Canadian Board of Occupational Medicine Research Project

A Literature Review of the Occupational Risks and Health Hazards to Pilots and Support Workers in Agricultural Aviation

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This paper seeks to highlight the wide range of health problems secondary to the occupational hazards experienced by pilots and ground support staff involved in Agricultural Aviation. Further, it will describe current preventative and mitigation strategies employed in the industry.
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In the early days of wheat farming in western Canada, farmers were perplexed as to how rust disease of wheat could suddenly appear in many wide spread locations at the same time. Investigations at that time revealed that the disease was introduced in the form of airborne spores. This discovery prompted an airborne solution to control plant disease in North America. Consequently, since 1912 Canadians have used aircraft to aid in the protection of field crops, orchards, and forests from the effects of fungi, insects, frost, and fire.

Today, Canada's Forest Services employ a wide range of forest protection aircraft including light single engine planes, faster twin-engine types and helicopters. Agricultural pilots and their support teams are involved in particularly hazardous occupational environments. They are exposed to a number of occupational risks not least of which are to be found in the agricultural chemicals they prepare and disperse. A number of accidents and illnesses have been reported attributable to the acute and chronic effects of agricultural chemical exposure.

Further occupational hazards experienced in agricultural aviation derive from the nature of the work. The greatest percentage of a pilot's flying time is spent in physically and mentally demanding low-level flight which, at peak times, results in long working hours leading to poor sleep and inadequate rest. Repetitive takeoffs and landings from less than desirable landing strips also contribute to the fatigue and danger. Thermal stress in the cockpit combines with other occupational hazards such as noise, vibration, G- forces, dehydration and chemical exposure which are other significant occupational hazards in this unique work environment.

In the interest of occupational and public safety the industry has now become federally regulated. Standard operating procedures have been developed in conjunction with specialized protocols for medical surveillance and biologic monitoring in an effort to mitigate some of the effects of these occupational hazards. However, given the inherent risks and occupational hazards of aerial spraying operations, it may be impossible to reduce all risks with effective mitigation strategies.

Like the farmers they serve, agricultural pilots and their support staff tend to rise very early, and the first 'positioning' flight from the base airstrip to the field often commences in the dark, landing at sunrise. Many agricultural pilots are also owners and operators. As such their responsibilities include maintaining accurate records, arranging contracts and aircraft maintenance, etc. This means that during the spring season their days are excessively long and without adequate rest they can commence the following days flying duties tired and not mentally prepared. This can cause cumulative fatigue which can have obvious safety implications on judgment and performance. It should also be noted that agricultural flying can only be done when the wind and rain conditions are right, and according to the seasonal vagaries of growing crops or the life-cycle of pests. These issues can result in unanticipated and unprepared flying operations which in some cases can pose an unacceptable risk to safety. There are further influencing factors: Volatility and viscosity of the chemical being applied, droplet size, evaporation, wind, drift, temperature, crop morphology, height and speed of the flight path, recent or impending rain and pest characteristics.

Gravity-induced Loss of Consciousness (GLOC): Pilots engaged in agricultural aviation will invariably experience the physiological effects resulting from the forces placed on them through the nature of the flight profiles their work demands. **Grayout -** As the term implies, graying of vision is caused by diminished flow of blood to the eyes. Although there is no associated physical impairment, this condition should serve as a warning of a significantly increasing impairment due to decreasing blood flow to the head. **Blackout -** In this condition, vision is completely lost. Blackout results when the oxygen supply to the light-sensitive retinal cells is severely reduced. Yet, contrary to other common usages of the term, consciousness is maintained. In blackout, some mental activity and muscle function remains, thus the occurrence of blackout warns of seriously reduced blood flow to the head and potential loss of consciousness. **Loss of Consciousness -** When the blood flow through the brain is reduced to a certain level, the pilot will lose consciousness. This condition is usually accompanied by tonic-clonic movements. These movements can cause the aircraft to enter flight configurations from which recovery may not be possible, even if consciousness is regained. In centrifuge studies, many pilots lost (and regained) consciousness without realizing they had done so.

Any factor that reduces the overall efficiency of the circulatory system will degrade the body's ability to tolerate gravitational forces. The following factors should be considered by the agricultural pilot: drugs and alcohol, intercurrent infection, hydration, physical fitness, blood glucose concentration and temperature:

Accident Prevention Strategies: Agricultural aviation is repetitive work requiring a number of takeoffs and landings. In conjunction the nature of this repetitive work, time-dependent tasks, variable weather conditions, and fatigue increase rates of error. Standard operating procedures must be employed and adhered to. All checklists must be completed in a repetitive and systematic manner. Regular fuel checks must be performed as part of normal operating procedures. Running out of fuel in certain phases of flight could have dire consequences. It is essential that companies involved in agricultural aviation develop programs to assess risks and institute safety measures. Pilots and ground crew should be provided with ongoing training. It is important that single pilot operations be required to participate in this type of training. They are a high-risk group and must be encouraged to maintain constant vigilance regarding safety and risks. A number of easily accessible online assessment tools and resources are currently available to assist in this way. The FAA promotes self-administered training aids and checklists to assess and reduce risk. There are also a number of organizations that contribute to research and educational programs focused on enhancing the efficacy and safety of aerial application (e.g. National Agricultural Aviation Association).

Noise: Noise and vibration are physical hazards and as such affect more than a single target end organ system. Both can adversely affect health and performance. Aside from these physical effects, the aviation context requires effective communication which can also be impaired by a noisy environment. Research has traditionally focused on large jet or military aircraft. There have also been a number of studies completed on the effects of noise on people living near large urban airports. Occupational noise can be a hazard in many ways. It is known that noise damages the ear but it can also adversely influence a number of other bodily functions. This added influence is important as most occupational noise standards and recommendations are more concerned with permanent damage to the ear. Standards have traditionally not addressed the deleterious effects noise has on other vital body functions. **Psychological Effects:** Industrial hygiene practices have recognized the non-auditory effects of long-term exposure to noise for some time. Annoyance, distraction, fatigue, stress, sleep disturbance, cognitive and sensorimotor performance decrements and increased workload have all been reported. Again the practical importance of these issues on performance and flight safety is well recognized. As in any hearing conservative program the basic principles should include modifying noise production at the source, blocking its transmission path, or modifying the receiver. It is recommended that all pilots and support personnel working in agricultural aerial applications receive training and be enrolled in an effective hearing conservation program. Measures such as this will undoubtedly reduce noise induced hearing loss, for the levels of exposure to noise in agricultural aviation are sufficiently high to be considered an occupational hazard.

Vibration: Vibration is defined as motion that repeatedly alternates in direction. It is a physical hazard and transmission to humans can result in a range of physical, physiological and psychological effects. Sources of vibration in agricultural aviation are generated by the propulsion systems of the aircraft and aerodynamic forces. One of the best examples of an occupational injury caused by vibration is vibration induced white finger disease (hand arm vibration syndrome). It is characterized by spasm of the digital arteries (Raynaud phenomena). Continued exposure ultimately leads to damage of peripheral nerves, vascular tissue, subcutaneous tissue, bone and in some cases can involve the joints of the hands and fingers. While it is unlikely pilots will experience this ground support staff can be at a significant risk through the use of hand tools. As with many effective mitigation strategies, vibration can be attenuated at source, by modifying its transmission pathway or by altering the dynamic properties of the body. Training and education are also important components. If the source of vibration is turbulent air than this can be avoided by alternative routing. Damping mechanisms and proper seat design also effectively attenuate vibration. Engineering controls, association controls, and regular maintenance are essential in reducing exposure and preventing its consequences.

Thermal Stress: The aerial application of pesticides requires the pilot to withstand the physiologic demands of high frequency, short duration flights in demanding conditions. Personnel are often exposed to high temperatures and the pilot to repeated aerobatic activities. A typical day consists of a number of short flights usually from a small uncontrolled airfield where the aircraft is frequently refilled. As aerial spraying is usually done during the summer, high temperatures are experienced leading to the problems associated with thermal stress. Also the aircraft will be operated in an envelope (on the ground and in low flight) where cooling systems operate suboptimally. The psychological and physiologic demands imposed on the pilot experiencing thermal stress have the ability to induce fatigue and seriously impair performance .Crew members should be fully conversant with local operating requirements, duty periods, and regulations in the jurisdiction they are working in.

Thermoregulatory Physiology: Failure of the thermoregulatory system to adjust appropriately to variations in environmental conditions can be related to the following: Exposure to such an extreme environmental condition that the thermoregulatory system is unable to adequately cope; Endogenous heat production overcomes the thermoregulatory system's ability to adequately dissipate heat; Normal thermoregulation is influenced by external factors such as illness, drugs or toxins.

Physiologic response to Hyperthermia: Maintenance of a normal body core temperature when working or exercising in a hot environment is dependent upon the body's ability to adequately redirect blood flow to the surface; the so called "vasomotor zone". As temperature further increases heat is dissipated autonomically by sweating which results in evaporative cooling. This is referred to as the "thermoregulatory zone".

Healthy Individuals: Many factors are thought to predispose otherwise healthy individuals to the effects of thermal stress. These include factors such as sleep deprivation, obesity, poor physical conditioning, failure to appropriately acclimatize, poor diet, aging, dehydration and illness.

Pharmaceuticals and Alcohol: A number of products readily available are known to render otherwise healthy individuals susceptible to the effects of heat stress. Alcohol is probably the most common and, when taken in excess, will cause dehydration and impair the body's ability to appropriately redistribute blood volume in thermoregulation. A number of widely used over-the-counter (OTC) cold medications can impair cutaneous vasodilation and increase susceptibility to heat illness. Diuretics can affect intravascular volume leading to a fluid deficit.

Pre-Existing Medical Conditions: A number of underlying medical conditions will interfere with the body's ability to dissipate heat appropriately. Many cardiac conditions or peripheral vascular disease (a possible complication of diabetes) will influence thermoregulation. However advanced disease of this nature would likely prevent medical certification. Other illness like thyroid dysfunction, or self-limiting problems such as fever, viral illness, and gastrointestinal disorders may also be of significance in a hot environment.

Chemical Hazards: Aerial application of pesticides is an effective method of targeting chemical application to increase crop production. Studies have shown that agricultural pilots have a higher rate of fatality than pilots involved in other flying operations (40). As previously mentioned, an inherent risk of ground contact exists, but there is also an added risk of exposure to hazardous substances. Unplanned and uncontrolled release of hazardous substances may occur during any phase of the application process including the mixing and loading of chemicals, into the aircraft as well as servicing of the aircraft. Chemicals used for the control of insects, weeds, and plant diseases are biologically active compounds. Esters are more volatile than amines and the esters are very seldom if ever used aerially-especially in Canada. A wide variety of these chemical compounds generally known as 'pesticides' are available, and a clear understanding of the distinctions between them is essential to proper risk management.

Principles of Prevention: There are a number of mitigation strategies that can be employed to protect the agricultural pilot and support staff. These include:legislation,product registration, well-developed safe working practices to protect the operator, the loader, and the public, health education and safety training, limitations on, or prohibition of, the use of very toxic chemicals, Minimum chemical handling and exposure by using premixed packs and secure packaging, clear labeling and loading instructions, protection of the operator.

Classification of pesticides: Frequently, pesticides are defined as toxic substances and are considered hazardous materials. Most countries regulate classification criteria and group hazardous materials into categories according to their LD50 rating, persistence in the environment and degree of mobility. The following is a conventional classification system including four main categories as well as a fifth covering exempted substances. 1. Deadly poisons 2. Dangerous poisons 3. Standard poisons (poisons) 4. Harmful substances 5. Exempted substances.

Education and training: In Ontario, an exterminator's license is required to permit work with these substances. Such a certificate is issued upon the completion of specific educational and training requirements. This training also introduces the candidate to the various stipulations involving the use of protective clothing, washing facilities, considerations around eating, drinking, and smoking, and restrictions on employment.

Protection of the Operator: Operating procedures for agricultural aviation should ensure the following to safeguard against occupational exposure to toxic chemicals: 1. Prevention of chemical handling accidents 2. Correct loading methods 3. Adequate protective clothing 4. First-aid when required 5. Prevention of Chemical Handling Accidents All personnel should train themselves in the observance of the following guidelines: Loading Methods, Adequate Protective Clothing, Medical Support for Agricultural Aviation

Agricultural aviation has inherent occupational risks that necessitate the provision of adequate medical services which should include:

- Medical supervision and surveillance on a continuing basis.
- Ongoing health education about chemical hazards, including their recognition, prevention, and treatment, is vital. Training should also cover other concerns such as the problems of drug interaction. Self-medication when handling agricultural chemicals must be avoided. Workers should also be educated on preventative health measures.
- Prearranged emergency treatment should be readily available as pesticide poisoning is an emergency medical condition. Pre-employment or pre-season physical examinations should be arranged and should include baseline cholinesterase levels on all personnel prior to exposure. Ideally, cholinesterase values should be obtained at weekly or biweekly intervals during the first month of each season. This will allow early intervention and prevention of illness.

Experience has shown that the greatest likelihood of overexposure occurs:

- At the beginning of the season, when inexperienced personnel begin handling chemicals for the first time.
- When a new pesticide is being introduced.
- During the first prolonged hot spell of the season. Hot, humid weather makes protective clothing and respirators uncomfortable to wear. Exposure is further complicated by the fact that dehydration can occur in these conditions.
- At the end of a long hard day (and especially towards the end of the season) when personnel become careless and may have already suffered mild exposure.
- Late in the season, especially if the workload has been prolonged and heavy. These workers may have experienced repeated small exposures to pesticides sufficient to cause some cholinesterase depression but not symptoms. It is these cumulative effects that can lead to symptoms of toxicity. Furthermore, equipment and protective devices which were functioning well earlier in the season may not be functioning optimally by this point.
- **Conclusion:** Relevant literature and research studies support the fact that occupational hazards to pilots and ground support staff exist in most areas of agricultural aerial spraying operations. In addition, the literature highlighted a number of other long term side effects from pesticide exposure which included:

- (Delayed) peripheral neuropathy
- cognitive deficits
- chloracne
- lung cancer
- liver disease
- sperm suppression and abnormalities
- porphyria
- lymphomas
- leukemia
- soft-tissue sarcoma
- immune suppression

Agricultural aviation is regulated, however, given the inherent risks and occupational hazards of top dressing and spraying operations it is impossible to eliminate all risk. Nevertheless, primary and secondary preventative measures, used in conjunction with effective mitigation strategies, will help reduce many of these problems. For a number of reasons that this paper has explored, many of the effective preventative strategies employed in this industry to control workplace hazards are impractical in aviation.Yet, chief amongst the strategies to counter these impracticalities include training and strict controls on application procedures, packaging, mixing, and the use of personal protective equipment. In conjunction with medical surveillance, many of the adverse effects associated with this hazardous occupation can be successfully mitigated. Another encouraging note though is that the industry is changing rapidly. Many of the chemicals that were applied in the past are no longer in use today. This has resulted in a safer environment for workers in all facets of agricultural aviation.