Agricultural health and safety

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Abstract

Employing over a third of the global workforce, agriculture remains a pivotal yet inherently risky sector. In many regions, family farms expose individuals, including children, to diverse hazards. The physical nature of the work poses musculoskeletal and noise-induced hearing risks, while chemical agents like pesticides and toxins pose potentially even greater dangers. Recognizing these evolving threats, this chapter outlines pertinent challenges and explores evidence-based approaches to safeguard agricultural communities, paving the way for a safer and more sustainable future.

Keywords

Agricultural health; Agricultural workers; Agriculture risks; Agriculture-related injuries; Disease prevention; Environmental exposure; Family of agriculture workers; Hearing impairment; Organic toxins; Pesticides; Repetitive motion; Stress; Youth health

Introduction

The relaxing image of rolling fields and bountiful harvests often masks a harsh reality. Agricultural workers, their families, and communities navigate a unique landscape of occupational hazards, jeopardizing their health and safety (ILO, 2020). This chapter explores the complexities of agricultural health and safety, weaving together the threads of occupational risks, environmental exposures, and consequences faced by those who sustain our very existence through food production.

At the heart of this exploration lies the agricultural workers and their families, the backbone of our food systems. Farmworkers, comprising a significant portion of the global workforce, are disproportionately burdened by a potent mix of physical and psychosocial stressors. Young children, particularly in family-run farms, are especially vulnerable, exposed to hazards without the knowledge or protection afforded to adults. Statistics paint an ugly picture: the International Labour Organization reports an estimated 210,000 fatal workplace accidents annually among agricultural workers alone (ILO, 2020). Every day, many more suffer nonfatal injuries and chronic health conditions. Understanding the sources of these threats is crucial for mitigating their impact.

The hazards in agriculture is woven from diverse threads. Machinery accidents, notably involving tractors and harvesting equipment, rank high among the causes of fatal injuries. The very tools that boost agricultural productivity such as hazardous substances like solvents, pesticides, and fertilizers, release a potentially chemical and microbial toxins, carcinogens, and skin

irritants (Amey and Christey, 2019). Exposure to these organic and inorganic compounds can lead to a spectrum of health problems, from respiratory issues and neurotoxicity to cancer. Even seemingly natural elements like sun exposure and noise contribute to both short and long-term skin damage and hearing issues, as does the physical toil inherent in agricultural work, leading to musculoskeletal disorders and trauma (Couth et al., 2019; Eurofound, 2023).

Beyond the physical realm lies the insidious realm of stress. The pressures of weather, market fluctuations, and economic uncertainty weigh heavily on farmers and their families, leading to anxiety, social isolation, and even suicide (Terrazas and McCormick, 2018). The sanitation challenges faced in rural communities further exacerbate health risks, particularly for children and families living on farms. These intertwined threats present a formidable challenge, demanding a multifaceted approach to prevention and intervention.

This chapter aims to illuminate the intricacies of agricultural health and safety. We will dig into the specific hazards faced by workers and their families, examining the mechanisms of injury and illness. The consequences, both immediate and long-term, will be explored, highlighting the human cost of agricultural production. By understanding the science behind these threats, we can move toward the development of effective strategies to protect those who nourish our world. Through targeted interventions, improved regulations, and a commitment to safety culture, we can strive toward a future where the act of feeding humanity is no longer synonymous with putting oneself at risk.

Scope of the problem

While agriculture ancient roots remain firmly in place, its present-day footprint has shifted. Although still a major industry, the share of the global workforce directly engaged in agriculture is now closer to 26.7%, or roughly 2 billion people, rather than the previously estimated third. This trend is particularly evident in Africa, where despite 57% of the population residing in rural areas, only 53% remained economically active in agriculture in 2016 (FAO, 2018). This suggests a gradual move toward diversification within rural economies, while still acknowledging the significant role agriculture plays in supporting livelihoods on a global scale.

Agriculture employment patterns vary significantly based on a country economic development. In developed nations, the trend continues: the largest share of employment is in the services sector, followed by industry, with a shrinking proportion in agriculture. However, the exact figures have changed since 2013. As of 2022, the World Bank estimates that agriculture accounts for only 3.9% of total employment in high-income countries, with some exceptions exceeding 5% (WorldBank, 2021).

In contrast, transitional and developing economies still see agriculture as a major source of employment. The FAO estimates that in 2018, agriculture provided 58% of all employment opportunities in low-income countries. Asia remains a significant contributor, with around 60% of its workforce engaged in agriculture (FAO, 2018; WorldBank, 2021). However, the trend is still toward gradual decline even in these nations, as economies develop and diversify. Farm size and ownership also differ greatly. Developed countries in North America and Europe are dominated by large-scale, commercial farms, often owned by corporations. The number of family-owned farms continues to decline, while their average size increases. However, it is crucial to note that despite their smaller scale, family farms still play a significant role in these regions, contributing a substantial portion of agricultural output.

The situation in developing countries is more complex. While large-scale commercial farms exist, the majority of agricultural production comes from small-scale, family-owned farms, often subsistence-based. The FAO estimates that these small farms produce 80% of the food consumed in low-income countries. Despite their critical role, these farmers often face significant challenges, including poverty, limited access to resources, and vulnerability to climate change.

The economic hardships of rural poverty are compounded by the health demands intrinsic to agricultural labor. Classified as one of the most hazardous occupations, farming exposes individuals worldwide to a spectrum of injuries and diseases, regardless of production scale. These hazards encompass traumatic injuries, chemical exposures, psychosocial stressors, and respiratory issues. While this article mainly focuses on farm owners, family members, and workers, the risks extend to children within the farm environment. Interventions aimed at preventing these occupational health risks are crucial for improving the well-being of rural populations.

Agricultural workers and their families

In the adult farming population, there exists a spectrum of significant health challenges, encompassing both acute and chronic afflictions. Respiratory disorders, cancer, neurologic complications, injuries, traumatic fatalities, skin ailments, hearing impairment, stress, and reproductive issues constitute prominent health concerns. Within mechanized farming nations, fatal and nonfatal injuries to farmers and farmworkers predominantly stem from tractors and agricultural machinery, followed by risks associated with livestock, structural elements, falls, and bodies of water. Environmental hazards encompass exposure to pesticides, volatile organic compounds (fuel), noxious gases, airborne irritants, noise, vibration, zoonoses, and stress. This intricate scenario extends to farm family members, underscoring agriculture as a distinctive realm where occupational and environmental exposures intersect, creating a multifaceted health landscape.

In 2017, the global agricultural workforce comprised roughly 873 million people, representing 27% of the total workforce. This marks a significant decrease from 2000, when 1027 million people were employed in agriculture, accounting for 40% of the global workforce. The most notable decline occurred in Asia, where the agricultural workforce shrank from 787 million to 581 million between 2000 and 2021 (FAO, 2022). This translates to a quarter of the agricultural workforce transitioning to other sectors of the economy. Europe witnessed a similar trend, with agricultural employment decreasing by 49% from 34.4 million in 2000 to 17.5 million in 2021. On the other hand, Africa experienced an increase in agricultural employment, rising from

164 million in 2000 to 229 million in 2021. Southern Asia, Eastern Asia, and sub-Saharan Africa accounted for the majority of the agricultural workforce, with 292.2 million, 148.4 million, and 215.7 million workers, respectively (FAO, 2023). As of 2023, the nonfatal injury rate in the EU27 is around 1540 per 100,000 workers, down from 1870 in 2011. Machinery, falls, and hazardous environments are still the leading culprits, similar to the United States. In less mechanized settings, livestock, pesticides, zoonoses, and stress pose the biggest threats to farmers and farmworkers (FAO, 2023; ILO, 2018b).

Farming is also unique in that child labor is common. Special consideration must be given to the health risks faced by children working in agriculture. The maturing organ systems of children and adolescents may be especially vulnerable to the harmful effects of hazards commonplace in agriculture such as chemical exposures and physical stressors. While estimates from 2012 suggested around 101 million children engaged in agricultural work globally, more recent ILO data reveals a significant rise (ILO, 2018b). An estimated 70% of child labor (equating to 108 million children) is now concentrated in the agricultural sector, representing a concerning increase of 10 million children since the 2012 figures. Geographically, Africa bears the heaviest burden, with 72 million child laborers in agriculture, followed by Asia with 62 million (ILO, 2018a).

Globally, child labor has been a part of plantation agriculture throughout its history: families working on plantations as contract laborers must rely on all members of the family unit working together to increase productivity and in turn, their compensation. Children all over the world are being exploited, prevented from going to school, or pushed into work that endangers their health and normal development. According to a 2021 USDA report, 98% of U.S. farms are family farms, and they account for 87% of farm production, with approximately 26% of beginning farmers under the age of 35. Nearly 60% of all child laborers who work in agriculture usually are working unpaid with their family (ILO, 2016; USDA, 2022). Although the exact number of youths exposed to farm hazards annually in the United States is unknown, it has been estimated at more than 2 million.

Women account for over half of the global agricultural workforce; however, they are often overlooked in international labor statistics. In addition to facing the same hazards as male agricultural workers face, women working in agriculture during their reproductive years may be exposed to toxic chemicals or physical demands that can also cause problems with reproduction and pregnancy maintenance. There is also concern that all women who are exposed to biologically active chemicals during agricultural work may be at risk for hormone disruption across the lifespan, from their pre-reproductive years through menopause and beyond.

Sources of hazards and health risks

Farmworkers are exposed to numerous safety, health, environmental, biological, and respiratory hazards. These include hazards related to grain bins and silos, hazard communication of chemicals, noise, musculoskeletal injuries, heat, and others. Two health specialty areas dealing with agriculture are worth noting. Agricultural medicine refers to the subdivision of public health and/or occupational medicine included in the training and practice of health professionals. Agromedicine refers to a specialty partnership between agricultural and medical professionals invested in reducing illness and deaths related to agriculture. Agromedicine has focused on core health areas of traumatic injury, pulmonary exposures, and agrochemical injury. Table 1 provides a general guide to these agriculture-related health hazards. Rather than serving as a complete guide, the table is designed to highlight the principal exposures and possible manifestations that agricultural practitioners should be aware of when designing programs to improve health and safety in the agricultural environment (Baron et al., 2011).

Fatal and nonfatal injuries

Agriculture holds a disturbing distinction: its workers face over three times the fatal occupational risk compared to other sectors. ILO estimates reveal over 210,000 yearly agricultural fatalities, with a staggering 22,000 involving children (ILO, 2020). These numbers only capture the tip of the iceberg, as non-fatal injuries and illnesses remain undocumented.

Beyond the chilling death toll lies the hidden human cost. Countless workers endure life-altering injuries, grappling with physical and emotional trauma that shatter livelihoods and wellbeing. Tractor rollovers, machinery accidents, animal attacks, and falls paint a grim picture of the dangers lurking on farms. Studies like Weichelt et al. (2022) underscore the issue, reporting 270 fatalities and 278 non-fatal injuries among just 548 young agricultural workers in the US alone (2016–2021).

Children account for about 20% of all U.S. farm fatalities and a higher proportion of the total number of nonfatal farm injuries. Farm machinery (including tractors) is the leading cause of fatality to farm youth less than 20 years of age in the United States. Thirty percent of farm machinery-related deaths are among children less than 5 years of age. Drowning is one of the leading causes of injury-related mortality globally. A Canadian study reported 44 drowning deaths and 306 non-drowning deaths on farm-related activities. Drowning deaths were at younger age (mean age of 5.4 versus 8.8 years old), non-work-related (25% versus 79%), and less likely to occur during adult supervision (36.4% versus 53.5%) (Randall et al., 2021). The most common injury resulting in death is to the head or brain, accounting for nearly two-thirds of the total. The leading sources of nonfatal injuries are surfaces, animals, and nonindustrial off-road vehicles; and the leading causes of these injuries are falls, off-road transportation accidents, and being struck by objects. The parts of the body most commonly injured are hands, head, and legs and the most frequent types of injury are lacerations, fractures, and scrapes or abrasions (Ouattara et al., 2023).

Agricultural work presents a unique confluence of factors contributing to elevated injury risk. Studies indicate a strong association between fatigue and occupational accidents, with field workers particularly susceptible due to demanding physical labor, long hours, and early starts often under extreme temperatures. This fatigue can hinder cognitive function and reaction times,

Table 1 Selected health hazards, health effects, and guiding control strategies in agriculture.

Health effect	*Health hazard*	*Control strategy*
Musculoskeletal disorders	Prolonged stooping, heavy lifting, repetitive movements of the upper extremities during planting, pruning, and harvesting	Ergonomic reengineering of tools and workplace; decrease of weight of loads; job rotation among repetitive and nonrepetitive tasks
Pesticide-related conditions	Mixing, loading, and applying pesticides; working in fi elds recently sprayed with pesticides; aerial drift of pesticides from adjacent fi elds; exposure to pesticides in living quarters	Substitution with less toxic substances; adequate protective equipment; training on prevention of pesticide exposures; administrative restrictions on working in fi elds where exposure may occur
Traumatic injuries	Work-related incidents with tractors and other farm equipment; motor vehicle crashes during transport to and from fields; lacerations from sharp tools for cutting and pruning	Use of roll-over protection systems in tractors; training and enforcement of safe use of equipment; transportation vehicles equipped with personal restraint systems; safe cutting tools
Eye conditions	Exposure to dusty conditions; foreign bodies from plant material penetrating the eye	Use of protective eyewear; dust control
Infectious diseases	Inadequate sanitation facilities; exposure to tuberculosis, sexually transmitted diseases, and other infectious diseases due to living arrangement of migrant workers	Improved sanitation facilities; improved housing facilities; improved medical care screening and treatment services
Skin	Skin contact with allergic and irritant substances, either naturally occurring in the soil and crops or in fertilizers and pesticides	Substitution with less toxic materials; use of gloves and sleeves, if indicated; administrative controls to remove sensitized workers from exposure
Mental disorders	Long working hours; inadequate pay; social isolation from family and friends	Improved working and housing conditions; availability of mental health services
Cancer	Exposure to chemical substances in pesticides and other agricultural products; prolonged sun exposure	Substitution with less hazardous substances; protective clothing and sunscreen; administrative controls to limit exposure

Adapted from Baron SL, Welch L, and Lipscomb J (2011) Addressing health and safety hazards in specific industries: Agriculture, construction, and health care. In Levy BS, Wegman DH, Baron SL, and Sokas RK (Eds.) *Occupational and Environmental Health: Recognizing and Preventing Disease and Injury*, 6th edn. pp. 753–778 Oxford University Press.

increasing the likelihood of errors and accidents. Furthermore, the analysis identifies inexperience as another key vulnerability, particularly among young workers. Their lack of familiarity with safe practices and procedures further heightens their risk. Additionally, the essay highlights the interplay between psychological factors and safety compliance. Farmers reporting stress and overwork are more likely to disregard safety measures like proper pesticide handling, exacerbating injury risk. The text also emphasizes the role of pre-existing health conditions, such as hearing loss and joint pain, in conjunction with longer working hours, as significant predictors of severe injuries (Amey and Christey, 2019; Ouattara et al., 2023).

Trauma from overexertion or repetitive motion

Ergonomic hazards refer to physical demands placed on the body that can lead to disorders and loss of function. Agricultural work in particular has been linked to musculoskeletal trauma due to the stresses on the body of constant bending, lifting, twisting, and other awkward or punishing work. The prevalence of work-related musculoskeletal disorders (WMSDs) remains a significant concern in the European Union, particularly among workers in certain sectors. According to the most recent European Working Conditions Survey (EWCS) 2023, close to 40% of workers in the EU reported experiencing pain in their back, neck, shoulders, or arms during the previous 12 months. This translates to an estimated 66 million workers across the 27 EU member states affected by WMSDs (Eurofound, 2023). Numerous farming tasks such as propagation and harvesting require workers to stand, bend, or stoop in demanding positions for long periods of time. Sprains, strains, and overexertion are all common injuries, especially for workers engaged in manual cultivation. Nursery workers engage in repetitive gripping and cutting. They work virtually full-time year-round without rotation to other jobs. In the short term, horticultural workers often report pain and numbness in the hand, wrist, and arm. After an extended time on the job, they are at high risk for carpal tunnel syndrome, a disabling condition of the hand.

Noise

Farming is a physically demanding occupation that often involves exposure to high levels of noise. This noise exposure can lead to hearing loss, which can have a significant impact on a farmer's quality of life. The prevalence of hearing loss among farmers is estimated to be between 25% and 55%. This means that one in four to three out of four farmers have some degree of hearing loss. The prevalence of hearing loss increases with age, with over 70% of farmers over the age of 65 having hearing loss (Couth et al., 2019). Hearing impairment related to noise generated by farm equipment develops early in life. Rural students have a 2.5 times greater hearing loss than urban students and that discrepancy increases with age and number of years worked in farming. Farmers and farm family members are exposed to excessive noise from equipment used on the farm, including tractors, grain dryers, combines, bush hogs, and chain saws. Noise-induced hearing loss occurs with continued exposure to high levels of noise; it is cumulative and irreversible. Noise-induced hearing loss results from the destruction of the cochlear hair cells in the inner ear.

There are two types of hearing damage caused by excessive noise. Acoustic trauma occurs when the ears are exposed to a single sudden sound above 140 dB(A) (decibels measured on the A scale, which incorporates weighting that takes into account the ear's varying response to sounds of different frequencies) and the sensory cells are permanently dislodged and destroyed. Gunshot blasts or explosions can cause acoustic trauma. Prolonged exposure to noises above 85 dB(A) can result in damage, though not necessarily permanent, to the cochlear nerve cells. Prolonged exposure to loud noises can inflict permanent damage on the auditory system, particularly the hair cells within the cochlea. These essential structures, lacking sufficient recovery periods between noise insults, succumb to irreversible injury. While the exact timeframe for recovery remains debated, the insidious nature of noise-induced hearing loss (NIHL) is undeniable. Often starting subtly in youth, it can culminate in significant deficits in speech comprehension later in life. Emerging evidence suggests a synergistic effect between occupational noise exposure and certain chemicals like solvents and pesticides, potentially amplifying the risk of NIHL. This worrisome interaction might pose an even greater threat to young farmworkers, highlighting the need for comprehensive hearing conservation strategies in high-risk populations (Ahmed et al., 2022).

Stress

There is little doubt that farming is one of the most stressful occupations in both developed and developing countries. Both farmworkers and farm family members are exposed to the economic pressures of their family livelihood, the future of which remains precarious at best. The influence of stress is manifested by psychological or emotional disturbance such as alcohol abuse among family members, as well as by the creation of insecure working conditions. Being unmarried, having negative life events within the past year (legal problems, substantial income decline, and loss of something of sentimental value), and lower perceived general health status have been identified as significant risk factors for depressive symptoms among male farmers in the United States.

Farmworkers in general have high rates of depression. Extreme poverty and hardship, the stress of job uncertainty and frequent moves, and social stigmatization and isolation are contributing factors. This is true for children and youth as well. Studies have also linked depression in workers to long hours of work in high-intensity, low-skilled jobs, precisely the kind of labor undertaken by farmworkers.

Having one's livelihood controlled by the uncertainty of the weather and the agricultural market combined with the social isolation often experienced by rural inhabitants increase the risk for psychological distress. Rural areas of China and Sri Lanka, for example, have seen an increase in suicides among subsistence farmers, many of whom are using toxic farm chemicals to poison themselves. Identifying symptoms of psychosocial stress in farmers requires history taking and consultation to determine current social and economic conditions in the family. Depressive symptoms are expressed differently in men and women. Knowing that adult farm owners and farmworkers are at higher risk for psychological disturbance should alert health-care providers and public health practitioners to the need for outreach to these high-risk groups. Because health-care providers are usually the first mental health contact for rural residents, they play an important role in the early identification of psychological distress in farmers, farmworkers, and their families.

Sanitation

Agricultural health clinicians have identified hygiene as being key in preventing bacterial infections from animals and dermatoses caused by chemical contamination. However, farmers themselves may forego the minimum sanitation requirements when working in fields as a means of saving time and effort or because water is simply not available. Regulations in the United States illustrate how basic public health protections may not be in place for agricultural workers. Access to clean drinking water, water for hand washing, and toilet facilities are the minimum sanitation requirements imposed on farms by the Occupational Safety and Health Administration (OSHA), the occupational regulatory agency in the United States. Even these minimal requirements, however, may be ignored by growers and by the farm labor contractors who bring in workers. Furthermore, labor laws prohibit enforcement of these regulations on farms with 10 employees or less, essentially exempting small farms. Health-care providers and public health practitioners should consider the multiple sources of contamination in the farm environment and consider hygiene as having a role in sources of infections, especially of the skin.

Heat

Heat illnesses can lead to death or brain damage and are an ever-present danger for field workers. In the United States alone, there are approximately 400 deaths annually from heat illnesses. Risk for heat stress during the growing season is particularly acute, especially during haying and harvesting. It is recommended that workers laboring under hot weather conditions drink a minimum of 8 oz. of water every half hour. Very high heat or humidity increases the amount of recommended water, so that, for example, a person working in 90 F heat under a full sun should drink 8 oz. of water every 15 min. Ensuring sources of fresh water are abundant is critical to maintain workers' hydration needs. Excessive sun exposure places farmers at risk for future skin malignancies and must be prevented with proper head and body covering, which can also increase the risk of heat stress from too much clothing. Keeping farmers hydrated, protected from the sun, and ensuring a minimum of 10 min of break time during each hour can reduce the risk of illnesses from overexposure to heat and sun.

Hazardous organic and inorganic exposures

Potentially harmful exposures exist in a variety of forms in the farm environment, including solvents, pesticides, paints, welding and combustion fumes, plant toxins, and animal bacteria and viruses. Their possible health effects vary widely and can include acute intoxication, Parkinson's disease, peripheral neuritis, acute and chronic encephalopathy, various cancers, and reproductive problems.

Solvents

A solvent is a liquid used to dissolve other substances, but the most toxic solvents are extracted or manufactured for chemical use. Most solvents are colorless liquids at room temperature that volatilize easily and have strong odors. These compounds may be referred to as volatile organic compounds (VOCs) in reference to their physiochemical properties. Many commonly used solvents such as gasoline, kerosene, and jet fuel are mixtures of solvents and other chemicals. They are widely used for manufacturing, degreasing and other cleaning, and as carrying agents in products ranging from insecticides to glues and paints. The most common solvents and solvent mixtures found in the farm environment include pesticides, fuels, paints, and metal degreasers. There is little information from animal or human studies about the health effects of chronic low-dose exposure. Solvents are most commonly inhaled in their volatilized form and absorbed via the respiratory track.

Significant doses of solvents may occur through skin exposure and absorption. Most solvents are lipid-soluble but some are water-soluble. Animal studies in the toxicology literature emphasize the role of solvents as neurotoxins. The majority of solvents are central nervous system depressants and some have long-term neuropsychological effects, including chronic toxic encephalopathy. In adults, the following neurobehavioral problems resulting from chronic solvent exposure have been recorded in the literature: memory loss, decreased problem-solving ability, decreased attention span, impaired dexterity and hand–eye coordination, altered reaction time, reduced psychomotor function, and altered personality or mood. In addition to neurotoxic effects, other documented health effects from solvent exposure in adults are pulmonary sensitization, bradycardia, and ventricular fibrillation, defatting of the dermis, chemical burns, and hearing loss.

Pesticides

Agriculture experienced a chemical revolution after the Second World War with the broad-scale introduction of pesticides to control unwanted pests and fertilizers to enhance soil productivity. This revolution brought with it a series of unintended occupational and environmental health consequences, and exposure to pesticides is a serious risk to farmworkers worldwide. Data from the U.S. paints a concerning picture of pesticide exposure in agricultural settings. The EPA estimates 300,000 farmworker poisonings annually, while the NRDC suggests 40,000 physician-diagnosed cases (CDC, 2011). However, these figures may underestimate the true scope, as underreporting remains a significant issue. Globally, the ILO reports 40,000 agricultural worker deaths per year due to pesticide exposure (ILO, n.d.). These statistics highlight the urgent need for improved data collection, safer application practices, and effective public health interventions to protect agricultural communities worldwide.

Pesticides include herbicides to control weeds, insecticides to control a range of insects, nematocides to control worms, and fungicides to control molds, fungi, and other mycotoxins. Exposures can happen when workers are mixing, loading, transporting, or applying pesticides and the three main routes of exposure are dermal, inhalation, or ingestion. Risk of exposure can be compounded by lack of or improper protective gear, leaking containers, illicit formulations, faulty labeling of the chemical, improper application, and illiteracy. Workers may also be exposed to pesticides if they drink from, wash their hands, or bathe in irrigation canals or holding ponds, where pesticides can accumulate.

While the detrimental acute health effects of pesticide exposure are well-established, the long-term consequences remain a subject of ongoing investigation. Toxicologic and epidemiologic data reviewed in this section largely originate from children and adult human studies. Infants and children may be exceptionally vulnerable to health complications from exposures due to their developing neurological, immunological, and reproductive systems and due to differences in their ability to metabolize and excrete toxicants (Perlroth and Branco, 2017).

Several studies illustrate the potential for chronic health effects associated with pesticide exposure. A Californian study involving children living near agricultural fields documented the presence of dialkyl phosphate (DAP) metabolites in 48.0% and 40.5% of urine samples from children and adults, respectively. This suggests widespread exposure even among non-agricultural workers residing in close proximity to application areas. Interestingly, the study also indicates no link between urinary DAP levels and occupational pesticide exposure, highlighting the potential for community-wide drift affecting even those not directly involved in pesticide application (Kuiper et al., 2023).

Further evidence comes from Thailand, where Forté et al. (2021) compared farmworkers lacking proper protective equipment to non-agricultural individuals. The farmworkers exhibited significantly lower levels of immune system markers and reported decreased confidence in handling personal problems, suggesting potential chronic effects on both immune function and mental health. These findings raise significant concerns about the long-term impacts of pesticide exposure on these crucial aspects of human health.

However, the picture is not entirely bleak. Seesen et al. (2020) investigated the association between organophosphate exposure and insulin resistance. While no direct link between overall DAP levels and insulin resistance was found, the study identified a higher level of diethylthiophosphate (DETP), a metabolite specific to the potentially risky chlorpyrifos pesticide, in pesticide sprayers. This suggests that specific organophosphate exposures might contribute to metabolic dysregulation. Importantly, the study

also highlighted the effectiveness of preventive measures like masks, proper work practices, and label reading in reducing exposure levels, emphasizing the crucial role of preventative measures in mitigating the risks associated with pesticide use.

Despite progress, unintended pesticide consequences persist worldwide. Weak public health safeguards leave workers vulnerable, while regulations often inadequately protect citizens. Alarmingly, some developing nations import or produce banned pesticides, including highly toxic and persistent organochlorines still used in over 20 countries. The long-term ecological and public health repercussions of this continued exposure remain concerning, demanding stricter regulations, robust health protections, and responsible pesticide practices globally.

Microbes and their toxins

Grain dusts, molds, and fungi are among several plant-based irritants that abound in the agricultural environment and that cause a host of respiratory problems in adult farmers. The clinical features of adult illnesses caused by these irritants should be considered with regard to the potential for child exposures as well. As with other chronic diseases, chronic respiratory diseases are likely to originate during early exposures, with damage accumulating over time until eventual clinical symptoms appear. Preventing such exposures early may be the key to reducing respiratory disease in adulthood.

Grain dust is a complex substance composed of plant debris, insect parts, silica, chemical residues, molds, fungi and bacteria and their metabolites, including endotoxins. Approximately 40% of its particles are less than 5 mm in mean diameter and represent a respirable piece that can penetrate the terminal bronchioles. Exposure to antigens from organic dusts may be responsible for hypersensitivity pneumonitis, which has a reported prevalence of 0.1–15% among adult farmers. Hypersensitivity pneumonitis is difficult to diagnose in adult farmers because it has an insidious course and appears as recurrent influenza-like episodes or nonspecific respiratory symptoms and may result in chronic respiratory problems that look like pulmonary fibrosis.

The organic-dust toxic syndrome is an acute response to inhaling organic dust, usually characterized by a delayed onset of fever, malaise, and chest tightness that does not evidence immunologic involvement and has an apparently benign course without long-term respiratory impairment. Possible mechanisms include a toxic reaction to endotoxins, mycotoxins, or proteinase enzymes of moldy plant materials. It is related to dust level and can be reproduced in laboratory subjects exposed to high concentrations of grain dust. Exposures responsible for the related condition extrinsic allergic alveolitis (farmer's lung) are actinomycetes such as *Micropolyspora faeni*, fungi, and animal proteins present in many agricultural environments.

Working in confined spaces such as silos or manure pits can pose risks for exposure to toxic gases such as nitrogen dioxide from fermented grain or methane gas emitted from manure. Both of these gases can be fatal when inhaled and proper ventilation of enclosures is critical for mitigating acute exposures.

Carcinogens

While the epidemiologic data are not conclusive enough to demonstrate causality for any one agricultural exposure, a number of increased cancer risks have been associated with either farming or specifically with pesticide exposure, including non-Hodgkin's lymphoma, leukemia, multiple myeloma, soft tissue sarcoma, Hodgkin's disease, and cancer of the prostate, pancreas, ovary, breast, and testis. Currently only arsenic-containing insecticides are recognized as known human carcinogens by the International Agency for Research on Cancer, but many other pesticides are suspected. Agricultural workers are also at excess risk for developing skin cancer, which is most often caused by chronic exposure to ultraviolet radiation from the sun.

Skin irritants

Modern agriculture uses a wide range of chemicals, pesticides, and herbicides to maximize crop output and limit losses caused by bugs. Consistent exposure to these chemicals is unhealthy for the skin, and as a result, a growing number of agricultural workers report skin irritation and diseases. Irritant reactions occur when skin is exposed directly to a chemical. Allergic reactions occur over time when the immune system is regularly exposed to a chemical. Photoallergic reactions are another risk. They occur when someone is exposed to both light and dangerous chemicals, causing skin disease. Workers can do a lot to limit this occupational risk by wearing proper work clothing, using appropriate protective gear, and washing their skin frequently (Brans et al., 2021). Skin cancers, dermatophyte infections, and pesticide-related skin diseases are common in farmers.

The impact of microscopic fungi on farmers health seems to be greater than originally understood. The infection may be transmitted from infected humans, animals, plants, or soil. To date, little epidemiological data on fungal skin disease in farmers are available. Working conditions on farms directly contribute to the development of fungal infections. Farmers may spend extended periods working in humid conditions and long hours wearing rubber boots or gloves. Besides infection, fungi may also cause noninvasive forms of skin disease, such as dermato-mycotoxicosis professionals or alternariosis. Most pesticide-related dermatoses are contact dermatitis, both allergic and irritant. Rare clinical forms also occur, including urticaria, erythema multiforme, ashy dermatosis, parakeratosis variegata, porphyria cutanea tarda, chloracne, skin hypopigmentation, and nail and hair disorders.

Reducing health risks to agricultural workers

Agriculture, a vital cornerstone of global food security, exposes its workforce to a multitude of hazards, ranging from musculoskeletal strain to chemical poisoning. To ensure the well-being of these individuals and the sustainability of the sector, a comprehensive strategy drawing upon public health, industrial hygiene, and environmental leadership is crucial.

Occupational illnesses and injuries affecting an estimated 179 million farmers globally emphasizing the need for proactive hazard control. A four-pronged approach forms the foundation of this strategy: risk assessments and incident investigations to identify dangers; continuous monitoring of exposure and health trends; root cause analysis of health effects; and implementation of engineering controls, safe work practices, and personal protective equipment.

Prioritization of control measures emphasizes eliminating hazards at the source. Agricultural production process reengineering, the preferred method, involves redesigning machinery, tools, and farming techniques. This can involve automation in developed nations or introducing machinery to alleviate manual labor in developing countries. Additionally, transitioning toward less chemically intensive practices, like Integrated Pest Management (IPM), reduces reliance on harmful pesticides, safeguarding both worker and environmental health.

Healthy farm environments extend beyond physical safety, encompassing mental and emotional well-being. Simple interventions like machine guarding and task diversification combat repetitive stress and injury. Administrative controls, such as child labor bans and pesticide regulations, protect public health, but preventive measures are paramount. Equipping workers with knowledge and training on risks empowers them to make informed decisions and protect themselves.

Investing in a holistic approach to worker well-being in agriculture is not just an ethical imperative, but a strategic investment. By fostering healthy farms, we not only ensure food security but also safeguard the health and well-being of the very hands that feed us.

Conclusion

As we close this exploration of agricultural health and safety, the gravity of the challenges faced by farmers and their families comes into sharp focus. Agricultural workers and their families, the backbone of our food systems, face an unacceptable burden of fatal and nonfatal injuries, chronic illnesses, and mental health struggles. These range from the physical toll of overexertion and noise exposure to the invisible dangers of chemical toxins and infectious agents.

While the statistics paint a daunting picture, it is critical to remember that prevention is not only possible, but essential. By recognizing the various sources of risk, we can enact a multi- faceted approach to safeguard the well-being of this vital workforce. Prioritizing engineering controls is key, from implementing effective machinery guards, utilizing ergonomic equipment, enclosed spraying systems and ensuring proper ventilation systems can significantly minimize the risk of injuries and hazardous exposures.

Fostering a culture of safety is equally critical. This involves ongoing training, education, and peer support empowers farmworkers on proper safety practices, hazard identification, and the importance of personal protective equipment. Continuing research is also crucial to explain the chronic health complications related to agricultural works and inform evidence-based programs.

Beyond individual farms, collaborative efforts are essential. Agricultural stakeholders, healthcare professionals, and policymakers must work together to (i) advocate for effective legislation that enforces safety standards and promotes the development of safer agricultural technologies; (ii) invest in research to better understand the long-term health effects of agricultural exposures and develop innovative solutions to mitigate them; and (iii) ensure impartial access to healthcare for farmers and their families, including preventative care and screenings for occupational illnesses.

Investing in agricultural health and safety is not just an ethical imperative; it is an economic one. A healthy and resilient workforce translates to increased productivity, reduced healthcare costs, and a more sustainable food system. By nurturing the well-being of those who nourish us, we cultivate a future where the hands that feed the world are also protected. Let this chapter serve as a call to action, a reminder that safeguarding agricultural health and safety is not just possible, but critical. It is time to prioritize the well-being of those who ensure our own, building a food system that is as nourishing for its workers as it is for its consumers.

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Further reading

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Relevant websites

http://www.cehn.org—Children's Environmental Health Network.
https://www.eurofound.europa.eu/—European Working Conditions Survey.
http://www.osha.europa.eu/—European Agency for Safety and Health at Work.
http://www.fao.org—Food and Agriculture Organization of The United Nations.
http://www.ilo.org/—International Labour Organization.
http://www.ncfh.org—National Center for Farmworker Health.
http://www.nagcat.org—North American Guidelines for Children's Agricultural Tasks (NAGCAT).
http://www.nasdonline.org/—U.S. National Agricultural Safety Database.
http://www.cdc.gov—Worker Health, Chartbook.