Chapter 12

RESPIRATORY HEALTH RISKS IN AGRICULTURE

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Many clinical studies have investigated the relationship between respiratory health disorders and exposures in agricultural workers. Little is known, however, about the incidence or prevalence of respiratory diseases, or the host of environmental factors contributing to pulmonary disease in this population. The paucity of epidemiologic data on agricultural workers is largely due to the nature of agricultural work, much of which still takes place on the family farm. The isolation of family farms, particularly in the United States, coupled with the small number of workers at each farm, has resulted in few population-based health surveys of agricultural workers because of logistical considerations and costs. Similarly, there have been few (Gamsky et al. 1990) epidemiologic studies of respiratory health hazards in migrant and seasonal workers because of the transitory nature of the work populations. Collection of respiratory health data on agricultural workers is further complicated by the fact that they seldom belong to unions, through which occupational health studies often are carried out. In addition, agricultural workers typically seek medical care only when they are seriously ill. This makes hospital records-based studies unreliable.

Epidemiologic studies, however, have been completed on the respiratory effects of exposure in grain- (Manfreda et al. 1989, Chan-Yeung et al. 1980, doPico et al. 1984, Tabona et al. 1984), cotton- (Schacter et al. 1984, Schilling et al. 1955, Molyneux and Tombleson 1970, Chen et al. 1991, Bouhuys et al. 1977), swine-

(Holness et al. 1987, Donham et al. 1984a, Noweir 1981, Donham et al. 1989), and poultry- (Morris et al. 1991, Muller et al. 1986) confinement workers. The large number of workers and the relatively homogeneous nature of the work exposures within each of these industries make epidemiologic studies much more practical than in the above-mentioned groups. There have also been numerous investigations of farmer's lung (Terho et al. 1983, Madsen et al. 1976, Stanford et al. 1990, Bing-gen et al. 1985, Gump et al. 1979, Boyd 1971, Depierre et al. 1988), many studies of storage mite allergy among farmers in Europe (Blainey et al. 1988, Cuthbert et al. 1984, van Hage-Hamsten et al. 1985), and several epidemiologic studies on the general respiratory health status of farmers in Europe (Iversen et al. 1990, Terho 1990, Heller and Kelson 1982, Heller et al. 1986, Iversen et al. 1988), Canada (Dosman et al. 1987), Australia (Woolcock et al. 1987, Cullen et al. 1968), and the United States (Carlson and Petersen 1978, Burmeister and Morgan 1982).

Agricultural workers are at risk of developing an array of respiratory disorders from exposure to a variety of inhaled substances, including: infectious agents; organic and inorganic dusts; pulmonary toxins in pesticides, herbicides, fumigants, and fertilizers; mycotoxins in moldy silage and endotoxins in animal-confinement buildings, grain storage areas, and cotton mills; and toxic gases such as methane, hydrogen sulfide, and ammonia. Respiratory disorders resulting from inhalation of these substances include occupational asthma, chronic bronchitis, pulmonary edema, hypersensitivity pneumonitis, organic dust toxic syndrome, and silicosis.

ACUTE RESPIRATORY DISORDERS

Most of the chronic respiratory diseases from which agricultural workers suffer are preceded by signs and symptoms of acute lung dysfunction. It is important that rural health workers and researchers of agricultural work-related diseases be familiar with these acute disorders because prevention of serious and sometimes irreversible chronic lung disorders depends upon the cessation and/or the reduction of further work exposures.

Grain Workers

Grain-exposed farmers frequently experience sore throat, rhinitis, and other respiratory symptoms associated with acute allergic responses, and an acute febrile syndrome called grain fever. There is evidence (Chan-Yeung et al. 1980, Enarson et al. 1985) that grain workers in Canada suffer more frequently from acute respiratory symptoms than do controls of civic and sawmill workers who do not handle grain. Some data suggest that acute respiratory symptoms of grain-dust exposure may lead to irreversible airways obstruction (Chan-Yeung et al. 1981). A study of the effect of layoff and rehire on the pulmonary status of Canadian grain-elevator workers, however, showed that pulmonary function improved during periods when workers were laid off, suggesting that some pulmonary deficits are partially reversible (Broder et al. 1980). Studies of grain workers who smoke suggest that the combined effect of cigarette smoke inhalation and grain-dust exposure on lung function is either additive (Chan-Yeung et al. 1980) or synergistic (Dosman 1977, Cotton et al. 1982).

Grain dust consists of a heterogeneous mixture of organic and inorganic particles such as rat hair, seeds, insect parts, pollen, fungal hyphae and spores, bacteria, parts of other plants, pesticides, and soil. As one would expect, much of the current research on hazardous agents in grain dust explores which agents are responsible for a particular respiratory disorder (see Figures 12-1 and 12-2). Studies have found a relationship between allergic reactions in grain workers and various mites (Blainey et al. 1989, Revsbech and Andersen 1987, Davies et al. 1976) and the grain weevil (Lunn and Hughes 1967). There is also strong evidence that the grain-fever syndrome is due to bacterial endotoxins in grain dust (doPico et al. 1982, Flaherty 1982). Endotoxins make up part of the cell wall in gram-negative bacteria and are released into the environment when cells undergo lysis, after ingestion by macrophages, and during periods of log phase cell growth. Endotoxins affect many cells. In particular, they activate alveolar macrophages, which release a host of chemical mediators, leading to complement activation and an alteration of the normal physiology of the lung. Symptoms of "grain fever" (acute fever, dyspnea, and coughing) subsequently develop (Rylander and Snella 1983, Jacobs 1989). A seasonal variation in the types of bacteria present in grain dust and a similar variation in grain-dust endotoxin concentrations have been demonstrated (DeLucca and Palmgren 1987).

Cotton Workers

Endotoxins also have been implicated in the pathogenesis of acute, as well as chronic, respiratory symptoms in cotton work-

Figure 12-1. Grain sorghum harvesting. (Photo by Chris Piacitelli)

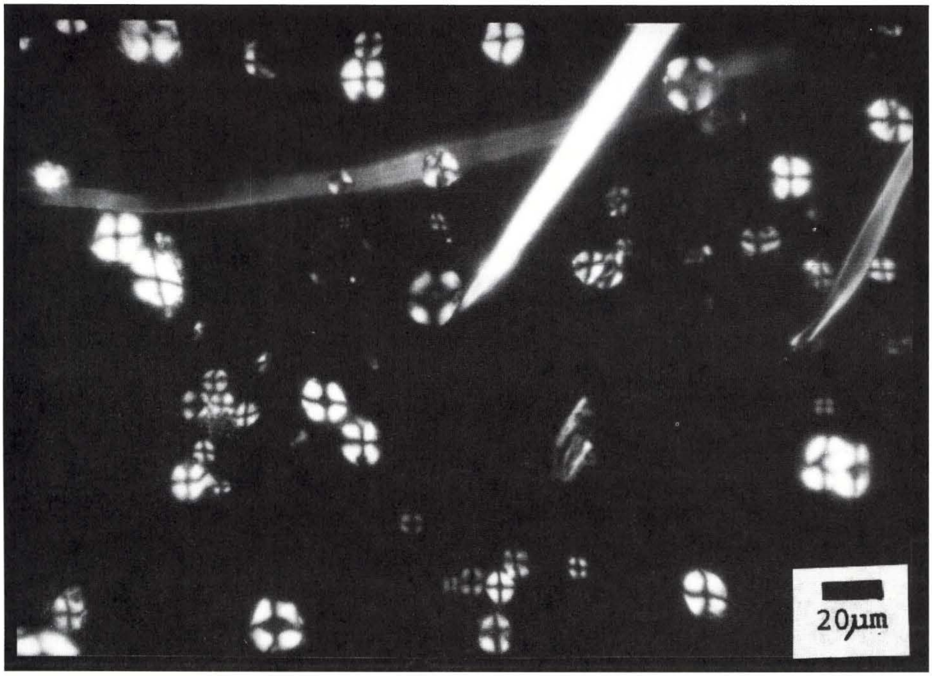

Figure 12-2. Photomicrograph of air sample taken during grain sorghum harvesting showing starch particles and plant hairs. (Photo by William Jones)

ers. Acute respiratory symptoms in cotton workers are associated primarily with the byssinotic syndrome, which consists of a subjective feeling of chest tightness and breathlessness on the first day of the workweek. These symptoms often are accompanied by reversible bronchoconstriction. Initially these symptoms subside during the remainder of the week, but, eventually, if exposure to high levels of cotton dust continues, the symptoms may persist throughout the week and even continue in the absence of further work exposure. After several years of work exposure, irreversible impairment of lung function may develop (Schacter et al. 1984, Berry et al. 1973, Elwood et al. 1986). An epidemiologic study of over 1,500 British cotton-mill workers found a byssinosis prevalence rate of 26.9% (Molyneux and Tombleson 1970), with smokers having 1.4 times as much byssinosis as nonsmokers (Berry et al. 1974).

Several studies (Castellan et al. 1984, Cinkotai et al. 1977, Rylander et al. 1985) have reported a strong association between workers' pulmonary reactions and their exposure to endotoxin-contaminated cotton. Endotoxin is present on all parts of the cotton plant and is found in particularly high concentrations on the bract. Studies (Haglind and Rylander 1984, Brown et al. 1979) have shown that the respiratory dysfunction associated with cotton work can be reduced by washing the cotton before it is processed. Among other things, washing cotton not only physically removes dust, but it also reduces the level of endotoxin in the residual, leading to lower endotoxin exposure and less severe decreases in respiratory function. As has been pointed out, however (Rylander et al. 1985), it is possible that the washing process removes unknown contaminants as well as endotoxins, and that these other contaminants contribute to adverse respiratory responses. There is general agreement that a component of cotton dust causes respiratory dysfunction, and not the cotton fiber itself. Most evidence points to endotoxins as the primary contaminant.

Poultry Workers

Poultry workers also suffer from a myriad of acute respiratory disorders. These include several acute symptoms largely related to inflammation of the bronchial epithelium (Morris et al. 1991, Rylander 1986), such as rhinitis, cough, wheezing, dyspnea, and chest tightness. Some of these symptoms are probably due to endotoxins produced by bacteria in the soil, on plants, in poultry foodstuffs (Thelin et al. 1984), and in bird feces (Lenhart et al.

1982). Other symptoms such as rhinitis may be due to ammonia vapors released from decomposing manure, which, even at low levels, can cause nasal and eye irritation (Manninnen et al. 1989). One study carried out in Yugoslavia suggests that some of the acute symptoms may be indicative of a hypersensitivity pneumonitis (HP) (Stahuljak-Beritic et al. 1977) although more recent studies (Thelin et al. 1984, Hagmar et al. 1990) have found no evidence of symptoms consistent with HP. As with grain and cotton workers, long-term exposure will lead to the development of chronic lung disease and reduced lung function (Morris et al. 1991).

Pig Farm Workers

Prevalence rates for acute respiratory disorders in pig farm workers are as high as 50 to 60% (Donham et al. 1977, 1984a) and can include such symptoms as cough, wheeze, dyspnea, rhinitis (Holness et al. 1987), and a mild airway obstruction resulting in decreased flow rates (Donham et al. 1984b). There is evidence that endotoxins play a significant role in the development of respiratory dysfunction in pig farm workers (Heederik et al. 1991).

Particulate matter on pig farms consists mainly of feed dusts, insecticides, inorganic dusts, fungi, and bacterial endotoxins (Attwood et al. 1986). One study (Holness et al. 1987) showed high dust levels to be strongly associated with certain feeding practices (and the feeding of high moisture corn), suggesting that altering feeding methods and/or practices might reduce dust exposures.

Several fatalities on pig farms have resulted from worker exposure to various gases that are released during the decomposition of manure stored in pits or tanks (Donham et al. 1982). The types of gases encountered by workers include hydrogen sulfide, carbon dioxide, carbon monoxide, and ammonia (Donham et al. 1984a). Methane, although nontoxic, has been implicated in swine-confinement building explosions (Donham et al. 1977).

ACUTE TOXIC EFFECTS OF INHALED CHEMICALS

The two primary toxic effects of inhaled chemicals and gases are irritation of the upper airways and pulmonary edema. Ammonia already has been mentioned as a cause of nasal and eye irritation in poultry workers, but it also can cause delayed lung effects.

Pulmonary edema can develop 12 to 24 hours after exposure to high levels of ammonia. Hydrogen sulfide, produced during the anaerobic digestion of liquid manure in a confined space, may cause both acute irritant symptoms and delayed pulmonary edema (Cockroft and Dosman 1981). Some chemicals, such as the fumigant phosgene and the herbicide paraquat, may cause pulmonary edema and fibrosis without initial acute symptoms (Cockroft and Dosman 1981, Levin et al. 1979). Nitrogen dioxide (NO_2) and other oxides of nitrogen produced during the fermentation of fresh silage can cause silo-filler's disease, resulting in pulmonary edema and bronchiolitis (Lowry and Schuman 1956). Low-level, short-term exposures to NO_2 occasionally will cause acute upper airway irritation but little parenchymal injury (Horvath et al. 1978). When acute symptoms do occur, they can and should serve as a warning to workers to avoid further exposure. Many of the deaths of swine-confinement workers are a result of exposure to odorless and nonirritant gases such as methane and carbon dioxide in manure pits. Workers entering these pits without supplied air respirators may be asphyxiated as a result of oxygen displacement by these gases (MMWR 1981, Donham et al. 1982).

HYPERSENSITIVITY PNEUMONITIS (EXTRINSIC ALLERGIC ALVEOLITIS)

Hypersensitivity pneumonitis (HP) is an acute illness with influenza-like symptoms. It develops in workers 3 to 12 hours after they inhale a specific organic antigen to which they are immunologically sensitized. A variety of such antigens have been implicated, and specific names, including farmer's lung disease (FLD) and sugar-cane worker's bagassosis, have been used to describe HP in particular occupational settings.

Acute HP symptoms will completely resolve if the worker ceases further exposure. Unfortunately, agricultural workers seldom are financially able to stop working, and the symptoms may become progressively worse. In the chronic form of HP, the worker develops an exertional dyspnea with weight loss, malaise, and a progressive interstitial fibrosis associated with irreversibly restricted lung function (Emmanuel et al. 1964, Hapke et al. 1968). Several longitudinal studies, however, suggest that some farmers may continue working without suffering permanent respiratory disability (Barbee et al. 1968, Cormier and Belanger 1985).

Besides clinical symptoms and associated physical signs such as bilateral dry rales, diagnostic techniques used to evaluate cases of HP include pulmonary function tests (PFTs), chest X-rays, and immunologic tests to detect serum precipitins against organic antigens. In acute episodes of HP, PFTs most commonly show decreased lung volume, reduced compliance, normal air-flow, and a fall in diffusing capacity, whereas the more chronic form of HP often results in a severe and persistent restrictive impairment, with reductions in lung volume and diffusing capacity. Chest X-rays usually show widespread nodular and linear shadows. Radiographs may be normal, however, in individuals who suffer infrequent episodes of HP. Immunologic tests have to be interpreted in light of clinical findings because the presence of serum-precipitating antibodies against antigens is an indication only of exposure and not of clinical disease. Many workers develop antibodies but remain completely asymptomatic.

Farmer's Lung Disease and Other Forms of HP

Farmer's lung disease (FLD), the most studied and most common form of HP, has generally been related to inhalation of spores and cell wall components from thermophilic actinomycetes (*Micropolyspora faeni*: now called *Faeni rectivirulga* or *Thermoactinomyces vulgaris*, or *T. sacchari*), which grow in warm, moist forage (see Figure 12-3, dairy barn air sample). The prevalence of clinically confirmed cases of FLD has been estimated to be as high as 4.3% among some farming populations in Scotland (Grant et al. 1972), with similar estimates derived for some farming communities in England (Morgan et al. 1975). One study in Finland (Terho et al. 1983) demonstrated regional, seasonal, and sex differences in the annual incidence of FLD among Finnish farmers.

HP also occurs in mushroom workers and among poultry handlers. In mushroom workers the implicated agents are the spores of thermophilic fungi as well as the spores of various mushrooms themselves. In poultry handlers, avian proteins from bird feces and dander have been found to be the inciting agents, and prevalence rates have been estimated to be as high as 15% (Christensen et al. 1975). Sugar cane workers, maple bark strippers, and malt workers also are at risk of developing HP. Sugar cane workers develop bagassosis, a form of HP, when exposed to moldy sugar cane fibers, and maple bark strippers develop HP after exposure to mold spores in wood. Malt workers develop HP after working with sprouting barley.

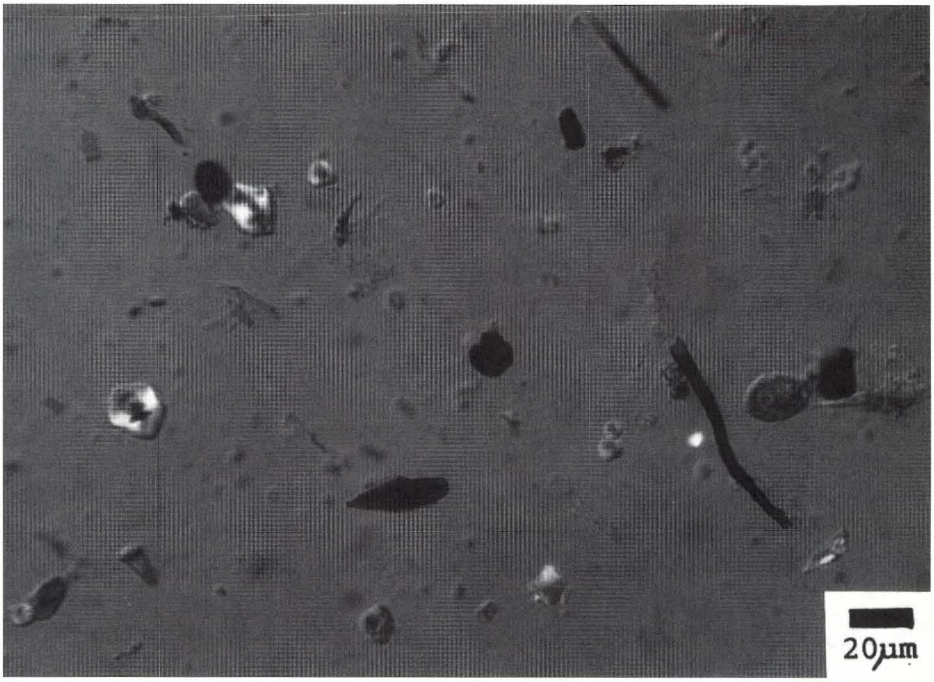

Figure 12-3. Photomicrograph of air sample from dairy barn showing fungal spores, starch particles, and hyphae. (Photo by William Jones)

Immunopathogenesis

The immunopathogenesis of acute and chronic HP is not well understood. There is evidence of both a cell-mediated immunity and an immune complex role. The detection of IgG antibodies in most patients along with the acute onset of symptoms suggests an immune complex and complement-mediated response. Some lung biopsies, however, show lymphoid cell infiltration and granuloma formation that are consistent with a cell-mediated reaction. It is possible that both conditions are necessary for hypersensitivity pneumonitis to be clinically manifested (Fink 1985).

Prevention

Prevention of farmer's lung and the other HPs is accomplished by removing the worker from the contaminated environment or by modifying the environment so that exposure to causal agents is reduced. It often is difficult for farmers and other agricultural workers to quit their jobs and seek employment elsewhere because it often means selling a family business and home and learning a new job skill at the same time. Most farmers continue to work in the contaminated environment even after they have been diagnosed with farmer's lung (Monkare and Haahtela 1987). The most practical method of preventing HP involves altering work practices and/or changing the farm environment to reduce exposure. Installation of exhaust ventilation in barns and automation of feeding procedures have successfully reduced exposures on some farms. It has been suggested, however, that the financial cost of making such alterations may represent an impediment for some individual farm operators (Monkare and Haahtela 1987).

ORGANIC DUST TOXIC SYNDROME

Organic dust toxic syndrome (ODTS), a recently named entity (Malmberg et al. 1988), increasingly has been recognized as an important disease of agricultural workers. ODTS historically was referred to as atypical farmer's lung (Jones 1982), precipitin-negative farmers's lung (Edwards et al. 1974), pulmonary mycotoxicosis (Emmanuel et al. 1975), and silo unloader's syndrome (Pratt and May 1984). There is some indication that the syndrome actually may be more common than FLD, and that previously reported cases of FLD actually may have been ODTS cases (Malmberg et al. 1988).

ODTS develops as an acute febrile pulmonary illness with a leukocytosis, lasts for only a few days, and then resolves with only supportive measures. The syndrome resembles acute FLD, with chest X-rays occasionally showing interstitial and/or alveolar infiltrates (Emmanuel et al. 1975), but there is no conclusive evidence of an immunologic response to antigens as in farmer's lung. ODTS tends to occur in a higher proportion of exposed workers (30–40% or more) than HP, where only 5 to 8% of exposed workers come down with the disease (Schenker et al. 1991).

The syndrome usually occurs after an acute exposure to high dust levels generated during handling of moldy hay, moldy grain, or moldy wood chips. Silo unloader's syndrome describes ODTS associated with the manual removal of moldy forage from the top of feed in silos (Donham and Rylander 1986). A cross-sectional study of Swedish farmers found a prevalence rate of 44% for ODTS and a strong association between ODTS and grain handling (Rask-Andersen 1989). Interestingly, a seasonal difference in peak incidence of ODTS and FLD has been found, with ODTS occurring in late summer and FLD seen more often in late winter and early spring. This pattern might be due to seasonal variations in farming practices (Marx et al. 1990).

It is widely suspected that undefined microbial organisms and their products present in inhaled dust play a role in the development of acute inflammatory responses. Endotoxins, a common component of organic dust in agriculture (Olenchock et al. 1990, Dutkiewicz 1987), may be involved in triggering the development of the acute syndrome.

OCCUPATIONAL ASTHMA

The few studies of occupational asthma in agricultural workers that exist underestimate the prevalence of this disease. They often do not take into account workers who were forced to leave their jobs because of their allergies.

Studies have been carried out in tea (Zuskin and Skuric 1984) and coffee workers (Zuskin et al. 1979) and among workers in single-commodity enterprises such as those involving exposure to soybeans or soybean by-products (Zuskin et al. 1988, 1991). A cross-sectional study of respiratory symptoms in Danish farmers found the prevalence of asthma to vary with age and type of farming. Farmers aged 71 to 75 years experienced almost five times as much asthma as farmers in the 31 to 50 age group, and pig farmers had almost twice the frequency of asthma that dairy farmers had (Iversen et al. 1990).

Causes of Occupational Asthma

Antigens and irritants implicated in causing asthma include pollen from cereal grains, feed additives, mites, fungal antigens on plants and in grain dust, and antigens generated in the production of vegetable gums, teas, and spices. Animal dander and other animal antigens also have been implicated as etiologic agents in asthma (Terho et al. 1985).

Several studies (Blainey et al. 1988, Cuthbert et al. 1984, van Hage-Hamsten et al. 1985) have documented the importance of storage mites in causing IgE-mediated allergies in agricultural workers. Most of these studies have been carried out in Europe, but there is some indication that these mites also may be a problem in North American dairy barns (Campbell et al. 1989). Asthma also may occur by nonimmunologic means, for example, through histamine release after exposure to cotton dust (Bouhuys and Lindell 1961) and by exposure to insecticides (Weiner 1961).

Cigarette smoking appears to increase a worker's sensitization to a variety of allergens found in the farm environment. One study of Danish farmers found that smokers had a significantly elevated risk of sensitization to storage mites compared to nonsmoking farmers (Iversen and Pedersen 1990).

Clinical Manifestations

Asthma can be associated with immediate and/or late responses to environmental triggers. The immediate response occurs within minutes after exposure and resolves in a few hours, whereas the late response may not begin until 3 to 8 hours after exposure, often after the worker has left work. Further symptoms often occur at night and can last from 24 to 96 hours or longer following a single exposure to an environmental trigger. Asthma can present with biphasic early and late or "dual" responses (Merchant 1986), delayed recurrent responses (Pepys and Hutchcroft 1975), and recurrent nocturnal responses (Davies et al. 1976).

Characteristics of the immediate response include wheezing, cough, dyspnea, and eosinophilia. This response is commonly found in workers who have a preexisting bronchial hyperreactivity and can be elicited by such nonspecific respiratory irritants as histamine, exercise, and cold air. The late response may be associated with systemic reactions such as fever, malaise, and myalgia, as well as cough, dyspnea, and chest tightness. A leukocytosis and eosinophilia often are seen. Also seen is an increased degree of lung obstruction, which tends to be associated with more serious respiratory disability than the immediate asthmatic responses (Merchant 1986).

Diagnosis

Obtaining a careful occupational history and eliciting information about the patient's current and past work exposures are key elements in diagnosing cases of occupational asthma. Serial lung function testing, where work-related changes in airflow or nonspecific bronchial reactivity sometimes can be documented, is also used. Skin tests, such as the radioallergosorbent test (RAST), and, less commonly, bronchial provocation tests are other techniques employed in diagnosing occupational asthma (Salvaggio et al. 1985).

Prevention

Modification of job processes to reduce exposures that may cause asthma remains the most effective means of prevention. As with workers suffering from HP, the best management technique for workers already suffering from asthma involves removal of the patient from further exposure to inciting agents. Leaving the farm, however, usually is not an option for most workers.

CHRONIC BRONCHITIS AND AIRWAYS OBSTRUCTION

Several studies clearly identify chronic bronchitis and airways obstruction as the most prevalent and most studied pulmonary dysfunction in agricultural workers. A survey of respiratory disease in Finnish farmers found the prevalence of chronic bronchitis to be higher than the prevalence of asthma and farmer's lung disease combined. The mean annual incidence of chronic bronchitis was over four times the rate of asthma or farmer's lung (Terho 1990). Chronic bronchitis also is often seen in association with farmer's lung, with one study demonstrating that 50.6% of farmers with farmer's lung also had chronic bronchitis (Depierre et al. 1988).

Epidemiology

Studies comparing farmers with nonfarmers show that farmers have higher rates of chronic bronchitis than nonfarming populations, even after controlling for smoking (Dosman et al. 1987, Husman et al. 1987, Saia et al. 1984). Among farmers in Finland, those who smoke appear to have twice as much chronic bronchitis as nonsmoking farmers (Terho et al. 1987). Pulmonary function measurements in farmers usually show very small (Dosman et al. 1987, 1988; Heller et al. 1986) or no (Malmberg et al. 1985, Rautalahti et al. 1987) reduction in FEV_1 and FVC compared with nonfarming control populations. The prevalence of chronic bronchitis appears to be age- and sex-dependent. A study of Danish farmers found that the prevalence of chronic bronchitis in farmers aged 71 to 75 years was twice the rate among farmers in the 31 to 50 age group (Iversen et al. 1990). A survey of an agricultural population in Wales showed men to have a higher prevalence of chronic bronchitis than women in all age groups except the 25 to 35 group (Higgins 1957).

Chronic Bronchitis in Swine Farmers

A cross-sectional study of swine-confinement workers in Iowa, matched by age, sex, and smoking history with nonconfinement swine farmers, demonstrated a 58% prevalence of chronic bronchitis in the confinement group and a 21% rate in the nonconfinement controls. This study also suggested that a minimum exposure period of one to two years was required for the development of chronic symptoms although self-selection of workers to leave swine farming may have influenced these findings (Donham et al. 1984a).

Chronic Bronchitis in Grain Handlers

Studies of farmers in Canada, where comparisons were made with nonfarming controls, show a strong relationship between exposures to grain dust and chronic respiratory symptoms (Manfreda et al. 1989, Cotton et al. 1982). An association between grain-dust exposure and respiratory symptoms has been demonstrated in numerous other studies (Chan-Yeung et al. 1979, 1980; Broder et al. 1979, 1980). The prevalence of chronic bronchitis in grain workers who have been on the job a mean of 24.4 years is reported to be as high as 35.7% (Dosman et al. 1980). An epidemiologic study comparing city workers with grain handlers in the northern United States found grain handlers to have 4.4 times as much chronic bronchitis, regardless of their smoking status (doPico et al. 1984). The study also found that cigarette smoking alone increased the odds of having airways obstruction 2.7-fold, whether the worker was a grain handler or not (doPico et al. 1984).

Chronic Bronchitis in Cotton Workers

There is some evidence that endotoxins in cotton dust are the cause of chronic bronchitis in cotton workers (Rylander 1987). The chronic inflammatory response, however, appears to be dependent on dose as well as on the inhalation of other agents containing endotoxins (Rylander 1987). A three-year prospective study of mill workers in Lancashire, England, found chronic bronchitis to be more common in workers who had a history of smoking or a concomitant diagnosis of byssinosis (Molyneux and Tombleson 1970).

RESPIRATORY EFFECTS OF INORGANIC DUSTS

Although restrictive lung disease due to inhalation of inorganic dusts is seldom documented in agricultural workers, studies of dust exposures in agricultural operations consistently show that levels of inorganic dusts exceed standards set for other industries (Louhelainen et al. 1987, Popendorf et al. 1982). Researchers have demonstrated that farm dust can contain as much as 6.5% (Farant and Moore 1978) to 10% (Popendorf et al. 1982) respirable inorganic dust particles such as quartz. An analysis of airborne dust in Canadian grain terminals revealed that inorganic material made up approximately 35% of the dust, with most of the inorganic fraction consisting of free silica from soil contained in the grain (Cotton and Dosman 1978).

Cases of silicosis have been reported in Russian forestry workers (Dynnik and Khizhniakova 1981) and in California agricultural workers (Sherwin et al. 1979) exposed to high concentrations of silica during agricultural work (produce farming and vineyard-related work). Exposure to the airborne dust of soil with a high silica content has been suggested to be one possible cause of decreased pulmonary function among California grape workers (Gamsky et al. 1992).

Inorganic dusts other than crystalline silica also are responsible for the development of restrictive lung disease in agricultural workers. Mica, talc, silica, and asbestos fibers were found in the lungs of a Norwegian farmer diagnosed with a mixed-dust pneumoconiosis (Gylseth et al. 1984). More than 150 cases of asbestosis have been diagnosed in agricultural workers who farmed land located near an asbestos mine in Bulgaria. One hundred thirty-two of these asbestosis cases were in individuals who had never worked in the asbestos mine, and the authors of the study concluded that these cases probably resulted from inhaling asbestos-laden dust during agricultural work (Zolov et al. 1967). Talc and asbestos also are found in pesticide powders which are mixed with water and then sprayed, representing additional pulmonary hazards for workers who apply the pesticides (Abraham 1982). Cases of a disease characterized by interstitial pulmonary lesions also have been reported in vineyard workers who inhale sprays containing copper sulfate in solution (Pimental and Marques 1969).

Diagnosis

Diagnosis of pulmonary dysfunction resulting from inorganic dust-induced pulmonary fibrosis requires the careful collection of an occupational exposure history, chest X rays, and pulmonary function measurements. A majority of workers with mild restrictive lung deficits are asymptomatic or exhibit nonspecific symptoms. Many cases have been identified after a routine chest X ray, and many others are likely to go undiagnosed. Cases suggestive of a restrictive deficit caused by inhalation of silica or other inorganic agents can be confirmed by lung biopsy, followed by analysis of extracts from the lung tissue using electron microscopy or X-ray microanalysis (Gylseth et al. 1984).

It has been suggested (Schenker et al. 1991) that difficulties in diagnosing pneumoconioses, the lack of readily accessible medical care for agricultural workers, and the migrant nature of a large portion of these workers contribute to underestimation of the true prevalence of pulmonary disease from exposure to inorganic dusts.

RESPIRATORY CANCERS

There are indications that agricultural workers are at increased risk of developing respiratory cancers from their exposure to pesticides and other carcinogens. A retrospective questionnaire study that compared male lung cancer patients with their siblings found that the patients had been exposed more frequently to herbicides, diesel fuels, and to a greater number of chemicals than siblings who did not develop lung cancer (McDuffie et al. 1988). Pesticides containing arsenic may be the cause of increased rates of lung cancer among French farmers (Benhamou et al. 1988) although epidemiologic studies of orchardists in Washington State who had been exposed to similar pesticides found no excess of respiratory cancer (Wicklund et al. 1988, Nelson et al. 1973). A retrospective cohort study of lung cancer among German agricultural workers found a twofold increased risk of lung cancer among workers who had been exposed to pesticides (Barthel 1981).

Lung cancer and mesothelioma have been reported in sugar cane workers following exposure to biogenic silica found in the leaves of mature sugar cane plants (Boeniger et al. 1988, Das et al. 1976). Biogenic silica fibers are released from sugar cane leaves during burning and subsequent harvesting of sugar cane.

The similarity of these fibers to other cancer-causing mineral fibers suggests that they are a possible cause of respiratory cancer. The burning of organic materials such as those found in sugar cane plants, however, may produce many carcinogens, any of which could be an etiologic agent. Regardless of the specific cause, one study has shown that sugar cane farmers are at increased risk of developing lung cancer (Rothschild and Mulvey 1982).

Several studies have shown that workers exposed to wood dust may be at increased risk for the development of nasal cancers (Vaughan and Davis 1991, Acheson et al. 1968, Hadfield 1972). A case-control study of nasal cancer deaths in Washington State, Oregon, Mississippi, and North Carolina found, however, that industries where wood-dust exposure was the greatest did not experience an increased risk of nasal cancers (Viren and Imbus 1989). Other studies also have failed to show an excess risk of nasal cancer among woodworkers (Ball 1967, Milham 1976).

RESPIRATORY INFECTIONS

Serious respiratory infections caused by infectious agents seldom are reported in agricultural workers. Several zoonotic diseases, such as anthrax, plague, histoplasmosis, brucellosis, psittacosis, coccidioidomycosis, tularemia, mycobacterial infections, hydatid disease, listeriosis, leptospirosis, and Q fever, either induce a respiratory illness (after inhalation) or are inhaled and subsequently affect organs other than the lung.

"Inhalation anthrax" is transmitted through inhalation of the infectious agent. The subsequent disease occurs primarily in the mediastinal lymphatic system. Inhalation anthrax most often has occurred when workers handling goat hair have inhaled *Bacillus anthracis* spores. It has been estimated that fewer than five thousand workers are at risk of developing anthrax (Brachman 1986).

Agricultural workers who come in contact with soil containing avian or bat feces may be at increased risk of developing histoplasmosis (Larsh 1983). Farmers who periodically clean chicken coops sometimes inhale the histoplasmosis fungus, which grows well in soil enriched by the nitrogen content of bird guano. The farmers subsequently develop a (usually) mild febrile illness or remain asymptomatic. In some persons who receive a heavy exposure of fungal spores, a more severe influenza-like illness can develop. Immunologically compromised individuals are at risk of developing chronic progressive pulmonary disease or a disseminated infection.

Coccidioidomycosis, another fungal disease of agricultural workers, is endemic to semiarid regions of the southwestern and western United States (Johnson 1981). Contact with contaminated soil and subsequent inhalation of the spores of the *Coccidioides immitis* fungus will, as with histoplasmosis, usually cause a mild or an inapparent respiratory infection in immunocompetent individuals.

Livestock producers, veterinarians, and slaughter plant employees are at risk of developing brucellosis. Every year, approximately two hundred cases of brucellosis are reported, with most cases occurring in slaughter plant employees who have close contact with animal fluids and tissues contaminated with the *Brucella* organisms (Kaufmann and Porter 1985). Typical signs and symptoms of brucellosis include fever, chills, anorexia, body aches, lymphadenopathy, and splenomegaly.

Individuals, such as veterinarians, poultry workers, and turkey processors, who work with infected birds are at risk of developing human psittacosis after inhaling the *Chlamydia psittaci* bacteria present in tissues and feces of the infected birds. Psittacosis is an acute infectious disease characterized by fever, headaches, pneumonia, weakness, and myalgia. Outbreaks among poultry or turkey workers can involve hundreds of people. One outbreak among turkey processors involved 117 cases of psittacosis (Pullen 1982).

ENVIRONMENTAL SAMPLING

Environmental sampling can be useful for diagnosing work-related lung disease in the agricultural environment. When the diagnosis is not certain, the agent causing the disease can be isolated from sampled material and the diagnosis confirmed. Sampling also may provide information to help investigators develop inferences about the exposure agent and the diseases it might cause. When exposure limits have been established for an agent (e.g., for gases and some pesticides), quantification of the level of exposure to the agent can be helpful in determining control measures. For most agricultural dusts (the agents predominantly responsible for chronic lung problems), exposure limits have not been established; quantitative analysis of dusts may yield results too complex to be useful for diagnosing disease. The difficulty lies not so much in the available sampling methods as in the variety of possible agents detectable around farms. Therefore, qualitative analysis may be a better first step for identifying a suspect agent.

Environmental sampling methods may vary, depending upon whether qualitative or quantitative measures are required. There are two basic approaches, bulk sampling and exposure sampling.

Bulk Sampling

Bulk sampling, including settled dust sampling, is the collection of material suspected of causing a health problem in order to determine the presence of an agent (and its percent composition) rather than to measure its concentration in the air. Affected individuals often assist in identifying suspect agents by describing the situations in which exposures occurred. In such a case, it still is preferable to obtain a small amount of the material involved. Bulk samples should be collected from a surface where other contamination can be minimized. Settled dust samples should be taken from a surface that has been cleaned before the dust of interest collects. If settled dust cannot be collected, the bulk material from which the contaminant is generated may suffice.

Exposure Sampling

Exposure, or air, sampling is conducted when it is important to measure the concentration of a substance to which an affected worker is exposed. Ideally, the air sample is drawn from the worker's breathing zone during the suspected exposure period. A less desirable but often sufficient option is to draw a sample from the general area in which the exposure is taking place. A general guide to air sampling instrumentation, containing descriptions of current sampling equipment, is available (ACGIH 1989a). Some principles and instruments, however, are particularly applicable to the agricultural environment.

Gases

For the gases most commonly encountered in agricultural problems (i.e., carbon monoxide, hydrogen sulfide, and ammonia) simple, inexpensive, length-of-stain gas detector tubes are available. Used with a calibrated hand pump to sample a set volume of air, these tubes provide a direct measure of a selected gas concentration. The air is drawn through a clear glass tube filled with reactive granules, which change color for the selected gas. The length of the color change along the tube is proportional to the concentration of the gas. The process of sampling in this manner can take several minutes. Because all of these gases are known to occur in lethal concentrations in agricultural environments, the use of gas detector tubes is not appropriate if a life-threatening situation exists, unless the person doing the sampling has taken precautions to avoid exposure to the gas. Evacuated containers can be used to take instantaneous samples for later analysis. Expandable, gastight bags also can be filled by using a pump. These devices are not suitable for reactive gases such as volatile organics, which change composition too rapidly to be analyzed.

Direct-reading monitors can be used for specific contaminants. Devices allowing remote sampling, such as long sampling tubes or remote sensors, are particularly suitable for monitoring potentially lethal situations. The devices need to be calibrated on a regular basis and used by trained personnel. Such monitors are available for a variety a substances, but most are specific for one or two substances only, and the few monitors that are capable of detecting a range of substances are difficult to use and to maintain.

Dusts

The measurement of dust exposure is complicated by the lung's preferential deposition of particles on the basis of size. For particles larger than 0.5 μm this problem is further complicated by the effects of both shape and density of the particles. Guidelines have been established by dividing the lung into three distinct regions (ACGIH 1985). Criteria for size-selective sampling are based on the ability of dust particles to penetrate (though not necessarily deposit) into one of those three successive regions. Only a fraction of any size particle may actually penetrate to a region, and successive regions require successively smaller particles for equivalent penetration (see Figure 12-4). The sum of all size-fractions able to enter the upper airways is designated the inhalable fraction; the size-fraction able to penetrate past the upper airways and into the trachea and beyond is called the thoracic fraction; finally, the size-fraction of dust small enough to penetrate to the nonciliated airways is termed the respirable fraction.

Although devices are becoming available to collect airborne dust according to the appropriate size-fraction, it also is possible

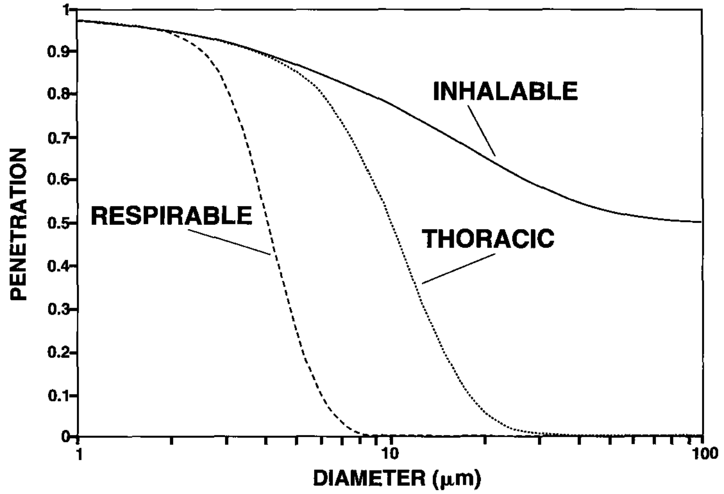

Figure 12-4. Size-dependent criteria for sampling dusts whose effects are regional in the lung. These criteria are meant to be matched by instruments used to collect dust for exposure assessment.

to determine this fraction from the size-distribution of the dust. In this particular case, sizing can be done with a sieve (even on bulk samples), microscopically (with filter samples or particle counters), or aerodynamically (with impactors or centrifugal classifiers). With the exception of aerodynamic classifiers, it is necessary to apply a shape or a density correction to the particle-size distribution information. Once the size distribution is obtained, the regional penetration as well as the regional deposition can be calculated (Hewett 1991, Hewett and McCawley 1991).

Microorganisms

Microbial contamination requires both specialized sampling procedures and personnel acquainted with environmental microorganisms as opposed to organisms commonly encountered in clinical situations (Burge and Solomon 1987). It is important to understand that microorganisms need not be viable to cause a problem, especially if allergies are the main concern. Viable microorganism sampling can be done either into a nutrient or onto a filter for later culturing. Filter samples are not appropriate, however, for microorganisms that may be sensitive to desiccation.

Enumeration is the first step in analyzing sampled microorganisms, followed by identification. If it is to be meaningful for diagnosis, the identification must be done at least to the species level. It is helpful to have some idea of which species could be encountered, particularly for fungi. Identification of fungal species is relatively specialized, and laboratories capable of doing the analysis should be located before sampling commences.

A general guide to sampling microorganisms in residences and commercial buildings is available (ACGIH 1989b). This guide may be useful for sampling, but the approach taken assumes generally lower concentrations and fewer sources than might be encountered in agricultural settings.

Bulk versus Exposure Sampling

In most situations, it is preferable to obtain samples that represent a worker's actual exposure. It may be difficult or impossible to collect the samples during exposure periods, however, because of time, equipment, and personnel constraints. For example, air samples must be collected on the appropriate media by someone trained to operate the sampling equipment. Where a dust is the suspected agent, bulk dust samples can be more easily obtained than exposure samples, even by the worker. Also, if the concentration of the contaminant is low, an exposure sample may not provide sufficient material for analysis.

The two types of sampling need not be viewed as mutually exclusive. A bulk sample may be used to isolate a suspected agent through laboratory analysis or challenge testing. Exposure samples then can be analyzed to quantify exposure by either duration or level. The question is not whether it can be done but whether it is necessary for the case at hand.

Sample Analysis

A gravimetric method is most commonly used to analyze air samples. This method requires a microbalance capable of recording to at least milligram levels in a temperature- and humidity-controlled environment. Bulk or exposure samples also can be evaluated microscopically. A trained microscopist can identify dust components such as pollen grains, insect parts, and mold spores.

When asthma is the suspected problem, immunochemical assessment may be useful. It should be noted that the agent responsible for an asthmatic reaction can occur in such low air concentrations that bulk samples may be the only way of providing sufficient quantities of material for the initial assay. In most cases, either an allergist or an immunologist will be needed to perform assays such as the enzyme-linked immunosorbent assay (ELISA) and RAST inhibition, using both the dust and appropriately prepared sera from affected workers. The levels of antigen may be found to be associated with either sensitization or provocation. With that information it may be possible to estimate exposure limits capable of protecting the patient (Smith et al. 1989).

CONCLUSION

Respiratory hazards in agriculture are numerous and are responsible for a diverse range of respiratory diseases and symptoms. Agriculture itself is tremendously diverse and can include everything from fish farming to mushroom cultivation. Clinical studies are useful in documenting the signs and the symptoms of specific exposures, but there is a tremendous need for research on the epidemiology of respiratory diseases in agricultural workers. Epidemiologic information is needed on the effects of respiratory hazards among children and elderly farm workers. More studies need to be carried out in workers on small family farms—who make up the majority of the workforce in agriculture (Mutel and Donham 1983)—where there are multiple concurrent exposures involving heterogeneous mixtures of animal dander, grain dusts, molds, toxic gases, and chemicals. Epidemiologic studies are needed to assess the usefulness of dust masks and to identify changes in work practices that reduce the risks of respiratory disease. Studies need to be carried out on migrant workers to evaluate the series of respiratory hazards they are exposed to as they travel from one work environment to another, and the potential consequences of these exposures. Further research should be multidisciplinary and take into account the social, economic, and political factors that influence the work-related hazards faced by farmers and farm workers.

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