

Conferences and Reviews

Health and Safety Risks in Production Agriculture

SUSANNA G. VON ESSEN, MD, *Omaha, Nebraska*, and STEPHEN A. McCURDY, MD, *Davis, California*

Production agriculture is associated with a variety of occupational illnesses and injuries. Agricultural workers are at higher risk of death or disabling injury than most other workers. Traumatic injury commonly occurs from working with machinery or animals. Respiratory illness and health problems from exposures to farm chemicals are major concerns, and dermatoses, hearing loss, certain cancers, and zoonotic infections are important problems. Innovative means of encouraging safe work practices are being developed. Efforts are being made to reach all groups of farmworkers, including migrant and seasonal workers, farm youth, and older farmers.

(Von Essen SG, McCurdy SA. Health and safety risks in production agriculture. *West J Med* 1998; 169:214–220)

Agriculture is a major industry in the United States. About 10 million people work in production agriculture. These include owner-operators and their families, full-time employees, migrant and seasonal workers, and persons who regularly work on farms, such as veterinarians and crop consultants.

As consumers, we know of the variety of agricultural products. Many people, however, including some health care professionals, do not realize that production agriculture is associated with a risk of injury and illness greater than that of most other industries. Agriculture is unique because these risks affect many children and elderly persons as well as workers between the ages of 18 and 65 years.^{1–4}

Farmers and farmworkers are at greater risk of traumatic death and disabling injury than workers in all industries except mining.⁵ According to the National Safety Council, the number of fatalities has greatly decreased in recent years in mining and construction but has fallen only slightly in agriculture.⁶ Risks of acute pesticide poisoning and long-term effects of pesticide exposure such as lymphoid malignant neoplasms are present in a variety of settings where crops are grown. Respiratory disorders develop from the inhalation of grain dust, other types of organic dusts, and work in animal confinement facilities. Hearing loss is an important problem in settings where machinery is in use. Skin cancers caused by sun exposure are a serious problem. Irritant and allergic dermatoses occur from exposures to plants and farm chemicals. Zoonotic infections can cause life-threatening illness. Heat and cold stress occur from exposure to the elements.

In recent years, efforts have increased to characterize and reduce these hazards. Interventions have included engineering innovations, legislation, education programs, and improved occupational medicine services for farmers.^{7,8} Programs are being developed to provide insurance incentives for farming more safely.^{9,10} The increasing number of corporate farms, which do not employ children and which often have safety programs, may reduce the risk for farm workers. A great need still exists for changes that will further reduce the number of occupational injuries and illnesses related to production agriculture.¹¹ In this article, we review the major health and safety risks in production agriculture.

Agricultural Workers

There are few data describing the size and characteristics of agricultural populations, and great disparities exist in figures given by different sources, especially for hired laborers. The 1992 Census of Agriculture reports 3,801,878 directly hired farm laborers on the nation's 1,925,300 farms.¹² Martin and others have estimated there are about 2.5 million hired farmworkers in the United States, of whom about 2.0 million are involved in crop production.^{13,14} About 900,000 of these are migrant and seasonal workers, two thirds of whom shuttle from a fixed location outside the United States and stay for the season ("shuttle migrants"); about a third travel to follow crop employment.¹⁴

Hired farm laborers are especially difficult to count because of the social, economic, and linguistic margin-

From the Department of Internal Medicine, Pulmonary and Critical Care Section, University of Nebraska Medical Center, Omaha (Dr Von Essen); and the Department of Epidemiology and Preventive Medicine, University of California–Davis (Dr McCurdy).

Reprint requests to Susanna G. Von Essen, MD, Department of Internal Medicine, Pulmonary and Critical Care Section, University of Nebraska Medical Center, Box 985300, Omaha, NE 68198-5300 (e-mail: svonessa@unmc.edu).

alization characteristic of this population.¹⁵ The Bureau of Labor Statistics reports an average annual employment in 1996 of 752,200 persons in production agriculture.¹⁶ The 1990 Census indicates 182,235 migrant and seasonal farm workers in California, yet figures based on employment, average crop-specific labor demand, and crop volume statistics suggest a population size between 563,000 and 720,000—an undercount by the census of about 60% to 70%.¹³

Migrant farmworkers tend to follow three main migration streams: the eastern stream comprising the Atlantic seaboard, the midwestern stream comprising Texas through the midwestern states, and the western stream based in California and Arizona and ranging up to Oregon and Washington.¹⁷ The eastern stream is the most ethnically diverse and includes African Americans, Caribbean peoples, and Hispanics. About 90% of the workers in the midwestern and western streams are Hispanic.¹⁷

The National Agricultural Workers Survey provides useful demographic information on the farmworker population.¹⁸ The population is predominantly young men and overwhelmingly Hispanic, Spanish speaking, and foreign born. Mexico is the most common place of birth. Farmworkers typically have a seventh-grade education and have spent 10 to 12 years in agriculture. California farmworkers work an average of 35 weeks per year in agriculture and two additional weeks per year in non-agricultural jobs. The median family income is between \$10,000 and \$12,499. Individual incomes are about half this figure and lowest among unauthorized workers. Nearly half of farmworkers live in poverty. Despite these extreme circumstances, farmworkers infrequently use social support programs. About 13% of California seasonal agricultural workers reported using social support programs, primarily food stamps.¹⁹ In the 1990-1991 California survey, about 9% were unauthorized to work in the United States. More recent data from the workers survey show that about 37% of agricultural workers were unauthorized.¹⁸ The most likely reason for this pronounced increase in unauthorized workers is that the Immigration Reform and Control Act of 1986 conferred citizenship on noncitizens with work authorization, who then left agricultural employment. This created a demand for workers and drew illegal immigrants, primarily from Mexico. Economic instability in Mexico has also contributed to such immigration.

Traumatic Injury

Work injury data are not as readily available for agriculture as for other industries. The reasons for this are varied, including that most American farms do not fall under the reporting requirements of the Occupational Safety and Health Administration because they do not have 11 or more employees. Also, many persons who work on farms are not covered by workers' compensation insurance systems.^{1,20,21} Death certificates have been widely used to identify fatal injuries on farms. This practice has been found to lead to an underestimation of the number of such deaths.²²

A number of well-designed studies conducted recently have documented a high rate of traumatic injury in farmworkers. Injury rates reported range from 9.6% to 16.6% per year.²³⁻²⁸ The greatest number of injuries occurred in the seasons during which crops are grown and harvested. The use of machinery and animal handling were important causes of traumatic injury, as were falls. Dairy farming, a type of agriculture that involves extensive animal handling, is associated with a high risk for injury. Machinery injuries most often include trauma to the hand and eye.²⁹ The power takeoff, a device used to transfer energy from a tractor to farm equipment, is a common source of serious injury if it is not fitted with a safety shield. Machinery trauma includes high-pressure-injection injuries from devices, such as grease guns, and these require emergent surgical decompression.³⁰ Farm chemical exposures to anhydrous ammonia and other caustic substances are another cause of severe eye injuries.³¹ Death from electrocution is fairly common.

Fatalities associated with farm tractors are the most common cause of work-related death in the US agricultural industry.³² Most fatalities occurred from tractor rollovers or run overs. Fatal injuries from tractor rollovers are much more likely to occur if the tractor does not have a rollover protection structure. A great deal of effort is being made to provide incentives and means for farmers to retrofit older tractors with rollover protective structures. Legislation requiring rollover protective structures on tractors has been successful in nearly eliminating tractor rollover deaths in Sweden.³³ Despite this, less than half of US tractors are equipped with rollover protection structures.³⁴

Respiratory Illness

Various respiratory disorders occur in agricultural workers.³⁵ The disorders are a common problem in this group of workers and are a cause of substantial morbidity. These disorders overlap considerably. For example, in a worker who has had farmer's lung, chronic bronchitis may develop as a complication.

Exposures that play an important role in causing respiratory disorders include grain dust, dust and gases in animal confinement units, mold and thermophilic bacteria in hay and grain, and silo gas. Many of the bioaerosols inhaled by agricultural workers are rich in endotoxin, which has been associated with both acute and chronic illness. Evidence exists that other substances in the organic dust, including mycotoxins and silica, play an important role as well.^{36,37}

Acute respiratory illnesses include organic dust toxic syndrome, a febrile, influenza-like illness that occurs 4 to 12 hours after exposure and is self-limiting.³⁸ This problem develops in about a third of grain and livestock farmers at some time. The syndrome is associated with heavy organic dust exposure, usually to grain dust or a swine confinement building.^{35, 36} Its symptoms resemble those of a far less common problem, farmer's lung. The symptoms also resemble those of metal fume fever, a

disorder seen in welders working with galvanized metal in the agriculture setting and elsewhere.

Farmer's lung is one of many forms of hypersensitivity pneumonitis.³⁹ This problem is becoming rare, which is likely due to the reduction of exposure to organic dust from the increasing mechanization of agriculture and the effect of farm health and safety programs. Acute farmer's lung is characterized by dry cough, fever, and malaise four to eight hours after exposure to a substance to which the worker has been sensitized. The onset of the subacute form may be less clearly linked to a specific exposure. Biopsy of lung specimens taken in the acute and subacute phase are notable for the presence of noncaseating granulomas and a mixed population of inflammatory cells. These forms of farmer's lung respond to treatment with oral corticosteroids.⁴⁰ A chronic form of farmer's lung also exists that is characterized by the presence of pulmonary fibrosis that cannot be distinguished from fibrosis with other causes. The pulmonary fibrosis associated with farmer's lung may lead to respiratory failure and death.⁴¹

Chronic bronchitis is more common in agricultural workers than in the general population.⁴²⁻⁴⁵ The prevalence of this disorder ranges from 3% to 30% of non-smoking farmers in the populations studied. Causes for this problem include exposure to grain dust and the animal confinement unit environment. The findings of spirometry may be signs of airways obstruction in these workers, or they may be unremarkable. Inflammation and respiratory tract symptoms can also be seen after acute, heavy exposures of this type.^{46,47} These forms of bronchitis infrequently cause severe respiratory impairment unless an agricultural worker also smokes cigarettes; the adverse effects of the farm environment and cigarette smoking on lung function are additive.

Animal confinement workers are at risk for an asthmalike syndrome characterized by chest tightness, cough, and dyspnea with exertion. Various studies have shown that 2% to 40% of workers have symptoms of the asthmalike syndrome on a daily basis. The asthmalike syndrome is not related to atopy. Risk factors include increasing age; working in swine confinement units for at least six years; and exposure to high levels of ammonia, endotoxin, total dust, and respirable dust in the barns.⁴⁸ The results of spirometry are usually normal in these workers, but they commonly have a cross-shift decrease in the forced expiratory volume in one second. These workers also commonly have an irritant rhinitis.

According to most studies, the prevalence of asthma in agricultural workers is similar to that in other populations.^{49,50} Even though many farmworkers are sensitized to substances in their work environment, no clear evidence exists that exposure to those substances in the work setting causes asthma. Farmworkers who have asthma are at increased risk of suffering exacerbation of their asthma after exposure to dusts and fumes.

Toxic gas exposures, which can be fatal, are another important respiratory problem in production agriculture. Silage stored in concrete silos may release nitrogen dioxide for several weeks after the silo is filled.⁵¹ Nitrogen

dioxide may cause death in a matter of minutes with heavy exposure. Exposure at lower levels may cause acute respiratory tract symptoms, and bronchiolitis obliterans may develop weeks later. The bronchiolitis obliterans responds to treatment with corticosteroids. Some silos are oxygen-limiting, and entering these structures can result in asphyxiation.

Animal wastes are frequently stored underground and are a source of toxic gases. Entering confined spaces used for manure storage can lead to fatalities, which are often caused by hydrogen sulfide exposures.⁵²

Entrapment and suffocation in stored grain is an important problem in production agriculture. Measures such as wearing a safety harness and not working alone help reduce the risk of death when handling stored grain.⁵³

Environmental controls are important for preventing respiratory illness in agricultural workers. These include measures to reduce dust, such as increased ventilation and the use of canola oil sprinkled to reduce dust in the air in swine confinement buildings.⁵⁴ Workers should also use respirators to reduce dust exposure. Evidence exists that the risk of episodes of farmer's lung is substantially reduced by wearing a respirator.⁵⁵ Mechanical filter respirators may be disposable paper masks or may consist of a rubber or plastic face piece and replaceable filter elements. These respirators should not be confused with the nuisance dust masks commonly available in hardware stores. Disposable respirators used in agricultural settings should have two straps for optimal fit and should be certified by the National Institute for Occupational Safety and Health as being suitable for use against dust and mists. Powered air-purifying respirators offer more protection than the other types of respirators and reduce the physical stress of wearing these devices.⁵⁶ Entering confined spaces with possibly toxic gas levels should be avoided if possible. The use of proper equipment with an air supply is essential for entering spaces known or suspected of containing dangerous levels of hydrogen sulfide, nitrogen dioxide, or other toxic gases.

Hearing Loss

Farmers are regularly subjected to loud noises when working with machinery such as tractors, feed grinders, and chain saws.^{57,58} Noise made by large animals such as pigs can be loud enough to damage hearing.⁵⁹ Hearing loss has been documented as early as the teenaged years in farm youth.⁶⁰ As with other industries where high levels of noise are a problem, the noise-induced hearing loss initially occurs in the region of the cochlea responsible for higher frequencies. If noise exposure continues, the hearing loss extends to lower and higher frequencies, making normal human speech difficult to understand. In a recent study, 65% of dairy farmers had hearing loss. Screening audiograms to identify affected persons, engineering controls to reduce noise exposure, education programs, and the use of hearing protection are an important part of occupational health services for farmworkers.

Cancer

The overall cancer risk for farmers is lower than for the general population. The risk for common cancers such as those of the lung and colon is lower in farmers.^{61,62} That for several types of cancer, however, is increased in farmers, including leukemia, Hodgkin's disease, non-Hodgkin's lymphoma, multiple myeloma, and cancers of the lip, stomach, skin, prostate, brain, and connective tissue. With the exception of cancer of the lip, the relative risk for these cancers is fairly low but has been identified in most studies of cancer in agricultural workers. Evidence exists that ongoing exposure to pesticides, insecticides, herbicides, and fungicides may be linked to an elevated relative risk for some cancers,⁶³ but not all studies find a relationship between exposure to farm chemicals and cancer.

Farm Chemical Poisoning

Pesticide exposure can cause serious illness and death. Illness from pesticide exposure is likely frequently not recognized or reported as being linked to this exposure. Various pesticides can cause acute illness.⁶⁴ Organophosphates irreversibly block the enzyme acetylcholinesterase, causing acetylcholine to accumulate at nerve synapses and the neuromuscular junction and leading to excess parasympathetic stimulation. Signs and symptoms of organophosphate poisoning include bradycardia, hypotension, salivation, lacrimation, urinary incontinence, diarrhea, vomiting, abdominal cramping, bronchospasm and bronchorrhea, muscle fasciculations and weakness (which can cause respiratory failure), confusion, hallucinations, seizures, and coma. Treatment of this problem includes the anticholinergic agent atropine sulfate and oximes such as pralidoxime chloride, which are used to displace the organophosphate from cholinesterase.

Long-term exposure to organophosphates is seen in farmworkers such as orchard sprayers and in other groups. Symptoms include headache, nausea, weakness, fatigue, and chest tightness. Evidence is increasing that long-term organophosphate exposure can cause permanent neurologic deficits,⁶⁵ including peripheral neuropathy and deficits in memory, attention, and motor skills.

Biomarkers of exposure to organophosphates include cholinesterase levels in plasma and erythrocytes. Levels should be determined at baseline and at the time of suspected poisoning. Moderate symptoms may be expected with a 60% to 90% reduction in levels from baseline.

Carbamate insecticides cause a reversible inhibition of cholinesterases with symptoms similar to those of organophosphate poisoning. Treatment consists of the administration of atropine.

Pyrethrin and pyrethroid insecticides are substances that have a better safety profile than do organophosphates and carbamates, but they can also cause severe symptoms and death.

A variety of herbicides and fungicides in common use can cause serious systemic symptoms. These include 2,4-dichlorophenoxyacetic acid and paraquat. The

ingestion of paraquat may result in fatal pulmonary fibrosis and renal failure.

The key to avoiding poisoning from farm chemicals is the safe storage of these substances and the use of proper personal protective equipment. Accurate records must be kept regarding farm chemical use. Also, pesticide-contaminated clothing must be laundered separately from other clothing.

Anhydrous ammonia is widely used as a fertilizer. Common injuries from anhydrous ammonia exposure include eye and skin burns and injury to the larynx.^{67,68} Long-term impairment from lower respiratory tract injury can occur.

California is unique among the states in maintaining reporting systems for pesticide use and pesticide illnesses. In 1990, California instituted full-use reporting for pesticides, requiring monthly reporting to county agricultural agents.⁶⁹ Reports include the date and location (section, township, and range) where the application was made, the crop, and the kind and amount of pesticides used. The primary exceptions to the full-use reporting requirements are home and garden use and most industrial and institutional uses. In 1995, 211,798,752 lb (active ingredient) were used. Of this total, 192,471,136 lb (90.9%) were used in production agriculture.^{69,70}

California has required the reporting of pesticide-related illnesses since 1971.⁷¹ Reported cases are categorized with respect to pesticide causation as definite, probable, possible, unlikely, or indeterminate. In 1995, 1,593 illnesses occurred that had a possible or confirmed link to pesticide use. Of these, 656 (41.2%) cases occurred in agricultural settings. In 1995, the latest year for which published data are available, 1,117 definite or probable pesticide-related injuries or illnesses occurred in California. Unfortunately, published data do not separate the agricultural cases from this total. Exposure to pesticide aerosol from spraying ("drift") was the most commonly reported exposure circumstance and occurred in 277 (24.8%) cases. The use of applicator equipment was associated with 251 (22.5%) cases. Definite or probable cases included 12 persons admitted to a hospital (totaling 54 reported hospital days) and 212 persons suffering disability days (totaling 883 days). No agriculturally related pesticide fatalities occurred. Insecticide combinations were associated with 142 definite or probable cases, organophosphates were associated with 103 cases, and fumigants were associated with 92 definite or probable cases.

Risk factors for severe organophosphate-related illness (that is, associated with disability or hospital admission) include direct exposure to residue (odds ratio, 4.6), work as mixer-loader or applicator (odds ratio, 4.1), and Spanish surname (odds ratio, 1.6).⁷² The use of diethyl organophosphates (versus dimethyl organophosphates) was also associated with increased severity.

Dermatoses

Occupational skin disorders are common in agricultural workers. The effects of sun exposure are an important cause of morbidity in this occupational group, particular-

TABLE 1.—Zoonotic Diseases Of Occupational Significance In Agricultural Workers

Disease	Organism	Exposure	Management
Anthrax	<i>Bacillus anthracis</i>	Cattle	Penicillin
Encephalitis	Arboviruses	Horses, mosquitos	Supportive care
Lyme disease	<i>Borrelia burgdorferi</i>	Tick <i>Ixodes ricinus</i>	Tetracyclines or penicillin
Brucellosis	<i>Brucella abortis</i>	Cattle	Tetracyclines and streptomycin or doxycycline and rifampin
Gastroenteritis	<i>Campylobacter</i> species	Sheep, cattle	Erythromycin
Spontaneous abortion	<i>Chlamydia trachomatis</i> and <i>Chlamydia psittaci</i>	Lambing sheep	Avoidance
Pneumonia	<i>C. psittaci</i>	Turkeys, chickens	Tetracyclines
Q fever, endocarditis	<i>Coxiella burnetii</i>	Sheep, cattle	Tetracyclines
Tetanus	<i>Clostridium tetani</i>	Soil contaminated with animal feces	Supportive care
Diarrhea	<i>Cryptosporidium parvum</i>	Water contaminated by cattle feces; Cats, dogs	No effective therapy
Hydatid disease	<i>Echinococcus</i> species	Sheep, dogs	Resection
Tularemia	<i>Francisella tularensis</i>	Sheep	Streptomycin or gentamicin sulfate
Respiratory failure	Hantavirus	Rodents	Supportive care
Leptospirosis, spontaneous abortion	<i>Leptospira</i> species	Exposure to cattle, pigs, rodents	Penicillin, avoidance
Listeriosis, meningitis	<i>Listeria monocytogenes</i>	Cattle, sheep, goats, fowl	Penicillins
Cellulitis	<i>Pasteurella multocida</i>	Bites by cats, dogs	Penicillin
Rabies	Rabies virus	Infected mammals	Supportive care
Salmonellosis	<i>Salmonella typhimurium</i>	Sheep, cattle	Supportive care
Meningitis	<i>Streptococcus suis</i>	Pigs	Penicillin
Toxoplasmosis	<i>Toxoplasma gondii</i>	Cats, fur-bearing animals, raw pork and mutton	Pyrimethamine, sulfadiazine
Ringworm	<i>Trichophyton</i> species	Small mammals	Topical antifungals

ly in those with fair skin.⁷³ Persons who sunburn easily are at increased risk for skin cancers. The most common type of skin cancer in agricultural workers and in the general population is basal cell carcinoma. Lip cancer is also more common in agricultural workers, as is squamous cell carcinoma. The relative risk for the development of nonmelanoma skin cancers in farmers ranges from 0.8 to 1.8 and for lip cancer from 1.3 to 3.1.⁶¹ The risk for melanoma apparently is also increased for this occupational group, with the relative risk in various studies ranging from 0.5 to 6.3. Preventive efforts have included encouraging the routine use of sunscreens and the wearing of broad-brimmed hats instead of baseball-style caps.

A variety of farm chemicals and materials used for veterinary care can cause allergic contact dermatitis. Important causes of this problem include many pesticides, fertilizers, topical antibiotics designed for veterinary use, and latex.

Zoonoses

A long list of pathogens can cause zoonotic disease in agricultural workers, including bacteria, viruses, rickettsiae, chlamydiae, parasites, and fungi.⁷⁴⁻⁷⁹ The zoonotic disorders range in severity from fungal infections such as ringworm that are easily treated to life-threatening problems like rabies or anthrax (Table 1). Measures to prevent these

infections include maintaining the health of farm animals, avoiding skin contact with animals known to be infected, and wearing respirators approved by the National Institute for Occupational Safety and Health when working in high-risk situations where diseases such as brucellosis and Q fever may be contracted by inhalation.

Heat and Cold Stress

Because farmworkers spend a great deal of time outdoors, they are at risk for physical stress from excessively cold and excessively hot environments.⁸⁰ The magnitude of heat and cold stress problems in agriculture is not well documented. Tolerance to such environments varies among individuals and may be difficult to predict.⁸¹ Agricultural workers should be provided the means to compensate for extremes of temperature. For example, adequate water supplies while working outdoors in hot climates are essential.

Musculoskeletal Disorders

Agricultural production labor is often physically demanding and may involve repetitive motions, characteristics associated with an increased risk for acute and chronic musculoskeletal disorders. In California, workers' compensation data show that sprains and strains make up more than 40% cases of lost work.⁸²

Few data are available that address chronic musculoskeletal condition among agricultural workers in specific commodities. In a recent study, 71% of swine producers reported chronic back problems.⁸³ Osteoarthritis of the hip and knee are common problems among New York dairy farmers.⁸⁴ An increased risk for shoulder pain has been demonstrated among greenhouse tomato workers⁸⁵ and orchard farmers harvesting pears and apples.⁸⁶ Overhead work requiring arm and head elevation was associated with an increased risk for shoulder-neck complaints.⁸⁶

The prevention of musculoskeletal conditions requires eliminating or reducing exposure to highly demanding, repetitive tasks. New production methods to reduce exposures, however, may not be acceptable to employers or workers. Methods that reduce production or increase costs are unlikely to be accepted unless there is a clear and offsetting reduction in injury-related costs. Workers take pride in being among a select group able to perform difficult jobs; they may not accept innovations that open their employment to a wider field of potential competitors for their work.⁸⁷

Green Tobacco Sickness

Workers harvesting tobacco by hand are known to suffer from an illness that consists of nausea, vomiting, weakness, diarrhea, headache, and dizziness.⁸⁸ This problem is caused by the dermal absorption of nicotine during the harvest process.

Conclusion

Work in production agriculture is associated with a wide variety of health hazards. The US farm-work-related death rate has fallen in the past 30 years, but there is still a great need for effective programs that will further reduce the risk of injury and illness on our nation's farms.

Acknowledgment

Dr. McCurdy is supported in part by the National Institute for Occupational Safety and Health (NIOSH #5 R01 OH03444-02) and the University of California Agricultural Safety and Health Center at Davis (NIOSH # 407/CC906162).

REFERENCES

- Purschwitz MA, Field WE. Scope and magnitude of injuries in the agricultural workplace. *Am J Ind Med* 1990; 18:179-192
- Cogbill TH, Steenlage ES, Landerscaper J, Strutt P. Death and disability from agricultural injuries in Wisconsin: a 12 year- experience with 739 patients. *J Trauma* 1991; 31:1632-1637
- Schenker MB, Lopez D, Wintemute G. Farm-related fatalities among children in California, 1980-1989. *Am J Public Health* 1995; 85:89-92
- Rivara FP. Fatal and non-fatal farm injuries to children and adolescents in the United States 1990-1993. Sponsored by Farm Safety 4 Just Kids. Seattle: University of Washington, Harborview Injury Prevention and Research Center and the Departments of Pediatrics and Epidemiology; 1997
- Accident Facts. Itasca (Ill): National Safety Council; 1996
- Report to the nation. Agricultural Occupational and Environmental Health: Policy Strategies for the Future. 3rd edition. National Coalition for Agricultural Safety and Health (Iowa City, Iowa); 1989
- Aherin RA, Murphy DJ, Westaby JD. Reducing Farm Injuries: Issues and Methods. St Joseph (Mich): American Society of Agriculture and Engineering; 1992
- Donham KJ, Thu KT. Agricultural medicine and environmental health: the missing components of the sustainable agriculture movement. In: McDuffie HH, Dosman JA, Semchuk KM, Olenchock SA, Senthilselvan A, eds. *Agricultural Safety and Health*. Boca Raton (Fla): CRC Press; 1995, pp 583-589
- Shutske JM, Ohmans PJ. Shifting the paradigm: rethinking our approach to agricultural safety and health issues. *J Agromed* 1995; 2:39-44
- Von Essen SG, Thu K, Donham KJ. Insurance incentives for safe farms. *J Agromed*; in press
- Schenker MB. Preventive medicine and health promotion are overdue in the agricultural workplace. *J Public Health Policy* 1996; 17:275-305
- US Dept of Commerce: 1992 Census of Agriculture. Vol 1, Geographic Area Series. Part 51: US Summary and State Data. Washington (DC): Economics and Statistics Administration, Bureau of the Census; 1994
- Gabbard S, Kissam E, Martin PL. The Impact of Migrant Travel Patterns on the Undercount of Hispanic Farmworkers. Research Conference on Undercounted Populations. Washington (DC): Dept of the Census; 1993, pp 207-245
- Martin PL, Martin DA: The Endless Quest: Helping America's Farm Workers. Boulder (Colo): Westview Press; 1994
- McCurdy S. Occupational health status of migrant and seasonal farmworkers. In: McDuffie HH, Dosman JA, Semchuk KM, Olenchock SA, Senthilselvan A, eds. *Agricultural Health and Safety: Workplace, Environment, Sustainability* (suppl). Boca Raton (Fla): CRC Press; 1995, pp 213-216
- US Dept of Labor. Workplace Injuries and Illnesses in 1996. Washington (DC): Bureau of Labor Statistics; 1997
- Meister JS: The health of migrant farm workers. *Occup Med* 1991; 6:503-518
- Mines R, Gabbard S, Steirman A. A Profile of US Farm Workers: Demographics, Household Composition, Income, and Use of Services. Washington (DC): US Dept of Labor, Office of the Assistant Secretary for Policy; 1997
- Rosenberg HR, Gabbard SM, Alderete E, Mines R: California Findings from the National Agricultural Workers Survey: A Demographic and Employment Profile of Perishable Crop Farm Workers. Washington (DC): US Dept of Labor; 1993
- Gunderson P, Gerberich S, Gibson R, Adlis S, Carr P, Erdman A, et al. Injury surveillance in agriculture. *Am J Ind Med* 1990; 18:169-178
- Rosignol M. Completeness of provincial workers' compensation files to identify fatal occupational injuries. *Can J Public Health* 1994; 85:244-247
- Russell J, Conroy C. Representativeness of deaths identified through the injury-at-work item on the death certificate: implications for surveillance. *Am J Public Health* 1991; 81:1613-1618
- Brisson RJ, Pickett CWL. Nonfatal farm injuries in eastern Ontario: a retrospective survey. *Accid Anal Prev* 1991; 23:585-594
- Pratt DS, Marvel LH, Darrow D, Stallones L, May JJ, Jenkins P. The dangers of dairy farming: the injury experience of 600 workers followed for two years. *Am J Ind Med* 1992; 21:637-650
- Zhou C, Roseman J. Agricultural injuries among a population-based sample of farm operators in Alabama. *Am J Ind Med* 1994; 25:385-402
- Brackbill RM, Cameron LL, Behrens V. Prevalence of chronic diseases and impairments among US farmers, 1986-1990. *Am J Epidemiol* 1994; 139:1055-1065
- Stueland D, Mickel SH, Cleveland DA, Rothfusz RR, Zoch T, Stamas P Jr. The relationship of farm residency status to demographic and service characteristics of agricultural injury victims in central Wisconsin. *J Rural Health* 1995; 11:98-105
- Beaumont JJ, Goldsmith DF, Morrin LA, Schenker MB. Mortality in agricultural workers after compensation claims for respiratory disease, pesticide illness, and injury. *J Occup Environ Med* 1995; 37:160-169
- Layde PM, Nordstrom DL, Stueland D, Brand L, Olson KA. Machine-related occupational injuries in farm residents. *Ann Epidemiol* 1995; 5:419-426
- Flotre M. High-pressure injection injuries of the hand. *Am Fam Phys* 1992; 45:2230-2234
- Centers for Disease Control and Prevention (CDC). Eye injuries to agricultural workers - Minnesota, 1992-1993. *MMWR Morb Mortal Wkly Rep* 1995; 44:364-367
- CDC. Farm-related tractor fatalities - Kentucky 1994. *MMWR Morb Mortal Wkly Rep* 1995; 44:481-485
- Thelin A. Epilogue: agricultural, occupational and environmental health policy strategies for the future. *Am J Ind Med* 1990; 18:523-526
- Kelsey JW, Mey JJ, Jenkins PL. Farm tractors and the use of seat belts and roll-over protective structures. *Am J Ind Med* 1996; 30:447-456
- Von Essen SG, Donham KJ. Respiratory diseases related to work in agriculture. In: Langley RL, McLymore RL, Meggs WJ, Roberson GT, eds. *Safety and Health in Agriculture, Forestry and Fisheries*. Rockville (Md): Government Institutes, Inc; 1997, pp 353-384
- Malmberg P, Palmgren U, Rask-Andersen A. Relationship between symptoms and exposure to mold dust in Swedish farmers. *Am J Ind Med* 1986; 10:316-317
- McCurdy SA, Ferguson TJ, Goldsmith DF, Parker JE, Schenker MB. Respiratory health of California rice farmers. *Am J Respir Crit Care Med* 1996; 153:1553-1559
- Von Essen S, Robbins RA, Thompson AB, Rennard SI. Organic dust toxic syndrome: an acute febrile reaction to organic dust exposure distinct from hypersensitivity pneumonitis. *Clin Toxicol* 1990; 28:389-420

39. Fink JN. Hypersensitivity pneumonitis. *Clin Chest Med* 1992; 13:303–309
40. Mönkäre S, Haahela T. Farmer's lung: a 5-year follow-up of eighty-six patients. *Clin Allergy* 1987; 17:143–151
41. Barbee RA, Callies Q, Dickie HA, Rankin J. The long-term prognosis in farmer's lung. *Am Rev Respir Dis* 1968; 97:223–231
42. DoPico GA, Reddan WG, Anderson S, Flaherty D, Smalley E. Epidemiologic study of clinical and physiologic parameters in grain handlers of the northern United States. *Am Rev Respir Dis* 1984; 130:759–765
43. Jorna THJM, Borm PJA, Valks J, Houba R, Wouters EFM. Respiratory symptoms and lung function in animal feed workers. *Chest* 1994; 106:1050–1055
44. Schwartz DA, Donham KJ, Olenchock SA, Popendorf WJ, Van Fossen DS, Burmeister LF, Thorne PS, Yagle SJ, Burmeister LF, Olenchock SA, Watt JL et al. Determinants of longitudinal changes in spirometric function among swine confinement operators and farmers. *Am J Respir Crit Care Med* 1995; 151:47–53
45. Von Essen S. Bronchitis in agricultural workers. *Semin Respir Med* 1993; 14:60–69
46. Von Essen SG, Thompson AB, Robbins RA, Jones KK, Dobry CA, Renard SI. Lower respiratory tract inflammation in grain farmers. *Am J Ind Med* 1990; 17:75–76
47. Larsson KA, Eklund AG, Hansson LO, Isaksson BM, Malmberg PO. Swine dust causes intense airways inflammation in healthy subjects. *Am J Respir Crit Care Med* 1994; 150:973–977
48. Donham KJ, Reynolds SJ, Whitten P, Merchant J, Burmeister L, Popendorf WJ. Respiratory dysfunction in swine production facility workers: dose-response relationships of environmental exposures and pulmonary function. *Am J Ind Med* 1995; 27:405–418
49. Zejda JE, Dosman JA. Respiratory disorders in agriculture. *Tuber Lung Dis* 1993; 74:74–86
50. Senthilselvan A, Chen Y, Dosman JA. Predictors of asthma and wheezing in adults. Grain farming, sex and smoking. *Am Rev Respir Dis* 1993; 148:667–670
51. May JJ. Agriculture. In: Harber P, Schenker MB, Balmes JR, eds. *Occupational and Environmental Respiratory Disease*. St Louis (Mo): Mosby; 1996, pp 188–200
52. Update. NIOSH Warns: Manure Pits Continue to Claim Lives. Lexington (Ky): National Institute for Occupational Safety and Health; July 6, 1993
53. Update. NIOSH Warns Farmers of Deadly Risk of Grain Suffocation. Lexington (Ky): National Institute for Occupational Safety and Health; April 28, 1993
54. Senthilselvan A, Zhang Y, Dosman JA, Barber EM, Holfeld LE, Kirychuk SP, et al. Positive human health effects of dust suppression with canola oil in swine barns. *Am J Respir Crit Care Med* 1997; 156(pt 1):410–417
55. Mueller-Wening DH, Repp H. Investigation on the protective value of breathing masks in farmer's lung using an inhalation provocation test. *Chest* 1989; 95:100–105
56. Prather TG. Personal protective equipment in agriculture, forestry, and fisheries. In: Langley RL, McLymore RL, Meggs WJ, Roberson GT, eds. *Safety and Health in Agriculture, Forestry and Fisheries*. Rockville (Md): Government Institutes, Inc; 1997, pp 181–195
57. Siebens D. Noise and hearing loss in agriculture, forestry, and fisheries. In: Langley RL, McLymore RL, Meggs WJ, Roberson GT, eds. *Safety and Health in Agriculture, Forestry and Fisheries*. Rockville (Md): Government Institutes, Inc; 1997, pp 59–65
58. Plakke B, Dare E. Occupational hearing loss in farmers. *Public Health Rep* 1992; 107:188–192
59. Kristensen S, Gimsing S. Occupational hearing impairment in pig breeders. *Scand Audiol* 1988; 17:191–192
60. Broste SK, Hansen DA, Strand RL, Stueland DT. Hearing loss among high school students. *Am J Public Health* 1989; 79:619–622
61. Blair A, Zahm SH. Cancer among farmers. *Occup Med* 1991; 6:335–354
62. Weisenburger DD. Human health effects of agricultural use. *Hum Pathol* 1993; 24:571–576
63. Zahm SH, Weisenburger DD, Babbitt PA, Saal RC, Vaught JB, Cantor KP, et al. A case-control study of non-Hodgkin's lymphoma and the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) in eastern Nebraska. *Epidemiology* 1990; 1:344–356
64. Meggs W, Langley RL. Chemical hazards of farming. In: Langley RL, McLymore RL, Meggs WJ, Roberson GT, eds. *Safety and Health in Agriculture, Forestry and Fisheries*. Rockville (Md): Government Institutes, Inc; 1997, pp 249–265
65. Rosenstock L, Kiefer M, Daniell W, McConnell R, Claypoole K. Chronic central nervous system effects of acute organophosphate pesticide intoxication. The Pesticide Health Effects Study Group. *Lancet* 1991; 338:223–227
66. Weinbaum Z, Samuels SJ, Schenker MB. Risk factors for occupational illnesses associated with the use of paraquat (1,1'-dimethyl-4,4'-bipyridylum dichloride) in California. *Arch Environ Health* 1995; 50:341–348
67. Helmers S, Top RH, Knapp LW. Ammonia injuries in agriculture. *J Iowa Med Soc* 1971; 61:271–280
68. Leduc D, Gris P, Lheureux P, Gevenois PA, De Vuyst PD, Yernault JC. Acute and long term respiratory damage following inhalation of ammonia. *Thorax* 1992; 47:755–757
69. Pesticide Use Reporting: An Overview of California's Unique Full Reporting System. Sacramento: California Environmental Protection Agency, Dept of Pesticide Regulation; 1995
70. Pesticide Use Report, Annual 1995, Indexed by Chemical. Sacramento: California Environmental Protection Agency, Dept of Pesticide Regulation; 1996
71. Overview of the California Pesticide Illness Surveillance Program, 1995. Sacramento: California Environmental Protection Agency, Dept of Pesticide Regulation; 1997
72. Weinbaum Z, Schenker MB, O'Malley MA, Gold EB, Samuels SJ. Determinants of disability in illnesses related to agricultural use of organophosphates (OPs) in California. *Am J Ind Med* 1995; 28:257–274
73. Burke WA. Skin diseases in farmers. In: Langley RL, McLymore RL, Meggs WJ, Roberson GT, eds. *Safety and Health in Agriculture, Forestry and Fisheries*. Rockville (Md): Government Institutes, Inc; 1997, pp 321–352
74. Langley RL, Morrow MWE. Zoonotic hazards in humans in agriculture, forestry, and fisheries. In: Langley RL, McLymore RL, Meggs WJ, Roberson GT, eds. *Safety and Health in Agriculture, Forestry and Fisheries*. Rockville (Md): Government Institutes, Inc; 1997, pp 127–141
75. Donham KJ. Zoonotic diseases of occupational significance in agriculture: a review. *Int J Zoon* 1985; 12:163–191
76. Keusch GT, Hamer D, Joe A, Kelley M, Griffiths J, Ward H. Cryptosporidiosis—who is at risk? *Schweiz Med Wochenschr* 1995; 125:899–908
77. Ruppanner R, Schwabe CW. Early records of hydatid disease in California. *Am J Trop Med Hyg* 1973; 22:485–492
78. Flanagan PG, Westmoreland D, Stallard N, Stokes IM, Evans J. Ovine chlamydiosis in pregnancy. *Br J Obstet Gynecol* 1996; 103:382–385
79. Arends JP, Zanen HC. Meningitis caused by *Streptococcus suis* in humans. *Rev Infect Dis* 1988; 10:131–137
80. Brown WD. Heat and cold in farm workers. *Occup Med* 1991; 6:371–389
81. Gun RT, Budd GM. Effects of thermal, personal and behavioral factors on the physiological strain, thermal comfort and productivity of Australian shearers in hot weather. *Ergonomics* 1995; 38:1368–1384
82. Occupational Injuries and Illnesses Survey, California, 1995. San Francisco: California Dept of Industrial Relations, Division of Labor Statistics and Research; 1997
83. Holness D, Nethercott J. What actually happens to the farmers? clinical results of a follow-up study of hog confinement farmers. In: McDuffie HH, Dosman JA, Semchuk KM, Olenchock SA, Senthilselvan A, eds. *Agricultural Health and Safety: Workplace, Environment, Sustainability*. Boca Raton (Fla): CRC Press; 1995, pp 49–52
84. May JJ. A study of osteoarthritis of the knee and hip in dairy farmers. NIOSH Symposium on Efforts to Prevent Injury and Disease Among Agricultural Workers. Lexington (Ky): National Institute for Occupational Safety and Health; 1994
85. Palmer KT. Musculoskeletal problems in the tomato growing industry: "tomato trainer's shoulder"? *Occup Med (Oxf)* 1996; 46:428–431
86. Sakakibara H, Miyao M, Kondo T, Yamada S. Overhead work and shoulder-neck pain in orchard farmers harvesting pears and apples. *Ergonomics* 1995; 38:700–706
87. Miles JA, Steinke WE. Citrus workers resist ergonomic modifications to picking ladder. *J Agric Safety Health* 1996; 2:7–15
88. McKnight RH, Levine EJ, Rodgers GC Jr. Detection of green tobacco sickness in a regional poison center. *Vet Hum Toxicol* 1994; 36:505–510