Chronic Pesticide Exposure in Farming: Risks and Solutions

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During the 1950s and 1960s a major trend towards replacing traditional methods of pest control with chemical pesticides occurred.[1] This development enabled increased crop yields.[2] However, it soon became apparent that pesticides were causing toxic effects to not only the targeted organisms, but to other organisms and the environment.[3]

Farmers are individuals who work with the direct application of pesticides and as a result, have the potential for chronic exposure. However, it is important to note that pesticide exposures are not limited to farmers and may also occur in the general population, as well as those working with lawns, golf courses, and right of ways.[4] Although, one study found that individuals exposed to pesticides were 14 times more likely to report farming as their occupation.[5]

As Naturopathic Doctors, this is an important consideration when treating farmers. Understanding what the risks of chronic exposure are and how these risks may be prevented or mitigated is an essential component of treatment. Similarly, it is important to know which tests may be used to help guide diagnosis, as well as possible treatment strategies.

Health Implications of Pesticide Exposure

There are a number of potential health problems associated with chronic pesticide exposure and numerous studies have been published. The following is a review of some common health outcomes, with many of the studies coming from the Agriculture Health Study (AHS). The AHS is an ongoing project involving over 89,000 commercial and private pesticide applicators and their spouses, mainly from North Carolina and Iowa, a significant number of those being farmers.[6]

Respiratory Effects

Farmers may be exposed to a variety of pesticides, many of which may be inhaled. Therefore, the impact of pesticides on respiratory health is important to address. Studies have been conducted to determine the prevalence of chronic rhinitis, bronchitis and asthma among pesticide users. For the majority of pesticides analyzed, there was no clear association between their use and risk of developing chronic rhinitis. However, six insecticides did show a significant correlation, including organophosphates.[7] A significant association between pesticide exposure and the prevalence of chronic bronchitis has also been shown to occur. In one study, the prevalence of chronic bronchitis increased with age and years living on a farm.[8] Another study found that high pesticide exposure doubles the risk of developing asthma, but generalized use does not.[9] However, other studies have found a link between asthma and generalized use.[10] It is possible that pesticide exposure negates the potentially protective effects of living on a farm. Studies looking at traditional dairy farms have found that exposure to increased microbial diversity as a result of living on these farms may have protective effects against asthma and allergies.[11] Further studies are required to determine if these benefits occur on other farms, including more modern factory farms.

Neurological Symptoms

The nervous system is another area of concern for farmers exposed to pesticides. One study that used questionnaires to capture lifetime exposure, found six organophosphate pesticides to be significantly associated with abnormal toe proprioception and four organophosphates significantly associated with postural tremor abnormality. The researchers concluded that there was a risk of developing peripheral nervous system abnormalities after long term use of organophosphate pesticides.[12]

Similarly, Parkinson's disease is strongly linked to a history of pesticide use. The pesticides rotenone and paraquat act as complex I mitochondrial inhibitors or oxidative stressors which are thought to play a role in the disease.[13] In a prospective cohort study of more than 140,000 people, the risk of Parkinson's disease was found to be 70% higher (adjusted relative risk, 1.7; 95% confidence interval, 1.2–2.3; $p = 0.002$) for those who were exposed to pesticides.[5]

Unfortunately, there are also a number of other nervous system disorders associated with pesticide use, including, but not limited to Alzheimer's disease, Amyotrophic Lateral Sclerosis, cognitive and psychiatric disorders.[14]

In Utero and Early-Life Exposure

Pesticide exposure during pregnancy and early childhood is a concern. Studies indicate a link between Attention Deficit

Hyperactivity Disorder, Autism, neonatal reflexes, as well as mental and psychomotor developmental implications with perinatal and early childhood exposure.[15,16] A number of animal studies indicate problems as well. Animal studies have found that when methoxychlor, a synthetic organochlorine, is given to rodents in early pregnancy, as well as neonatal or perinatal periods, that abnormalities may occur when adulthood is reached.[17] High does exposure of methylchlor during fetal and neonatal ovarian development in rats affected female offspring by accelerating the onset of puberty and first estrus, decreasing fertility and litter size, increasing cycle irregularity and leading to premature reproductive aging.[18] A lower dose, considered more environmentally relevant, induced non-significant cyclical irregularities as well as significantly affecting serum estradiol (E_2) and ovarian Anti-Mullerian Hormone (AMH) levels.[18] Preimplantation exposure may cause reproductive abnormalities in adult male mice by decreasing sexual arousal and altering seminal vesicle weights.[19] These studies indicate that pesticide exposure *in utero* or early in life may have adverse health consequences years ahead. However, not all human trials find adverse affects *in utero*. One study conducted in Salinas Valley California, found that no adverse affects other than shortened gestation with exposure to organophosphate pesticides,[20] whereas, another study conducted in New York found decreased length and birth weight associated with blood measurements of chlorpyrifos in pregnant women.[21] The differences may in part be attributed to different exposures as well as geographical variables, i.e., the New York study consisted of inner city minority populations which are high risk groups for adverse birth outcomes,[21] whereas the California study was based on an agricultural population.

Infertility

Reproductive health is another area of concern. One study found that 28% of the couples were infertile when both partners were involved in applying pesticides,[22] compared to 10-15% couple infertility in the general United States population.[23] Studies on male infertility have suggested that pesticides contribute to poor semen quality and altered semen parameters.[24] Similarly, a higher rate of miscarriages was found in females exposed to pesticides.[25]

Epigenetics

A number of animal studies indicate that transgenerational changes in gene function may occur when exposed to pesticides. For example, the fungicide vinclozolin, and the pesiticide methoxychlor, may cause subsequent generations to have spermatogenic defects.[26] Similarly, the pesticide permethrin may induce epigenetic inheritance of ovarian disease.[27] One study with rats found that females preferentially chose males where vinclozolin exposure three generations previous did not occur.[28] It is important to note that while we can't extrapolate results from rodents to humans directly, the same pesticides that affect animals may have epigenetic effects in humans as well.

Cancer

The overall incidence of cancer is lower among agricultural populations when compared to the general population. Despite the significant association between pesticide use and certain respiratory ailments, such as, asthma, bronchitis, and rhinitis, the rates of lung cancer are lower in farmers versus the non-farming population, and lower in farmers who smoke compared to smokers in the general population.[29] However, there are certain types of cancer that seem to be over-represented among farmers. These include: prostate, lymphohematopoietic cancer, and melanoma.[30] Farmers exposed to high levels of pesticides had a two-fold risk of prostate cancer compared to unexposed farmers.[31] A questionnaire based study on British Columbia farmers found a significant risk of prostate cancer with exposure to DDT, simazine, lindane, dichlone, dinoseb amine, malathion, endosulfan, 2,4-D, 2,4-DB and carbaryl.[32]

Farmers also have an increased incidence of ovarian cancer, lip cancer, diffuse large B-cell lymphoma, multiple myeloma, chronic lymphocytic leukemia, small lymphocytic lymphoma and mantle cell lymphoma.[33, 34] Whether this is attributable to pesticide use or not is uncertain, as farmers may be exposed to a number of potentially dangerous agents, such as welding fumes, solvents, engine fuels and exhausts, organic and inorganic dusts, mycotoxins, and viruses.

Lab Testing

When considering lab testing it should be recognized that all individuals are exposed to pesticides and carry some level of these toxins in their bodies.[35] Farmers are generally exposed to higher than average pesticide levels. Often chronological history of specific pesticides used, such as a good case history, can direct the physician as to which lab tests will provide the most information. The Center of Disease Control (CDC) has questionnaires for acute pesticide poisoning,[36] and the U.S Department of Health and Human Services has a questionnaire for exposure history.[37] A common pattern of neurotoxicity and immunotoxicity, possibly followed by endocrine toxicity has been proposed to suggest a toxic burden on the body.[35] If pesticide exposure is suspected, as is in the agricultural community, testing may be warranted. Unless otherwise indicated, the following lab tests may be ordered by an ND in Canada, and may be used for exposure or poisoning from chemicals found in pesticides:

Cholinesterase Tests: Acetylcholinesterase, RBC Cholinesterase, Butyrylcholinesterase, Plasma cholinesterase, Pseudocholinesterase

> Measures organophosphate exposure, a common component of agricultural insecticides. High organophosphate exposure can inhibit cholinesterase and pseudocholinesterase activity causing overstimulation of nerves within body tissues and organs and disruptions in the processing and metabolizing of certain medications.[38] (not available to NDs)

Hepatic Function Panel (Liver Function Tests): Alanine Aminotransferase, Alkaline Phosphatase, Aspartate Aminotransferase, Bilirubin, Albumin

> The liver is responsible for metabolizing and detoxifying drugs and other substances that are harmful to the body, such as pesticides. The Hepatic Function Panel is a group of tests that are performed together to detect, evaluate, and monitor liver damage.[38]

Kidney Function tests

> Creatinine may be decreased with pesticide exposure.[39]

Autoantibody testing:

> Gold immunochromatography assay strip test for detecting organophosphorous pesticides based on monoclonal antibodies.[40] (not available to NDs)

Complete Blood Count:

> To assess for signs of immunotoxicity; such as but not limited to, low red blood cell count, thrombocytopenia, leukopenia or neutropenia.[41]

Heavy Metals Panel: Arsenic

> Arsenic is used in certain pesticides and may be formed from exposure to pesticides and solvents.[41]

A number of individual pesticides can also be tested in clinical laboratories through the following biological matrices: blood, serum, plasma, urine, and fat,[42] many of which are not available to an ND.

Prevention and Mitigating Factors:

The first step in managing a patient with potential pesticide toxicity is the prevention of further exposure. This may pose a problem when treating the farming population. For the general population, avoidance can include avoiding living in or travelling through agricultural areas during spraying seasons, avoidance of areas where known pesticide spraying has taken place and finding out when neighbours or government agencies are planning to spray an area.[43] Washing and peeling fruits and vegetables, as well as eating organic foods or foods produced using integrated pest managment (IPM) practices is also recommended.[44]

However, for the agricultural community who farm for a living, and who rely on pesticide use, it is difficult to avoid environmental pesticide exposure. Therefore, it is important for farmers to wear protective clothing; such as, coveralls, apron, broad-rimmed waterproof hat, boots, rubber gloves, goggles or face shields, and respirators.[43] The fabric of these materials is important for adequate protection, and studies have shown that fluorocarbon finished fabric, or a coated nonwoven fabric such as Gore-Tex may provide increased protection against pesticides.[45] Health Canada states that all pesticides used in Canada must have a label which states the specific type of personal protective equipment that should be worn with each pesticide and it is imperative to follow the instructions.[46] It is also important for farmers not to eat, drink or smoke around pesticides, and to wash hands before undertaking these or other activities, which may increase the risk of ingestion or inhalation. When preparing pesticides, farmers should ensure there is adequate ventilation and that all livestock and people leave the area, especially those at higher risk; such as, pregnant mothers, children, elderly and the immunocompromised.[43] Pesticide users should also be aware of restricted entry intervals after pesticides have been applied and pre-harvest intervals, meaning the time between the last application and harvest. Finally, it is also important to store and dispose of pesticides properly to prevent contamination.[43] All private pesticide applicators in Canada are required to undergo specialized training and be certified in the proper use of pesticides.[47] It is important that these safety procedures be followed to protect farmers from the adverse health effects of pesticide use.

Supplementation

Secondly, supplementation of certain nutrients is indicated in cases of pesticide exposure or toxicity. This is essential to support the body's detoxification system and it aids to promote pesticide clearance from the body. Currently, there are limited clinical trials available that study the effects of Natural Health Products on humans with pesticide exposure. However, animal studies suggest efficacy of supplement treatment in humans.[48] Nonetheless, there is a need for more research using human subjects to definitely prove the efficacy of supplements in treating farmers with potential pesticide toxicity. Studies with rats have shown that the combined effect of selenium and vitamin E was effective in mitigating the oxidative damage of various pesticides, especially organophosphates, and at decreasing their levels in the body.[48] Similarly, studies on rats have also shown elevated plasma transaminases, lactate dehydrogenase activity and bilirubin levels were found in those exposed to pesticides and the co-administration of selenium and vitamin E improved these biochemical parameters and decreased liver damage associated with pesticide exposure.[49] Ascorbic acid or vitamin C supplementation, has also shown beneficial effects at promoting the detoxification of oxidative species in the body and may be most effective against organochlorine insecticides.[50] Likewise, when combined with garlic extract, vitamin C supplementation to male rats preconception or pregnant female rats, dampen the reproductive toxicity and teratogenicity caused by certain pyrethroid insecticides.[51]

Glutathione is another powerful defence that helps protect the cell against xenobiotics, intracellular oxidants and is necessary for lymphocyte function.[52] However, under normal physiologic conditions glutathione is produced intracellularly and is poorly absorbed into the cell,[53] making other means of raising glutathione other than direct supplementation of interest.[52] Supplementation with N-Acetyl cysteine (NAC) has been shown to increase glutathione levels in the body.[45] The research also suggests that the supplementation of vitamins E, C and selenium increase glutathione levels in the body which aids to decrease the toxin burden in the body.[52, 55, 56, 57]

Other studies show that zinc citrate supplementation decreases reactive oxygen species and lipid perioxidation in those exposed to high levels of organophosphate pesticides and increases glutathione levels to promote detoxification.[58] Combined, this results in an improvement in neurological and physical functioning in those with organophosphate pesticide toxicity.[58] Similarly, Docosahexaenoic acid (DHA), has been shown to protect against neurological and retinal damage due to organophosphate exposure. This is accomplished by preventing apoptosis in retinal and other neurons.[59]

Liver detoxifying botanicals should also be included as part of a treatment plan for an individual with significant pesticide exposure. Of these, the most widely used and researched is Milk Thistle or Silymarin. A systematic review found that Milk Thistle supplementation clearly demonstrated antifibrotic, antioxidant and metabolic hepatic effects. All of which would benefit those exposed to pesticides.[60]

It is also important to restore common pesticide-induced deficiencies and prevent tissue damage from these compounds. Decreased hepatic stores of vitamin A were found in rats exposed to organochlorine pesticides. These rats also experienced growth retardation, endocrine organ deformities and had elevated levels of liver enzymes indicating toxicity. Restoring vitamin A levels through supplementation resulted in significant protection against toxicity, a decrease in physical abnormalities and an increase in the hepatic xenobiotic metabolizing enzymes, that promote pesticide clearance.[61] Various studies demonstrate a beneficial effect of thiamine supplementation for thiamine deficiency due to organochlorine pesticide exposure. This was evidenced in a decrease in early mortality syndrome in salmontids in the Great Lakes of North America as well as alligator embryo survival in southern United States.[62, 63]

From a dietary perspective, adequate protein and reduced sugar intake improves liver clearance of toxins from the body. Specifically, whey protein increases glutathione and provides a complete protein to the body. Therefore, whey protein can enhance liver function to promote detoxification.[35]

Physical Therapy

Naturopathic physical therapy treatments that may be beneficial for decreasing pesticide levels in the agricultural population includes infrared saunas, hydrotherapy, dry skin brushing and castor oil packs.[64] Infrared saunas act to mobilize toxins and increase circulation. This increases the elimination of toxins through perspiration.[64]

Contrast hydrotherapy improves circulation and immune system function to remove toxins.[65] Dry skin brushing encourages waste removal and increases blood and lymph flow to promote detoxification.[65] Finally, castor oil is a powerful anti-inflammatory. When castor oil is absorbed through the skin, it promotes increased circulation, elimination of toxins, and healing of organs. In cases of pesticide toxicity, castor oil packs should be placed over the liver to maximize the detoxification effect.[53]

Conclusion

Farmers are at risk of developing a number of diseases from chronic pesticide exposure. Of the risks reviewed in this paper, it was found that respiratory ailments, neurological ailments, cancers and reproductive consequences exist. The research is largely observational and not without limitations, but the experimental evidence from animals backs up some of the findings. Further research is needed to better understand how pesticides affect humans and how great the increased risk for certain diseases are,

so that improved treatment strategies and safety protocols can be developed. However, because the association with various disorders does exist, it is very important that currently established precautionary measures be adhered to.

If exposure to pesticides is suspected, a number of lab tests are available that may help to direct treatment. Choosing a lab test will depend on which pesticides a patient has potentially been exposed to, and on which organs are thought to be affected.

Naturopathic Doctors can support farmers who may be chronically exposed to pesticides through supplementation and physical therapies. Research supports the use of selenium, vitamin E, vitamin C, garlic extract, NAC, zinc, DHA, vitamin A, and thiamine. However, it should be noted that the majority of research on supplementation involves animal studies and human research is lacking. More research is needed to better understand how and when to use particular supplements in humans However, healthy diet and life-style practices in combination with Naturopathic physical therapies are likely to be beneficial.

In conclusion, it is clear that farmers have an increased risk of developing several adverse health effects from using pesticides. As Naturopathic Doctors, it is our responsibility to be aware of these risks and to utilize effective treatment protocols to improve the health of the farming population and others exposed to high levels of pesticides.

About the Authors

Dr. Brian Casteels, ND is a graduate of the Canadian College of Naturopathic Medicine, and currently practices in Trent Hills Ontario, as a Naturopathic Doctor. He treats a variety of concerns and utilizes various Naturopathic modalities. Brian has a strong interest in helping patients develop a sense of awareness as a key rebalancing tool. He also writes regular articles for the Community Press.

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QUICK KEY:

SUPPLEMENTS INDICATED FOR PESTICIDE EXPOSURE

Selenium + Vitamin E mitigates oxidative damage.

Vitamin C promotes detoxification of oxidative species.

Vitamin C + garlic extract may decrease reproductive toxicity.

Glutathione (i.e increasing levels via supplementation of vitamins E, C, selenium and NAC) promotes detoxification of pesticides.

Zinc Citrate may improve neurological and physical function by reducing oxidative damage associated with pesticide exposure.

Docosahexanoic acid (DHA) protects against neurological and retinal damage.

Silymarin is protective via antifibrotic, antioxidant and metabolic hepatic effects.

Vitamin A and Thiamine supplementation if deficient, protects against the toxic effects of pesticides.

Whey protein in general may enhance detoxification by promoting glutathione production.

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