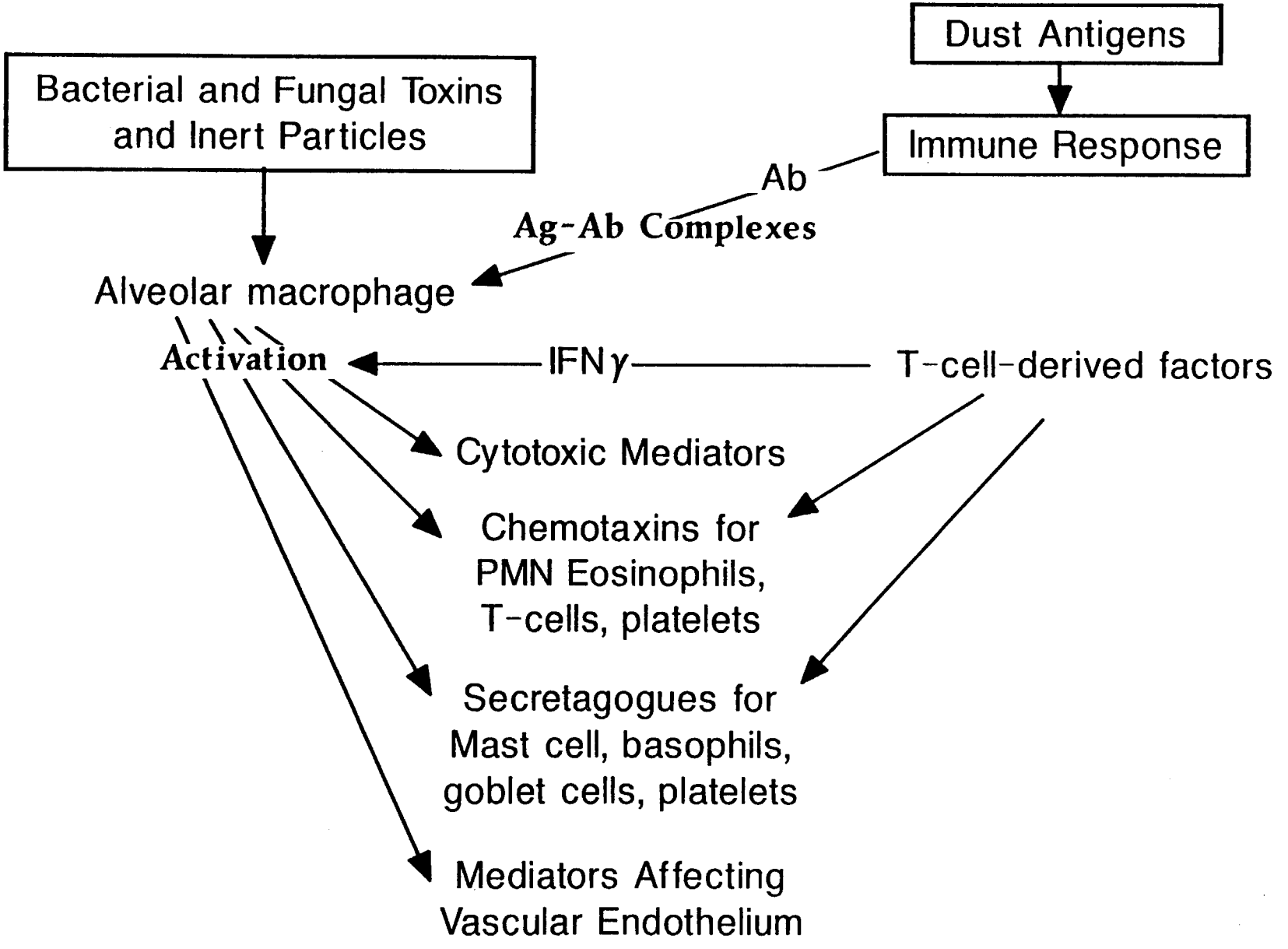
Deaths from Farm Accidents, 1980-1987, National Safety Council

National Safety Council, Accident Facts, 1990, Edition, Chicago, Illinois

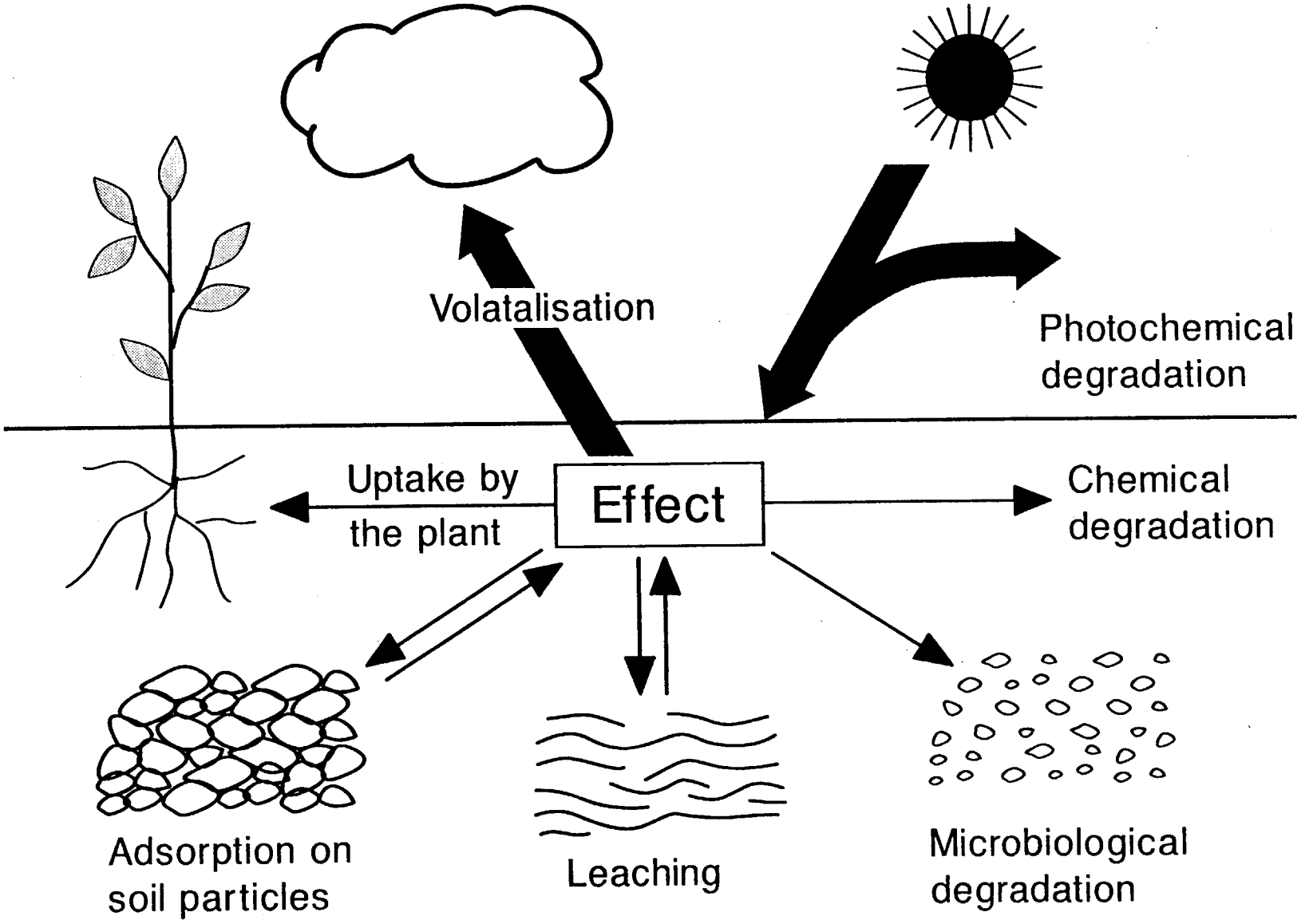


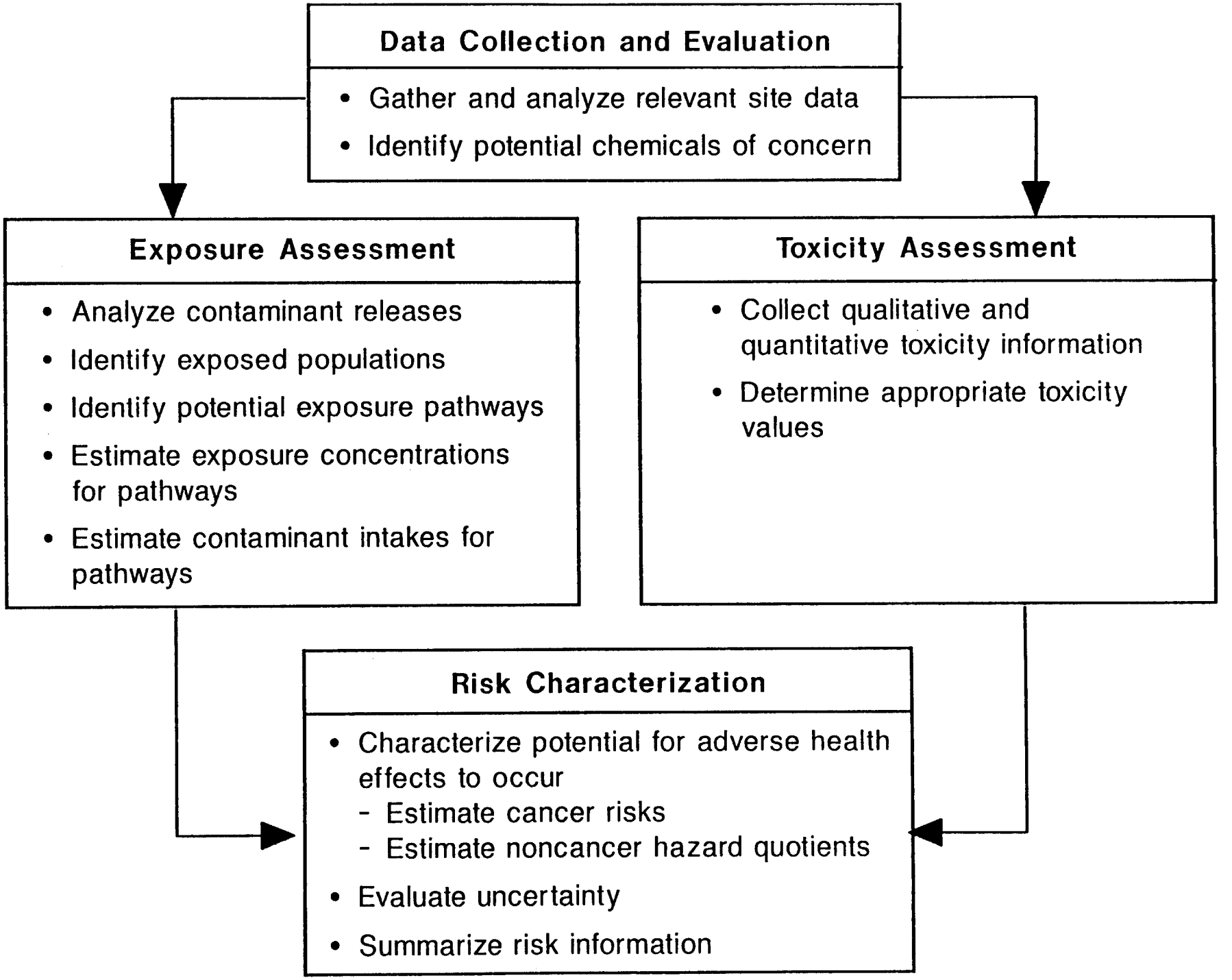
The Iowa Agricultural Health and Safety Service Pilot.

Inflammatory Cascade Induced by Organic Dusts Containing Microbial Contaminants



Scheme of Pesticide Degradation

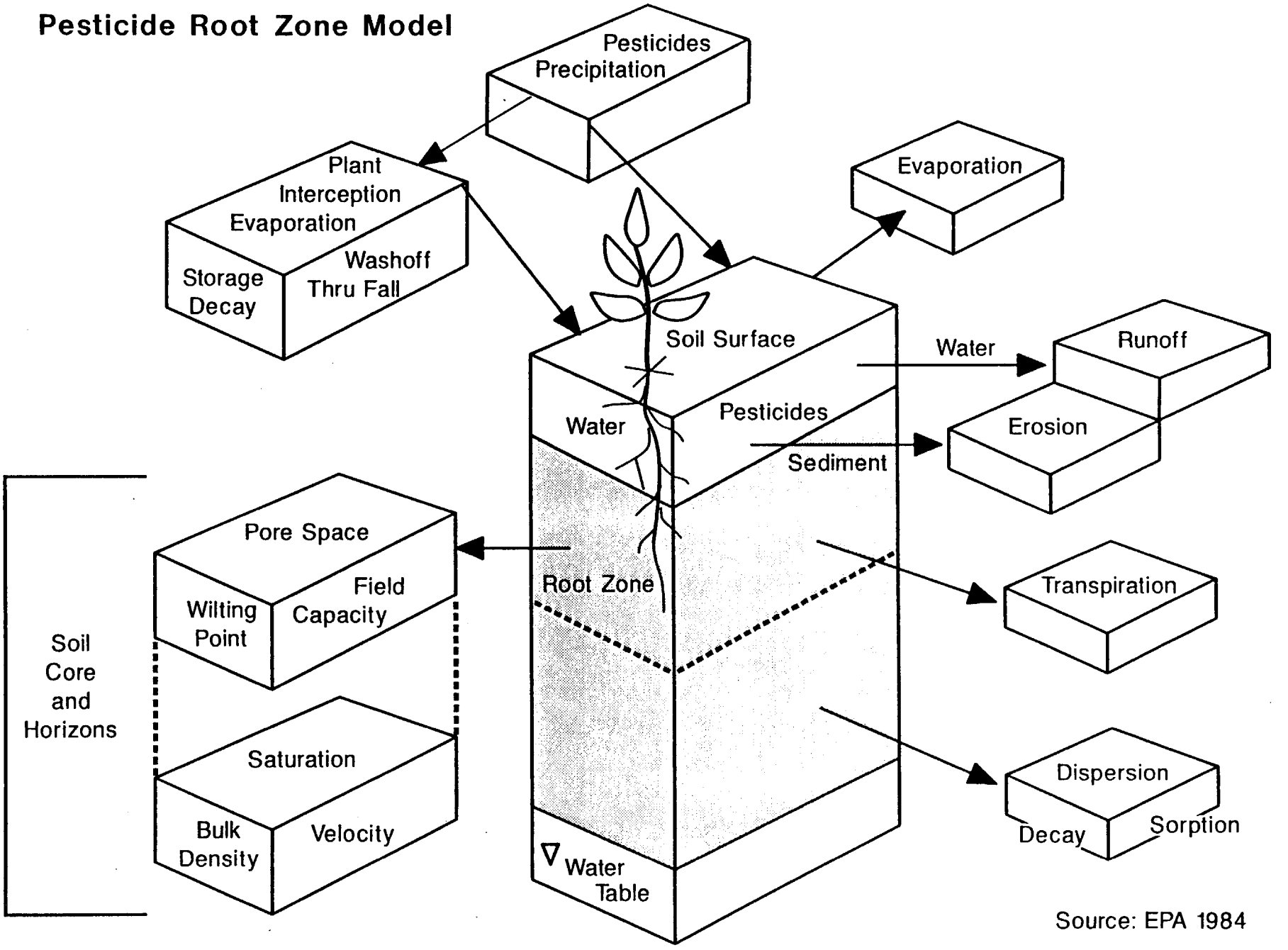



Data Collection and Evaluation
• Gather and analyze relevant site data
• Identify potential chemicals of concern
Exposure Assessment
• Analyze contaminant releases
• Identify exposed populations
• Identify potential exposure pathways
• Estimate exposure concentrations for pathways
• Estimate contaminant intakes for pathways
Toxicity Assessment
• Collect qualitative and quantitative toxicity information
• Determine appropriate toxicity values
Risk Characterization
• Characterize potential for adverse health effects to occur
- Estimate cancer risks
- Estimate noncancer hazard quotients
• Evaluate uncertainty
• Summarize risk information

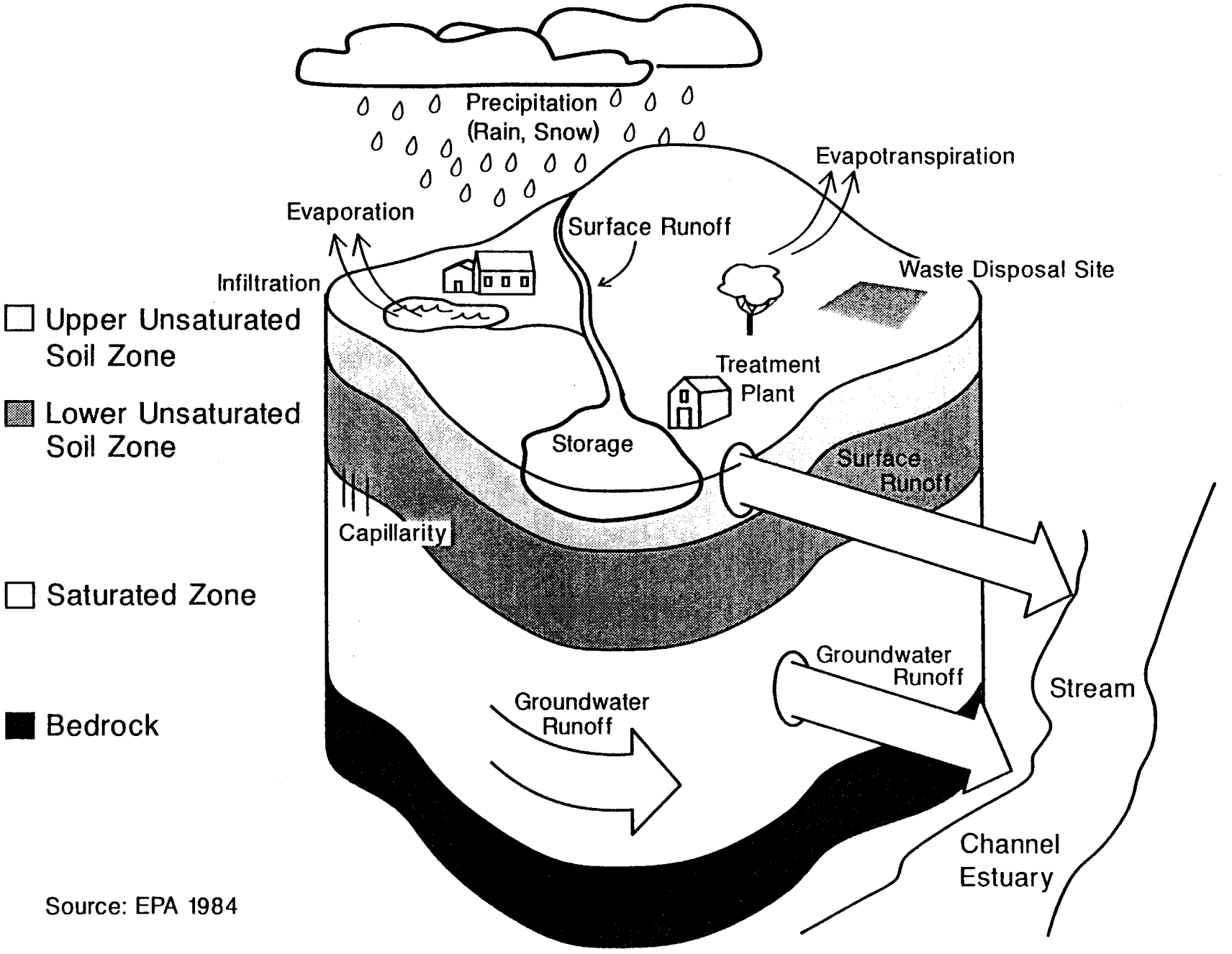
Elements of a Conceptual Evaluation Model

	Variables	Hypotheses to be Tested
SOURCES	• Contaminants • concentrations • Time • Locations	• Source exists • Source can be contained • Source can be removed and disposed • Source can be treated
PATHWAYS	• Media • Rates of migration • Time • Loss and gain functions	• Pathway exists • Pathway can be interrupted • Pathway can be eliminated
RECEPTORS	• Types • Sensitivities • Time • Concentrations • Numbers	• Receptor is not impacted by migration of contaminants • Receptor can be relocated • Institutional controls can be applied • Receptor can be protected

Pesticide Root Zone Model



Source: EPA 1984



Source: EPA 1984

Cumulative Frequency Distribution of Pesticide Leaving Root Zone