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Exploration of potential exposure to neonicotinoids in seed treatment and handling

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EXPLORATION OF POTENTIAL EXPOSURE TO NEONICOTINOIDS IN SEED TREATMENT AND HANDLING

by

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CERTIFICATE OF APPROVAL

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MASTER'S THESIS

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This is to certify that the Master's thesis of

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the thesis requirement for the Master of Science degree
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This thesis is dedicated to:

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ABSTRACT

Agriculture consistently remains one of the most hazardous industries. Hazards exist not only on farms, but also within pesticide manufacturers and distributors. Treating seeds with neonicotinoid insecticides is an important strategy to address pest problems. Neonicotinoids are a systemic insecticide that transfuse throughout the entire plant from roots to pollen. While research on the environmental effects of neonicotinoids is growing, research examining the potential adverse effects on humans is in its beginning phases. This pilot project provides an overview of the potential points of neonicotinoid exposure for manufacturers, distributors, and farmers who use seeds coated with neonicotinoid pesticides.

A descriptive, cross-sectional study design was used to collect information characterizing occupational neonicotinoid insecticide handling practices at three different work environments: manufacturers of treated seed, distributors of treated seeds, and at farms where neonicotinoid treated seeds are planted. Potential participants were identified through internet searches of Iowa seed treating facilities and neonicotinoid treated seed distributors as well as snowball sampling for identification of farmers who used neonicotinoid treated seeds.

Participants were interviewed at each worksite. Data were analyzed qualitatively by using a grounded theory approach to examine the written questionnaire responses, field notes, and photographs. The data were relatedly evaluated to identify themes, similarities, and differences between each work environment. Also, these facilities were examined for safety hazards associated with neonicotinoid insecticides during the tasks being accomplished at each site.

The seed treatment sites visited during this project varied greatly in facility size, number of employees and building age. Larger facilities were more likely than semitrucks small facilities to report safety as a priority, and the age of the facility did not seem to affect the chance of exposure to neonicotinoids. The seed distributors studied during this project varied greatly in numbers of full-time and types of safety policies. The most thorough safety policies included an Emergency Action Plan, many different SOPs, yearly safety training, and having the seed treating equipment recalibrated at the start of each season. In addition, most distributors, at a minimum, wore gloves. All the farm workers interviewed planted corn and soy beans and used almost no PPE, with the exception of one farmer who reported wearing gloves while handling treated seeds.

This pilot study provides suggestive evidence for a high potential of neonicotinoid exposure to workers at varying work environments. In order to quantify the range and magnitude of neonicotinoid exposures, future studies are needed that 1) expand the scope of the work environments examined; 2)

comprehensively measure neonicotinoid concentrations in all potential exposure (e.g., inhalation, ingestion, dermal) pathways; and 3) perform biomonitoring of neonicotinoids.

PUBLIC ABSTRACT

Annually, agriculture remains one of the most hazardous industries. These dangers exist not only on farms but within pesticide manufacturers and distributors. Treating seeds with neonicotinoid insecticides is a vital strategy to address pest problems. Studies describing the environmental effects of neonicotinoids are abundant, however, limited research has been published that examines either human exposure to neonicotinoids or potential adverse health effects related to neonicotinoid exposure. This pilot project provides a snapshot of the handling process of neonicotinoids from production to planting and highlights observed occurrences when manufactures, distributors, and farmers are potentially being exposed to neonicotinoids.

A questionnaire was used to determine occupational neonicotinoid insecticide handling practices at three different work environments: manufacturers, distributors, and farms. Data were analyzed by examining the questionnaire responses, field notes, and photographs. The data were reviewed to identify themes, similarities, and differences between each work environment.

The seed treatment sites varied greatly in number of employees and building age. Although, the year the building was constructed did not seem to affect the potential of exposure to neonicotinoids. Larger facilities appeared to prioritize safety. The seed distributors varied greatly in number of full-time personnel and degrees of safety policies. Most employees at a minimum wore gloves. All the farms interviewed planted corn and soybeans and used almost no PPE.

This pilot study provided suggestive evidence that workers at varying work environments had the potential for neonicotinoid exposure. Future studies are needed that more fully describe the actual range and magnitude of neonicotinoid exposure.

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CHAPTER I: INTRODUCTION

HISTORY AND OVERVIEW OF PESTICIDE USE

The practice of agriculture began more than 10,000 years ago in the Fertile Crescent of Mesopotamia, parts of present day Iraq, Jordan, Syria, and Turkey. From the beginning, it was evident that domesticated crops were exposed to pests and disease, resulting in a significant loss in crop yield. Consequently, famine was continuously a risk for these populations[1].

Approximately 4,500 years ago Sumerians became the first population known to use an insecticide to increase food yield by decreasing pests. The Sumerians' insecticide was comprised of sulfur compounds. Writings from ancient Greece and Rome also show the use of smoke to fight mildew and insects. Other noted insecticides were tar and pyrethrum, which are derived from dried flowers of *Chrysanthemum cinerariaefolium.* Salt or sea water were also commonly used to deter weeds [1]. By the early 20th Century, arsenical compounds were used as pesticides, causing many agricultural workers to become ill or die from exposure [2].

Prior to the 1940s, ancient pesticide products were still in use, and newer by-products of coal gas production or other industrial processes were also becoming common during the first half of the 20th century. These extremely toxic "first generation" pesticides largely consisted of arsenic or hydrogen cyanide [2]. First generation pesticides were heavily used with little consideration of the consequences they may have on the present and future wellbeing of humans and the environment [1, 2].

By the 1940s, a thriving new chemical industry also contributed new compounds with multiple uses, including pesticides. These new chemicals known as "second generation" pesticides were comprised of synthetic organic compounds. Due to their high efficacy, in that they worked well to eradicate pests, food prices decreased and the lack of documented illness attributed to these new compounds made "second generation" pesticides the favorable choice over options prior to the 1940s [1, 2].

In 1947, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) was passed [3]. FIFRA was the beginning of U.S. pesticide regulations that protect applicators, consumers, and the environment. The Environmental Protection Agency (EPA) pesticide law defines a "pesticide" (with certain minor exceptions) as: "any material or combination of substances intended for deterring, terminating, averting, or mitigating any pest; any material or combination of substances intended for use as a plant defoliant, regulator, or desiccant; any nitrogen stabilizer" [4].

Despite assumptions of improved safety, one notorious "second generation" pesticide is Dichloro-Diphenyl-Trichloroethane (DDT). Synthesized in 1874, DDT had no practical use until Dr. Paul Muller made an extraordinary development during WWII. He discovered DDT's insecticidal efficiency and received the Noble Prize for Medicine in 1948 [1, 5]. DDT seemed to be a miracle; it was economical to manufacture, simple to apply, exceptionally effective at decreasing the rate of insect-born disease, and appeared to have a low toxicity for mammals [1].

Around the same time that Muller discovered the effectiveness of DDT, a German company called I.G. Farben led the development of an entirely new class of organophosphate pesticides (OPs). Several of these insecticides are highly toxic. In recent years, the use of numerous OPs has been discontinued. All OPs cause cholinesterase inhibition and have the potential to cause acute or subacute toxicity in humans. However, the extent of toxicity varies between the compounds [6].

The perceived risk of pesticide use began to shift after scientist Rachel Carson published *"Silent Spring*" in 1962. She described the dangers of chemical pesticide use and predicted massive devastation of the planet's delicate ecosystems unless something was done to stop what she named the "rain of chemicals". Carson's emphasis was on chlorinated hydrocarbons, such as DDT. She suggested there was a connection between chlorinated hydrocarbon use and the death of non-target species through direct and indirect toxicity. Chlorinated hydrocarbons have a direct toxic effect on juveniles in multiple species. They are also exceptionally persistent, lingering in the environment for remarkably extensive periods of time and traveling lengthy distances in water, through the air, or carried by animals. Consequently, chlorinated hydrocarbons bioaccumulate within an organisms' tissues and undergo biomagnification throughout the food chain [2].

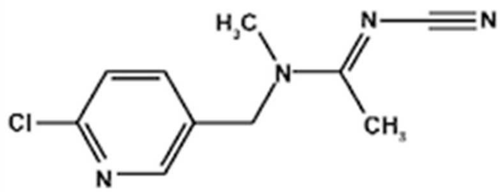
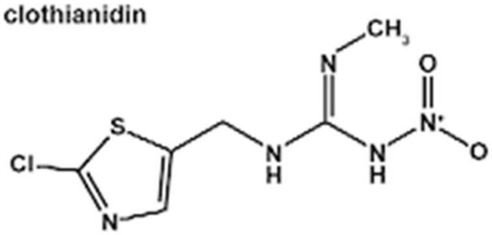
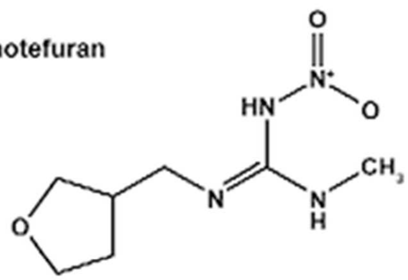
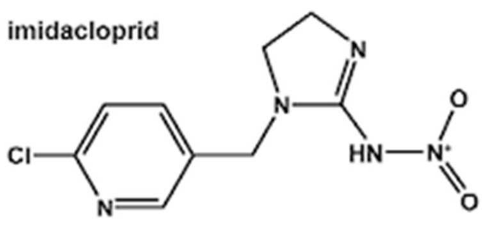
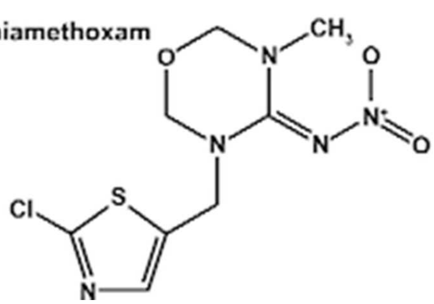
A notorious example of biomagnification is the case of the Bald Eagle. As the concentration of chlorinated hydrocarbons amplified up the food chain, Bald Eagles became so severely contaminated that their reproduction was compromised. The breakdown product of DDT is Dichloro-Diphenyl-Dichloroethylene (DDE). DDE caused the eagles' eggshells to become considerably thinner and consequently crack during incubation, severely decreasing the population and putting it at risk of extinction [2].

Not only was DDT determined to be a reproductive hazard, mammals exposed to DDT during scientific research developed liver tumors. Consequently, DDT was categorized by the EPA as a B2 carcinogen (i.e., data from animal studies suggest it is a probable human carcinogen) and was banned in the United States. The only exception of use being a severe public health emergency concerning vector diseases and the control of body lice. DDT is still produced in the United States, however, only foreign nations can buy and use the product [5].

RECENT TRENDS IN NEONICOTINOID USE IN US AGRICULTURE

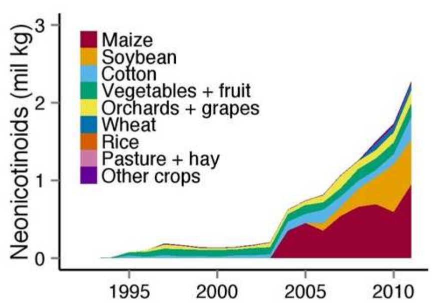
The first neonicotinoid, imidacloprid (IMI), was discovered by Shinzo Kagabu. Shinzo modeled his insecticide on nithiazine, a largely abandoned compound. In 1985 he first prepared IMI while working as a researcher for present day Bayer CropScience in Japan [7]. Currently, the most frequently used neonicotinoids in U.S. agriculture are: thiamethoxam (THX), clothianidin (CLO), imidacloprid (IMI), and acetamiprid (ACE)[7]. Neonicotinoids (neonics) are effective insecticides because of their neurotoxic action on the nicotinic acetylcholine receptor (Figure 1) [8]. Created to replace hazardous OPs and carbamate insecticides, neonics are systemic in design, transfusing into all parts of the plant, including nectar, pollen, and the fruits produced by those plants [7, 9, 10]. They are now used for pest management in hundreds of crops in horticulture, agriculture, and forestry. Additionally, they are used in aquaculture and timber conservation, as vector control treatments for livestock and pets, and in urban and household pest control products [10, 11]. They are highly effective against difficult to control boring, sucking, and root feeding insects such as glassy-winged sharpshooter [9].

Figure 1. Chemical structures and properties of common neonicotinoid insecticides[12]

Common Name	Properties
acetamiprid 	Solubility in water: 4.25 g L^{-1} (25°C) Vapor pressure: 4.4 x 10^{-6} mm Hg (25°C) Octanol-water partition coef. (log K_{ow}): 0.8 (25°C)
clothianidin 	Solubility in water: 0.327 g L^{-1} (20°C) Vapor pressure: 9.8 x 10^{-10} mm Hg (25°C) Octanol-water partition coef. (log K_{ow}): 0.7 (25°C)
dinotefuran 	Solubility in water: 54.3 g L^{-1} (20°C) Vapor pressure: 1.3 x 10^{-8} mm Hg (25°C) Octanol-water partition coef. (log K_{ow}): -0.644 (25°C)
imidacloprid 	Solubility in water: 0.62 g L^{-1} (20°C) Vapor pressure: 7 x 10^{-12} mm Hg (25°C) Octanol-water partition coef. (log K_{ow}): 0.57 (21°C)
thiamethoxam 	Solubility in water: 4.1 g L^{-1} (25°C) Vapor pressure: 4.95 x 10^{-11} mm Hg (25°C) Octanol-water partition coef. (log K_{ow}): -0.13 (25°C)

The use of neonicotinoids in U.S. agricultural production has increased significantly in recent years. In 2010, approximately 20,000 tons of the active substance imidacloprid was produced [13]. An article published by Pennsylvania State University included a graph, which shows that between 1995 and 2010 the use of neonicotinoids increased from a little above zero mil/kg on few fruits and vegetables to over mil/kg on multiple crops (Figure 2). Neonics are most commonly applied as a treatment to seeds prior to planting; however, they can also be applied after planting as a drip, broadcast, or foliar spray. The sale of seeds pretreated with neonics tripled from 2004 to 2014. Currently, half of soybeans and more than 90% of all corn are grown from seeds treated with neonics. They are not only used on those two crops but also on cereal crops, oil crops, fruits, and vegetables. Annually in the United States, approximately 4 million pounds of neonics are applied to between 140 and 200 million acres of farmland [14]. In Iowa, the nation's top producer of corn and soybeans, neonics are used throughout the state.

Figure 2. Neonicotinoid (mil/kg) Use from 1995-2010[15]



ENVIRONMENTAL EFFECTS CAUSED BY NEONICOTINOIDS

In the last century agriculture in the United States has intensified and expanded, producing higher crop yields for an increasing population to feed around the world. The high yields, however, have not come without a high cost. Environmental degradation caused by habitat loss and extensive pesticide use have produced substantial destructive consequences for wildlife. The continuous global decline of pollinators is disconcerting due to the vital role pollinators perform in ecological systems and crop productivity. Around ten years ago, beekeepers first indicated there was an increase in the normal rate of colony mortality. This phenomenon was then named Colony Collapse Disorder (CCD) and incited research worldwide. Climate change, nutrition, parasites, pesticides, pathogens were determined to be the potential cause of the phenomenon. Pesticides however are a consistent factor; numerous studies have established neonicotinoids' detrimental properties at both individual and colony level [16].

Neonicotinoids are a systemic insecticide, translocating the active ingredient throughout the entire plant. Pollen is the main protein and lipid source for bee colonies and a fundamental part of the nurse bees' and larval diet. Therefore, contaminated pollen results in exposure of the new generation bees, as well as the workers (female) and drones (male). Low levels of pesticides can elicit harmful effects on bees, not killing them but affecting their behavior and immune system. Italy restricted three major neonicotinoids, imidacloprid (IMI), clothianidin (CLO), and thiamethoxam (THX), use in 2009 due to their side-effects on honey bee health and the EU followed in 2013. The restriction prohibits the use of IMI, CLO, and THX in seed treatments, soil treatments, or spray treatments before and during flowering and on crops attractive to bees. However, a study conducted in Italy from 2012-2014 sampling pollen from honeybee hives demonstrated that neonics can be very persistent. IMI and THX were detected in pollen samples consistently within the three sampling years. Seventeen percent of the samples in total were contaminated with neonics. IMI concentrations were higher than the maximum Hazard Quotient levels (HQ > 1000) in 12% of its positive samples [17]. According to the EPA a HQ is defined as "the ratio of the potential exposure to the substance and the level at which no adverse effects are expected"[18].

Neonicotinoids are semi-persistent in the environment. They have been found in dust, wetlands, ground water, non-target plants, and foods common to the American diet, including wild and aqua cultured marine species [17]. Neonics' negative consequences on the environment and their water solubility are concerning for humans because of potential contamination of groundwater. This is of utmost concern for those who obtain their drinking water from wells, especially ones located on or in close proximity to a farm using neonic insecticides. In 2012, the FDA reported neonics were among the most commonly detected pesticide residues in toddler and infant foods. Since neonics transfuse throughout the plant entirely, they cannot be washed off food prior to consumption. In 2012 a study, researchers purchased 29 different variations of produce and organic honey from grocery stores in Boston and examined them for neonics. The study detected multiple neonics in seven apple varieties, oranges, cantaloupe, spinach, and in five organic honey samples [8, 19]. In 2013, the USDA annual pesticide monitoring report found 11 of 17 fruits and vegetables sampled were contaminated with neonicotinoids; two contained multiple neonics [11]. In 2014, the United States Department of Agriculture (USDA) detected neonics in 12 of 19 varieties of fruits and vegetables sampled; 11 contained multiple neonics [20].

MAMMALIAN HEALTH EFFECTS CAUSED BY NEONICOTINOIDS

The EPA approved neonicotinoids for commercial use because they were considered less toxic to wildlife and humans than organophosphate pesticides. This was assumed because of a higher chemical affinity for insect nicotinic acetylcholine receptors and an inability to cross the mammalian blood-brain barrier, therefore neonicotinoids potential to harm mammals is minimized. Studies essential for pesticide registration showed neonics to be less toxic to mammals than to insects. However, an increase in cancerous liver tumors in mice was reported, supporting the EPA's establishment of maximum residue limits (MRL) for the primary neonics used in American agriculture: thiamethoxam (THX), clothianidin (CLO), imidacloprid (IMI), and acetamiprid (ACE) [21]. Although the research remains limited, in vivo and vitro studies of mammals are reporting that neonics may be more dangerous than previously thought. Neonics may have a negative impact on many systems in the body and may be particularly hazardous for children [8, 22-25].

Hepatotoxicity

A study examined the hepatotoxicity of neonics by assessing the liver histological changes and enzyme activity in female albino rats exposed to a high ($1/10^{th}$ LD50) and a low ($1/50^{th}$ LD50) dose of imidacloprid for four weeks. In the higher dosed group, histological alterations involved a rise in liver enzymes, degeneration of hepatocytes, and dilations of the central vein. These results suggest that at $1/10^{th}$ the LD50 of imidacloprid is hepatotoxic as compared to the low dose [8, 14, 26].

Neurotoxicity

Certain neonic metabolites have been found to be more toxic to mammals than their parent compounds [27]. One example is desnitro-imidacloprid one of IMI's breakdown products and is acknowledged to be highly toxic to mice. Desnitro-imidacloprid has a high affinity for mammalian nicotinic acetylcholine receptors [7, 9, 11]. Desnitro-imidacloprid can be formed either in the mammal during the breakdown of IMI or in the environment [28]. Neonics affect mammalian nicotinic acetylcholine receptors resembling the effects of nicotine [29]. These receptors are vital for human brain function, particularly during development, and for behavior, cognition, and memory [30]. A distinct characteristic of neonic toxicity is the ability to bind to the most important subtype of nicotinic acetylcholine receptors in mammals, the $\alpha4\beta2$. The $\alpha4\beta2$ is in greatest concentration in the thalamus [11, 30]. In several central nervous system disorders, including Alzheimer's disease, depression, Parkinson's disease, and schizophrenia it has been found that the alteration of the concertation of the neuroreceptor $\alpha4\beta2$ plays a role in developing a central nervous system disorder. This subtype is involved in many steps in brain development including: apoptosis, differentiation, neural circuit formation, neural proliferation, and synapse formation [11, 31].

Other studies have shown neurotoxic effects caused by neonic exposure as well. Studies on rats dosed orally with high levels of imidacloprid for 28 days showed significant reduction in pain threshold and spontaneous locomotor activity. Rats dosed with high levels of thiamethoxam for seven consecutive days showed an increase in anxiety behavior as well, and this may be correlated with a decrease in acetylcholinesterase activity [11]. When compared to controls after being dosed with 24 mg/kg of clothianidin, an infant rat had significant deterioration of cognitive functions [32].

Reproductive Toxicity

Studies have found adverse reproductive and developmental effects in mammals exposed to neonics, including higher rates of embryo death, premature birth, reduced pregnancy rate, reduced sperm production and function, reduced weight of offspring, and stillbirth [22-24].

A systematic review examining neonic poisonings reported that cardiovascular effects were a rare but possible serious clinical outcome of acute neonic exposure. Two of the three studies reviewed reported acute neonic ingestion produced symptoms similar to acute organophosphate or carbamate poisoning. Both previously mentioned studies warned the antidotes for OPs (oximes and atropine) should not be used as a treatment for neonic poisonings as they may exacerbate health outcomes. One study reported that concentrations of IMI remained raised for up to 10-15 hours post-ingestion, signifying humans have a high absorption and slow elimination ability for high doses of IMI. This reaction is concerning because high concentrations of IMI can remain in the system potentially causing damage. A chronic exposure study [14] reported a significant connection between IMI exposure during early pregnancy and tetralogy of Fallot, a congenital heart defect, (AOR 2.4, 95% CI:1.1,5.4) and between urinary N-desmethyl-acetamiprid (a metabolite of acetamiprid) and an increased prevalence of neurologic symptoms. A suggestive association between IMI and anencephaly was also reported (AOR 2.9, 95%CI:1.0,8.2) [14].

Human Studies

A systematic review conducted on the effects of neonicotinoid pesticide exposure on human health found a multitude of adverse outcomes due to chronic and acute exposures. Common adverse outcomes from chronic exposure were developmental or neurological issues, including autism spectrum disorder, tetralogy of Fallot, anencephaly, memory loss and finger tremor[8].

Neonics are chemically similar to nicotine. Along with lung dysfunction, nicotine is known to cause gastrointestinal, pancreatic and breast cancer as well as cause negative effects on the cardiovascular, respiratory, gastrointestinal, immunological, ocular, renal, and reproductive system (both male and female) [32]. Therefore, it would be beneficial for more research to be conducted in this field.

A study comparing 25 non-spraying control farmers and 89 pesticide sprayers who used neonics in southeastern Spain reported a suggestive relationship between neonicotinoid application and lung dysfunction. The lung disfunctions included lower total lung capacity, residual volume, and functional residual capacity [8]. A study conducted in Japan detected levels of urinary neonicotinoids in 95 women between the ages of 45-75 from 1994- 2011. During this time the geometric mean concentrations of total urinary neonicotinoid continually increased (0.05 in 1994, 0.32 in 2000, 0.46 in 2003, 6.92 in 2009, and 12.83 in 2011) [33].

Another study conducted in Japan on 3-year old children used biomonitoring of the urine to determine which children had neonicotinoids, OPs, and pyrethroids in their system. Out of the 223 children monitored 80% had at least one neonicotinoid in their system. The highest detection rates of total urinary neonicotinoids in the children were 58% for dinotefuran; all other neonics were below 30% [34]. Another study found that mothers’ residential proximity to imidacloprid usage was positively associated with anencephaly [25]. Anencephaly is a birth defect in which infants are born without parts of the brain and skull [35]. Nicotine is known to cause negative effects on the fetus and children, therefore, it is unsettling that children have concentrations of neonics in their system when they never worked around the insecticide.

SEED TREATMENT

Treating seeds is a method that has been utilized for more than 4,000 years. The earliest reported use was in 60 A.D., when crushed cypress leaves and wine were used to shield seed from storage pests. However, the technology has improved dramatically since then. In 1948, a new fungicide was discovered named captan. In 1950 it was introduced as a seed treatment and was rapidly adopted for various crops including corn. Captan was applied to seed corn at a rate of 350 to 750 parts per million, an enormous amount compared to current application levels around 25 ppm [16, 36]. A substantial amount of pesticide dust was created and dispersed when transferring seeds from the treatment plant to the farm [16, 36]. Seed treatment coatings now use a polymer to ensure the pesticides stick to the seed and protect the seed during shipping and planting [16].

The first neonicotinoid insecticide was registered by the EPA in 1994. The introduction of neonicotinoids changed the seed industry and farmers' perception of precision seed treatment technology. Farmers began to realize the significance and capabilities of seed treatment products [16, 36]. The combination of neonicotinoids and fungicides used with a seed treatment polymer coating created a product with a new standard of seed and seedling protection. Using this new combination resulted in faster and earlier planting, healthier plants, more uniform emergence, larger crop populations, less insect damage, and higher crop yield [16].

Ignoring the potential for loss of seed coating once planted due the water soluble nature of neonics, treated seed is generally considered a more environmentally friendly way of applying pesticide since the chemicals are precisely placed on the surface of the seed, reducing the need to apply pesticides throughout entire fields [16, 37]. Seed treatment eliminates off-target spray drift pesticide exposure for both humans and animals [16, 19]. Treating seed also reduces input costs for farmers because the precise application of pesticide products to the seed itself replaces the need for broad- area crop spraying. By not handling a liquid chemical, pesticide drift is minimized and the crop producer's airborne exposure to the pesticide is reduced [38].

Seed treatments provide important protection against pests; however, they must be followed with additional forms of crop protection [19]. Seeds treated with insecticides form a protective barrier around the seed and root zone. Even at minimal rates of application, insecticides can be very effective against soil insects [39]. Systemic insecticides such as neonicotinoids, which move into the plant during germination or through root uptake, control against various soil and foliar feeding insects. As target insects feed on the crop, they ingest the insecticide either rendering them inactive so they stop eating the plant or killing them [40]. The period of effective control for systemic insecticide depends upon the dose applied to the seed and the sensitivity of the target insect species. As the plant matures the concentration of the insecticide in the plant declines, eventually to the point in which it has no protective effect [16, 19].

Polymers are used to adhere pesticides to a seed, producing a protective barrier and minimizing pesticide dust as the neonic solution dries. The success of the insecticide's active ingredients relies heavily on the polymers. Polymers have multiple functions including: ensuring the active ingredients stick to the seed, preventing the formation of pesticide dust, reducing friction of seed, minimizing abrasion to reduce loss of active ingredient, and refining planting accuracy by making the seed more consistent in shape and size [16].

Typically, neonics are applied to the seed as a liquid. However, once the insecticide dries, particles often break loose creating dust. Dust drift is defined as the amiss movement of pesticide dust throughout or directly after the application predominantly under the influence of air currents [8]. Aspects that determine the extent of dust drift include, design and setting of the drills, mass and size of particles, quality of seed coating, meteorological conditions, and morphological properties of dust particles [41]. Pesticides can contaminate the air through seed drilling, natural disasters and manufacturing, accidents, the application process, and can be found in homes up to 3700 feet from treated fields [42]. Wind-eroded soils tainted with organic chemicals are a significant source of contamination for off-target environments [41, 43, 44]. Significant quantities of the blended pesticide dust that contaminates homes collects in the carpet where young children are at a considerably greater risk of inhaling the pesticide dust than adults are. The dust gathers in homes through wind drift and workers transporting particles home on clothing and skin [19, 45, 46].

Seed treatment application technology over the years has developed from using ounces per hundred pounds of seed to treating each individual seed with a precise number of milligrams of treatment. The earliest mechanized treating systems used batch machines; these can still be found in seed treating facilities. When using a batch machine, a specific weight of seed would be placed in a rotating drum with mixing baffles. The seed would then be sprayed with a measured amount of treatment. Several different sized screen liners could be used to accommodate for various sizes and types of seed [16].

Following the batch machine was continuous coating machines. Continuous coating machines are still commonly used in the industry. They can accommodate tremendous quantities of seed at a time (e.g. <50,000 Ibs. of corn per hour). Continuous coating machines are an improvement over batch machines because they are able to adjust the quantity of product applied and regulate phased, sequential applications of numerous products. Seeds vary by size and weight, for example, one pound of soybean seed could contain 2,400 to 3,600 seeds. Therefore, different quantities of treatment may be required for different batches of the same type of seed. Continuous coating machines are cylindrical and hollow allowing the seed to rotate in the machine while it is being coated with treatment [16].

Currently, computerized closed systems are the most advanced form of seed treatment technology. These systems are capable of calculating the total product application rate for every batch of seed, can precisely modify the seed and treatment flow, and can make adjustments for each new batch of seed [16].

During the seed treatment process, facilities often send out samples of their seed to labs to undergo quality testing. Seed quality assessments include physical, physiological, and genetic tests for vigor and viability. The Association of Official Seed Analysts has numerous tests of seed vigor including: cold stress, seed viability, seedling growth rate, and accelerated aging [16]. Each seed company decides which tests it would like conducted; however, the two most common are accelerated aging and cold tests [47].

ADDRESSING THE GAP IN RESEARCH

Since the 1990s the use of neonicotinoids across the globe has been continually and rapidly increasing. Conversely, the amount of research done on neonicotinoids and human health has remained stationary. Although numerous studies have been conducted on animals both in vivo and vitro, there is still a need for further research on human health. A large portion of neonicotinoids used are in seed treatments and are considered to lower the exposure to crop producers when compared to foliar application methods because there is no liquid application and minimal exposure to pesticide dust [33]. However, there is minimal research on employees who are exposed to treated seeds during the treatment process and on-farm handling. The workers that need to be considered are employees working in a seed treating facility and distributors of the treated seeds. Although seed treatments are thought to be safer for farmers because they eliminate liquid spraying of neonicotinoids, there is limited research assessing the potential for exposure during seed handling and planting. The goal of this pilot project was to perform a preliminary review of the potential for human exposure to neonicotinoid pesticides and gain insight on potential neonicotinoid exposure during the manufacturing, distribution, and planting of treated seeds. The aim is to describe the handling process of neonicotinoids throughout their life-cycle and determine the points when manufacturers, distributors, and farmers are potentially being exposed to neonicotinoids. This study will aid in the development of future quantitative exposure assessments.

CHAPTER II: METHODOLOGY

INTRODUCTION

According to 2016 data from Bureau of Labor Statistics (BLS) agriculture remains one of the most hazardous industries to be employed [19, 48]. Hazards can be found beyond the farm and throughout the entire industry including seed treatment facilities and distributors. Within the different sectors of agriculture there are numerous categories of employees who are exposed to various hazards depending on the task. A major hazard these populations have in common is pesticides. Pesticides are vital for modern agriculture, and move through a manufacturing and distribution process before arriving at the farm. Pesticides can be utilized in multiple forms depending on the crop, including liquid or solid form, as well as on treated seeds.

Treating seed with neonicotinoids is an important strategy to address pest problems and increase crop yield. In the last few decades there has been considerable growth of seed treatment use for distinct reasons. The way current economics are in the agriculture industry farmers plant earlier in the season in soils that are often wet and cold to maximize production and it is essential for every seed to grow and flourish to make a profit [49]. Once a seed is planted there is no rescue treatment to control for below-ground pests, therefore seed treatment is crucial to protect the seed from early seasons pests.

Neonicotinoids are a key class of insecticides that protect seeds early in the season. Following germination, neonicotinoid molecules are promptly taken up by the roots of the plant and carried into the cotyledons. Insecticide is transfused throughout the plant, remaining persistently active, which makes neonicotinoids preferable to non-systemic insecticides for use as a seed treatment [16]. Neonicotinoids are also favorable to other insecticides because they control a wide variety of insects, do not impair germination and growth rate of treated seed, improve plant vigor, and increase yields [16].

Environmental effects of neonicotinoids have been reported in multiple studies. These studies show persistence in the environment and hazards to non-target species of both insects and plants [8, 11, 16, 17, 19, 20]. However, few studies have investigated neonicotinoid exposure in humans and even fewer examined occupational exposures [8, 25, 34]. Therefore, the goal of this project was to assess the potential for human exposure to neonicotinoid pesticides and gain insight on neonicotinoid exposure from the manufacturer, to the distributer, and the farmer. The first aim is to describe the handling process of neonicotinoids throughout their life-cycle. The second aim is to determine the points when manufacturers, distributors, and farmers are potentially being exposed to neonicotinoids.

METHODS

Study Design

A descriptive, cross-sectional study design was used to collect information characterizing occupational neonicotinoid insecticide handling practices at three different work environments: seed treatment facilities, distributors of treated seed, and on farms that use treated seeds. Participants were recruited through internet searches of Iowa seed treating facilities, distributors, and farms and through snowball sampling. Once recognized as a potential participant, the company was called or emailed using a script and, if they consented to being in the study, a meeting was scheduled. The inclusion criteria for the study were companies or persons who handle neonicotinoid treated corn or soybean seed and resided in the state of Iowa. The questionnaire was reviewed by an expert in the agricultural safety and health field (Dr. Brandi Janssen), an expert in aerosol physics (Dr. Thomas Peters), and an expert in the occupational and environmental health field (Dr. Bill Field). In addition, the questionnaire and tour process were piloted at a local farm prior to commencing the study. The study protocol underwent Human Subjects Research Determination by the University of Iowa's Institutional Review Board and was deemed non-human research. Three different questionnaires were developed, one for each work environment (manufacturing, distribution, farm). The questionnaires were administered through a face-to-face interview and followed with a tour of the facility. Responses were documented in a journal and later transcribed to a Microsoft word document. The questionnaire was designed to take around 45 minutes and the tour length depended on the size of the facility.

Data Collection

The questionnaire was administered as an interview to 15 participants at their worksite while touring the site. Five participants worked in manufacturing, five at a seed distributor, and five on a farm that used treated seeds. Responses to the questionnaire, as well as observations, were written as field notes in a notebook while on site and later transcribed to a Microsoft word document. Photographs were also taken during the tour. No incentives were given to participants.

Data Analysis

Data were analyzed qualitatively by using a grounded theory approach to examine the written questionnaire responses, field notes, and photographs [50]. The data were read and re-read to identify themes, similarities, and differences between each work environment; notes were also examined to identify safety hazards associated with the neonicotinoid insecticides during the tasks being accomplished at each site. When possible, the questionnaire gathered information about what chemicals were used at each site. Safety practices recorded at each site were then compared to the requirements indicated on the label. Sites were assessed during the tour and interview to determine areas where a potential exposure to neonicotinoids could be occurring.

RESULTS

The descriptive results of the questionnaire and walk-through from the manufacturer sites are provided below, followed by Table 1 comparing key similarities and differences between the worksites. The basic process for treatment was the same at all manufacturers and distributors, as shown in Figures 3 and 4. Corn seed treating begins with two cleaning steps. One to determine the shape and a second to determine the size. The processes then become identical between soybeans and corn. They are treated in a rotating treater so that the seeds are evenly coated, then go through a drying phase, then are packaged and stored. Participants had work roles that ranged from owners, to site managers, to seed treaters. On average, each visit took about an hour at each facility, the length of stay depended mainly on the size of the site. All sites used a blended product. Therefore, the product contained neonicotinoid insecticide as well as other pesticides.

Figure 3. Corn Seed Treating Process

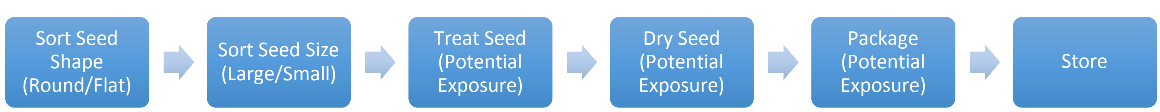
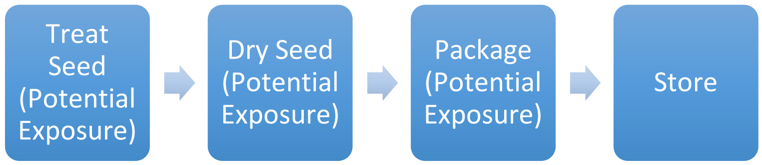


Figure 4. Soy bean Seed Treating Process



Manufacturer A

Background and Policies

Manufacturer A is a corn treating facility. It has seven fulltime employees and two seasonal employees. Four of these employees work in the processing area; only one employee applies chemicals to the seeds. This facility has no safety policies, PPE requirements, or dress code. However, the label for the pesticide they are applying (Cruiser Maxx Corn 250) requires, at a minimum, chemical-resistant coveralls over long sleeved shirt and long pants, chemical resistant rubber gloves, and shoes. The label also recommends hands to be washed thoroughly with soap and water after handling the seed. The dust collection system at the facility was built in 1988, and there was visible dust build up in the treatment area on equipment and piping. Excess pesticides are kept above the office entry on a shelf.

The employee who works in the application area has indirect contact with neonicotinoids a couple times a day, and has not experienced a spill. He has indirect contact when carrying the product in the sealed drum up three sets of stairs to where the pesticide is applied to the seed, when opening the drum to attach it to the hose, and when working in that area for extended periods of time throughout the day. Colorant is applied to indicate that the seeds have been treated.

The pesticides are ordered in as needed, and which brand is used per season is driven by cost.

Delivery

The corn arrives at the plants shelled and dried. Semi-trucks empty the seed into the elevator outside of the plant.

Cleaning

The seeds are pulled inside from a bin by an auger for their first round of cleaning (Appendix C). The goal of cleaning is to initially separate the round and the flat seeds. Unwanted material is sent to the elevator and will be ground into feed or other products. Unwanted material includes stems, seed that is too large or small, and half seeds.

The seeds then go through another cleaning step to sort by size and improve ease of planting and to ensure a specific number of seeds per pound. Uniformly sized seeds allow even spacing during planting.

Four different sizes of seeds are kept. Every 80,000 seeds, a sample is taken to ensure size and shape is correct, and to test how many kernels there are per pound. The four types are kept in four different bins which are automatically filled, in the bin is a sensor to determine when the bin is full. A let down ladder is used to gently drop down seeds into a storage bin.

Treating

Manufacturer A uses Cruiser Maxx Corn 250 on corn.

The dust collecting system was built in 1988. There are dust collectors at the bins and treater (Figure 5). The dust collectors consist of a metal rectangular suction, approximately one foot by four inches, which is attached to PVC pipe that vents to a container outside of the building. However, even with the dust collector directly at the treater, dust is visible on the floor and on equipment.

Figure 5.Dust Collector with visible dust around machine and on floor.

During treatment, water and colorant increase flow ability. The water and colorant are mixed in a slurry tank and then pumped to the application area.

The pesticide is drawn from a 15-gallon drum. A hose is attached to the top of the drum by hand by a single individual, where the pesticide is sucked out of the container and into the mixing machine. The drum is replaced when empty and picked up by the distributor. The temperature of the treatment room is above 50 degrees F and at 50% humidity.

Around 15 to 20 gallons of pesticide are used per day during mid-November until the middle of January. On average 20,000 bags of seed a day are filled Monday through Friday during this time. One-hundred pounds of seed are treated at a time. Inside the Gustafson treater, fins keep the seed rotating during treatment. The machine runs 15 to 20 seconds post treatment to ensure the seeds are dry.

The screens and floor are cleaned every few days or up to twice a day depending on volume of seeds being treated.

Bagging

Bagging is conducted mechanically. The seed pours into a paper bag and is then sewn shut mechanically. Once the bag is closed an employee manually places the bag on a pallet. Once the pallet is full a forklift is used to move it to storage.

Pick-up/Excess Seed

The finished product is picked up by the consumer on a semi-truck. A forklift is used to place the product bags on the semi-truck.

Excess chemicals are stored on a shelf above the office (Figure 6).

Figure 6. Chemical Storage Above Office

Manufacturer B

Background and Policies

Manufacturer B produces treated corn and has 15 fulltime employees and seasonal employees. Four of these employees work in the treatment area. The facility was built in 2007. At this facility, no safety policies exist. The label for Cruiser Maxx Corn 250 requires, at a minimum, chemical-resistant coveralls over long sleeved shirt and long pants, chemical resistant rubber gloves, and shoes. The label also recommends hands to be washed thoroughly with soap and water after handling the seed. The dust collection system at the facility was built in 2007, and there was visible dust build up in the treatment area on equipment and piping. Treated waste seed is sent to cement companies or to be burnt at a corn stove at corn stoves.

There is one main chemical room, where storage and treatment take place, and one extra area in case of overflow. Anything that is opened is kept in the main room which is in the treating area. Where the temperature is, climate controlled. After the treating season, there are only small amounts of chemicals kept at the facility.

Delivery

Seeds are emptied into the elevator where they are pumped into the building directly into the sorting machine.

Cleaning

Four sizes of seeds are treated. The color sorter is first used to show whether the seed is chipped, immature, or moldy. A gravity table then sorts by density, the heavier seeds fall to the bottom and drop into a bin for treatment, the lighter seeds are dropped into a different bin to be discarded for animal feed. The heavy seeds are then piped to the treatment area. Treatment occurs mainly between November and January. Once the seeds are treated, they come out of a short conveyer belt, about two feet long and dumped into storage bins or sent to bagging area.

Treating

Manufacturer B uses Cruiser Maxx Corn 250 on corn, along with colorant, and a polymer.

Treatment occurs mainly between November and January.

Every few batches of seed, a worker uses his bare hand to pick up a hand full of seeds to ensure seed quality and that the treatment is dry on the seed. The interviewee at this site reported that the seeds would be slightly wet and dye his hands, therefore they wash their hands right away if ever touching treated seed. During the mixing process gloves are worn, except at the point where the seeds are tested to determine if the treatment is dry.

There is a dust collection system at the initial cleaning step, at the treatment area, and bag filling station. The facility is cleaned yearly to remove any excess dust. Yet, dust buildup still exists within the facility (Figure 7).

Figure 7. Dust Collection on equipment

Bagging

Once the seeds are treated, they come out of a short conveyer belt, about two feet long, and are emptied into storage bins or sent to bagging area.

Pick-up/Excess Seed

The finished product is picked up by the consumer on a semi-truck. A forklift is used to place the product bags on the semi-truck.

Treated waste seed is sent to cement companies.

Manufacturer C

Background and Policies

Manufacturer C produces treated soy bean seeds. This manufacturer currently has four employees and one seasonal employee who work in the seed treatment area and handle the seed treatment. At this facility, all employees have a chemical applicator license. Rubber gloves are worn in the facility, throughout the entire treating process. The label for the pesticide they are applying requires at a minimum long sleeved shirt and long pants, chemical resistant gloves, and shoes. The label also recommends hands to be washed thoroughly with soap and water after handling the seed.

Every employee works in treating area and possesses a chemical applicator license. They treat soy beans with Cruiser Maxx.

Delivery

The seed is delivered clean and pumped into the building from the elevator. At all soy bean facilities, prior to delivery, the soy beans are cleaned prior by a different company to delivery.

Treating

The pesticide is delivered in a drum, which is picked up when empty. The entire seed treating is completed using an automated system. A computer is housed by the treating area; all the information is imputed into the computer. The employee will place needed ingredient drums on scales and then attach them to hoses before starting the system (Figure 8). They then engage in other tasks until the treatment process is complete. An auger pulls seed in from a bin outside the building and unloads it into a bin which flows into the treater. Once treated another auger pulls the seed up so that it can flow into a box or seed tender. The facility is climate controlled.

The employee has potential contact with the pesticides when they are connecting the drum to the system and while the seeds are being treated.

Figure 8. Treatment scales: Ingredient drums are placed on scales to determine amount of liquid remaining in the drum and being taken out during treatment process

Bagging

The automated system pumps the treated seed into the customers' preferred packaging, including boxes, totes, or paper bags.

Pick-up/Excess Seed

Manufacturer C either delivers in boxes or if the consumer desires they may pick them up themselves.

Manufacturer D

Background and Policies

Manufacturer D treats corn. This manufacturer currently employees eight people who work in the seed treatment area and handle the seed treatment. The pesticide comes premixed. When working in treatment areas, employees are required to wear goggles, gloves, and aprons. In case of an incident there is an emergency shower on premise. The label for the pesticide they are applying requires at a minimum chemical-resistant coveralls over long sleeved shirt and long pants, chemical resistant rubber gloves, and shoes. The label also recommends hands to be washed thoroughly with soap and water after handling the seed. The treated waste seed is sent to an EPA disposal facility once a year and about half a semi-truck load.

Chemicals are stored in a heated containment area, that is completely cement (Figure 9). Therefore, if there were to be a spill no chemicals can be released into the environment or travel further into the facility. Chemicals are in constant use year-round. Their newest seed handling employee has been working for the company for 15 years.

Figure 9. Chemical Storage Room: Excess chemicals are stored in climate controlled and sealed off room

Delivery

The seed is pumped into the building using an auger from an outdoor grain elevator.

Cleaning

The seeds go through two rounds of cleaning (Appendix C), then are sent through an aspirator, a machine used to remove an liquid from the seeds, to ensure the seed is dry before being treated.

Treating

An employee spends about 20 minutes in the seed treating area per week (Figure 10). There is a camera in area so that if anything goes wrong they can see without having to spend time in that section. The majority of employees' time is spent at the cleaner. Once treatment is complete the seed is sent to a bagging hopper.

Figure 10. Seed Treater in Rotation

Bagging

The seed is delivered on semi trucks; a forklift is used to unload the seed which is stored in bulk bags or small bags. Consumers pick up the seed from the facility as well.

Pick-up/Excess Seed

The finished product is picked up by the consumer on a semi-truck. A forklift is used to place the product bags on the semi-truck.

The treated waste seed is sent to an EPA disposal facility once a year and about half a semi-truck load. Untreated seed is sold as grain.

Manufacturer E

Background and Policies

Manufacturer E treats corn. This manufacturer currently employs approximately 70 full time employees. Only employees who are trained can access hazardous equipment, which is any equipment that requires lock out tag out. Their site has four full time safety employees as well as a site nurse who is familiar with the specific hazards found on site. All machines have a bar code which can be scanned by iPads and smartphones to obtain safety information about that equipment. Lock out tag out is used throughout the facility with a zero-tolerance policy for non-compliance.

There are four seed treatment machines which are operated by employees who have been trained specifically on the hazards of the task they are completing. Only employees who have had previous training have access to the equipment. These employees typically are employed by the company for longer periods of time and work their way up to this position. There are full time safety employees on site, and use OSHA standards unless the manufacturer's personal standards are stricter. There is also a site nurse, who has access to all Safety Data Sheets. Pictures were not allowed to be taken at this site.

Delivery

The seed and treatments are delivered by semi-trucks. After the seed is dropped off conveyers take it to the second floor to be treated. Treatments are brought into the facility by forklifts.

Cleaning

In the first step in the cleaning process, seeds drop through three different screens one by one to eliminate seeds that are to large or small. The discarded seed goes to a conveyer and into a bin. They then go through the gravity table which separates the large and small, again confirming only the optimal size seed remain. Discarded seed is sent to a bin. The proper size seeds are then scanned by an infrared camera to check for light, dark, or odd shaped seeds. These seeds are then sent through the scanner again if flagged twice they are sent to a bin to be discarded.

Treating

The seed treatments are stored on the bottom floor in 260-gallon metal boxes. The treatments are hooked up to pipes which pump the treatments upstairs where the seed treating takes place. In case of a spill this area is contained by a concrete boom.

Upstairs in the facility is a "treating room" which has two large TV screens. One which shows where the treatment is being applied, how much is left, if valves are on or off, and dictates which chemicals are being used when. This computer system was installed within the last three years. The second screen shows views from cameras around the facility and in treaters to ensure they are empty, that way batches aren't mixed.

The seed is mechanically weighed to determine how much treatment should be used. The treater spins the seeds in an orbital pattern within the machine to ensure the seeds are evenly coated. At this stage, there sometimes is a quality check to determine if correct amount of treatment is on seeds, these seeds are sent out to a lab for assessment. There are four treaters that can operate simultaneously within the facility.

Bagging

There are three packing lines where approximately three employees watch each line in case there is an error in the mechanics. The bags are mechanically filled and sewn shut. The bags then proceed down an assembly line where they cross a scale which ensures the bag weighted properly. They then are picked up by a robotic arm; if the weight is correct they are stacked on pallet in a pattern so that that they do not spill, however, if the bags were weighted improperly the arm moves them to the opposite side of the assembly line in order to be emptied and go through the bagging stage again. Seeds can be packaged in bags, totes, or boxes.

Pick-up/Excess Seed

Untreated discarded seed is sent to a grain elevator. Waste treated seed is sent to an incinerator.

Manufacturer Summary

The seed treatment sites visited during this project varied greatly in employee size, ranging from four full-time employees to approximately 70. Building age also varied greatly, ranging from 1960s to 2007. The year the building was built did not seem to affect the chance of exposure to neonicotinoids. It seems that the larger the facility the more safety is a priority.

Table 1. Manufacturers Questionnaire Responses

Manufacturers	Manufacturer A	Manufacturer B	Manufacturer C	Manufacturer D	Manufacturer E
Number of full-time employees	7	15	4	Approx. 25	Approx. 70
Number of seasonal employees	2	N/A	1	N/A	None
Year built	1988 (dust system)	2007	N/A	1960s/70s	2000
PPE used	None	None	Rubber Gloves	goggles, gloves, and bibs	Gloves, hard hats, goggles, reflective vest, ear protection
Existence of safety policies/ procedures/ training	None	None	Chemical applicator license	Emergency Shower	Extensive Training, LOTO, SDS, Equipment information
Chemicals used	Cruiser Maxx Corn 250, water, colorant	Cruiser Maxx Corn 250, colorant, polymer	Cruiser Maxx Beans	Companies' specific mix	Depends on customers' order
Closed System	No	No	No	No	Yes

DISTRIBUTOR REPORT

All sites used a blended product, therefore, the product contained neonicotinoid insecticide as well as other pesticides.

Distributor A

This distributor has five full time employees and five part-time during treating season. This distributor is unique in the study sample because they treat a small amount of seed for research purposes, not for profit. The seed they sell arrives at the distributor treated and bagged.

Background and Policies

Seeds sold are Monsanto round up and Cruisermaxx and Miller Hybrid. They sell corn and soybeans.

All chemicals have an MSDS available and SOPs exist for tornado, fire, and general emergency.

Storage/Distribution

Small amounts of chemicals are stored at facility for up to two years. Rarely, if chemical is unknown it is taken to the land fill as hazardous waste.

Treating

This distributor is unique because they do a small amount of seed treating at the facility research. One employee does the seed treating. Gloves and a mask are used during the treatment where Cruiser Vibrance Maxx is applied by hand. Participant was unaware of the type of mask used.

Bagging

Products is stored in either paper bags or large totes.

Pick-up/ Excess Seed

Customers pick up product in either bags or large totes (Figure 11).

Figure 11. Tote Bags are the "medium" size when ordering seed

Distributor B

Distributor B treats soy bean seeds. This distributor has eight full-time employees, however only one person is responsible for seed treatment. This employee wears chemical-resistant gloves, eye protection, and there is an emergency eye wash station within the building. Approximately 70% of their soy beans are custom treated on site.

Background and Policies

Seeds are treated between March and June, typically about 30 totes per day. The building is cement and contained by a dyke in case of a spill.

Storage/Distribution

The pesticide drums are kept on a pallet and only ordered as needed. They remain in the building for three to four months and after that if any remain are moved to a climate controlled location via fork lift.

Treating

The untreated seed is contained in a box. A forklift is used to lift the box and empty it into the lower bin where it is then treated before an auger pulls it into a drying bin (Figure 12). The pesticide is in a drum which an employee must manually place on the chemical scales. The employee then opens it by hand and attaches the drum to the treater via a hose.

Figure 12. Drying Bin and auger used to fill boxes

Bagging

An auger pulls the dried treated seed from the drying bin and unloads it into a seed tender or into a box and sealed. The boxes are raised on a forklift to prevent damage to the seed during unloading from the drying bin.

Pick-up/ Excess Seed

Untreated seed that is left over after season is saved for the next. Treated seed is either picked up by client or delivered by the distributor to the client's farm.

Distributor C

This distributor has over 40 locations, four of which treat seed. Employees conducting seed treatment are required to wear aprons, safety glasses, gloves, and close toed shoes. Employees must remain 25 feet away from the closed system seed treater while it is operating. The facility has forklift policies and behavioral based safety programs. All left over treated seeds that are from other distributors are sent back to that distributor at the end of the season.

Background and Policies

Distributor C treats soy bean seeds at all four facilities. This distributor operates out of 40 different locations. Forty-five employees in total handle treated seed. Out of the 40 locations 4 conduct soybean seed treatment.

During treatment employees are required to wear closed toed shoes, aprons, gloves, and safety glasses. There are also forklift policies and behavioral based safety programs.

The seed treater is self-enclosed at all locations. The employees must remain 25 feet away from system while it is operating.

Bagging

Seeds are sold in totes or boxes.

Pick-up/Excess Seed

Untreated soy beans that are left over are used for animal feed. Left over treated seeds that are from other distributors are sent back to that distributor at the end of the season. Orders are taken before treatment so minimal is left over.

Distributor D

Distributor D treats soy bean seeds. This distributor has 28 full-time employees, however only three conduct seed treatment on soy beans. The site has an EAP, many SOPs, and yearly safety training which covers seed treating. Seed treating equipment is recalibrated at the start of the season each year.

Background and Policies

When conducting seed treating gloves are required. The site has an EAP, many SOPs, and yearly safety training which covers seed treating. Seed treating equipment is recalibrated at the start of the season each year.

In the off-season chemicals are stored in a climate controlled area that is has a dyke in case of a spill. The excess chemicals are used the next season.

Treating

Outside the facility are four large bins which store untreated soybean seeds. They are moved into the building by imputing the amount desired into a computer system. The beans collect in the hopper. An augur then carries them to the treater (Figure 13). From there the employee opens the valves to which ever chemical is desired by the purchaser. The beans are then treated and sent to another hopper via a conveyer. The hopper then unloads the seeds into a box which is being vibrated via remote so that the seeds dry without sticking to each other.

Figure 13. Auger (middle) which drops seed into treater (left)

Bagging

Half the seed is delivered in boxes or seed tenders. The other half is picked up by the farmer and either transported in tote bags, boxes, or a seed tender.

Pick-up/Excess Seed

Untreated seed is discarded; treated seed orders are taken prior to treatment so there are no bulk excess seeds. Small amounts may be found around the facility which is thrown away in the garbage.

Distributor E

This distributor has 120 full-time employees, yet only three handle seed treatment.

Background and Policies

Distributor E produces treated soy bean seeds. In the machine shop safety glasses must be worn, however, in the warehouse where seed treatment is conducted there is no required PPE or safety policies. The company has an EAP for the whole facility.

Farmers can pre-order seed over the phone or in person at the building. Corn comes treated in either bags, boxes, or totes. Approximately 50% of the soy beans they sell are treated at the facility, the other half comes pretreated and packaged. In total seed sales 80% of sales are treated seeds.

Treating

The seed treating process starts with a semi-truck dropping off the clean seed. The seed is stored outside in a silo. It is then pulled into the building by an auger, as needed. The chemical drums are loaded onto their allotted scale and connected by hoses. The “recipe” ordered by the customer is entered into a computer system. The auger then pulls in the proper amount of seed and drops it into the treater (Figure 14). The seeds are mixed with the treatment in a rotating cylindrical machine, once evenly coated the seeds are pulled up by an auger and dropped into a drying bin, and from there they are packaged. The computer shuts off the system once complete. Two employees spend approximately ¼ of their day in the treating area –during the end of March until the beginning of June. One spends this time at the computer and where the chemicals are connected. The second spends his time on a forklift moving seed around the warehouse and conducting tagging and unloading pallets of bagged seed. The seed treater equipment is cleaned annually at the end of the season. A mask and gloves are worn during this procedure; however, the interviewees were unclear on the type of mask used.

Figure 14. Treater with view of chemical scales in front and bin above which drops the seed down into the treater

Bagging

Seeds come packaged in either a box or tote.

Pick-up/Excess Seed

Empty and unopened chemical containers are sent back to the company they were purchased from using FedEx. Left over chemicals are saved for next year in a different building that is climate controlled.

Distributor Summary

The seed distributors studied during this project varied greatly in the number of full-time personnel, ranging from five to 120. Every distributor treated seed and had varying degrees of safety policies. The most safety policies included and EAP, many different SOPs, yearly safety training, and the seed treating equipment is recalibrated annually at the start of the season. The majority of distributors at a minimum wore gloves. The highest level of PPE was closed toed shoes, aprons, gloves, and safety glasses. Most distributors store chemicals up to one year. Distributor A treated corn and soybeans; distributors B, C, D, and E treated only soy bean seeds at their facility.

Table 2. Distributor Questionnaire Responses

Distributor	Distributor A	Distributor B	Distributor C	Distributor D	Distributor E
Full Time Employees	5	8	Depends on location	28	120
Employees Handling Treated Seed	1	1	45	3	3
Seed Treatment on Premise	Yes. Small quantity research seed	Yes. 70% of seed sold	Yes. 4 locations.	Yes	Yes
Public/ Private	Private	Public	Public	Public	Private
Safety Policies	SDSs available. Emergency Action Plans.	Eye wash station	During treatment employee must remain 25 feet away forklift policies and behavioral based safety programs	EAP, many SOPs, and yearly safety training which covers seed treating. Seed treating equipment is recalibrated at the start of the season each year.	EAP
Chemical Storage	Up to 2 years	Up to 1 year	Up to 1 year	Up to 1 year	Up to 1 year
Packaging	Tote or bag	Box or seed tender	Tote or boxes	Tote or box	Bags, Tote, Boxes
Type of Seed Sold	Corn & Soy	Corn & Soy	Corn, Soy, Alfalfa, Rye	Corn & Soy	Corn, Soy, Rye

Table 2. Continued

PPE	Gloves & Mask	Chemical resistant gloves & eye protection	Closed toed shoes, aprons, gloves, and safety glasses	gloves	None
Hazardous Chemical Disposal/ treated seed disposal	Landfill	No excess treated seed/ treatment saved for next season	Excess treated seed is sent back to manufacturer	No excess treated seed/chemicals	No excess treated seed/chemicals
Pick up or deliver product	Pick up	Pick up or deliver	Depends on location	Half the seed is delivered in boxes or seed tenders. The other half is picked up by the farmer and either transported in tote bags, boxes, or a seed tender.	Pick up or deliver

FARM REPORT

Farm A

This farm has two full-time employees farming corn and soybeans on 1500 acres. No PPE is worn during the planting process.

Crops Produced and Chemicals Used

Farm A produces treated corn and soy beans on 1500 acres. The seeds used are dependent on pricing and are purchased from Pioneer, Wyfells, Becks, or Merschman by telephone order. Corn is delivered in paper bags with sewn tops to the farm. Soybeans are picked up from the dealer by using a seed tender (Figure 15). Seed tenders are meant to reduce exposure to pesticides and increase ease of transport of bulk seed. The full seed tender is then taken back to the farm. The seed is planted within three weeks. The farmer prefers seeds treated with neonicotinoids to protect against grubs.

Figure 15. Seed Tender: Used by a farmer to transport seed from suppliers to their farm in bulk. An auger pulls the seed out of the seed tender and loads it into the planter.

Handling Process

An auger is used to transport soybeans from the seed tender to the planter. If necessary, a coffee can is used as a makeshift scoop to spread around the seed inside the planter. No PPE is worn during the processes.

The corn seed bag is opened by pulling the string that stitched the bag shut, this action rips the top of the bag open. The seed is then manually loaded into the planter by lifting open each individual box and then pouring the seed into the planter boxes until each box is full. No PPE is worn during this process. Approximately 300 bags of corn are used within two to three weeks. At the end of the season the planter is power washed. Again no PPE is worn.

Excess seed is stored in a shed to be used the following year.

Farm B

This farm has three full-time employees and two part-time employees. No PPE is worn during the planting process.

Crops Produced and Chemicals Used

Farm B produces treated corn and soybeans on 350 acres. The farmers have recently started planting oats and alfalfa as cover crops. Depending on the prices the seeds used are purchased from Wyfells and/or Pioneer.

The corn seed is dropped off by a semi-truck in boxes and soybeans are dropped off in paper bags. The bags are delivered plastic wrapped to a wooden pallet, to ensure they do not slide around during transport. The farmers use neonicotinoid treated seeds to control root worms.

Handling Process

The seed delivered on pallets is unloaded using a forklift. Then the bags are loaded into the planter one bag at a time. A ladder is used in order to pour the seed into the planter. The planter used does not have row boxes, therefore all the seed is loaded into one opening on the front of the planter. The boxes are unloaded from a semi-truck using a fork lift. The boxes are emptied into the seed tender using the auger connected to the seed tender. Once in the seed tender the same auger is used to transport them to the planter. Seed is stored on the premise for four to six weeks. Corn is planted at a rate of 34,000 seeds an acre and soy 100,000 to 120,000 per acre.

Farm C

This farm has one full-time employee who plants corn and soybeans. This farmer wears gloves while planting.

Crops Produced and Chemicals Used

Farm C produces treated corn and soy beans. The farmer uses AgriGold seeds purchased from Big Country Seed.

Annually, Big Country Seed has a day in which all producers come and spend the day there. The company goes over new products and at the conclusion of the event producers place their orders for the upcoming season. The corn is delivered in paper bags and soy beans in totes. The farmer is using treated seeds to protect from cut worms, grubs, wireworms, and nematodes.

Handling Process

The seed is delivered plastic wrapped to wooden pallets by a semi-truck. A forklift is used to get the seed out of the semi-truck and into the shed. The corn is stored for approximately three weeks and the soy beans on average six weeks. The farmer wears gloves when opening the corn seed bags and loading them into the planter. The compartment the seed is loaded into on the planter is about four feet off the ground. Once finished working he then washes his hands. For the soy beans, an auger is placed in the tote which pulls the seed into a seed tender. The seed is then unloaded from the seed tender using the same auger into the planter. After planting is finished there generally is around half a bag left of seed which is stored in a sealed container in the shed until next season.

Farm D

This farm has three full-time employees. During the spring they plant corn and soybeans, in the fall they plant alfalfa as a cover crop. Any full unused bags are sent back to the dealer at the end of the seasons; any opened bags are kept in a closed container for use the next year.

Crops Produced and Chemicals Used

Depending on the price of the seed the farmers purchase LG or Pioneer seeds.

To purchase the seeds the farm calls in his order to a local shop. The seed is delivered on a semi-truck, both corn and soy beans are packaged in paper bags. The farmer is using seeds treated with neonicotinoids to protect against rootworm, corn borer, and wireworms.

Handling Process

The farmer opens the paper bags by pulling the string that rips off the top of the bag. They then manually load the planter boxes individually by opening each box pouring in the seed and then closing each box. The planter boxes are around four feet off the ground (Figure 16). At the conclusion of planting season any full bags are sent back to the shop. Any opened bags are placed in sealed containers and are used the next year.

Figure 16. 12-Row Planter: Each individual box is manually filled with seed during planting

Farm E

This farm has one full-time and one part-time employee. The dealer comes out to the farm to take purchasing orders for the season.

Crops Produced and Chemicals Used

Farm E produces corn and soy beans. Multiple seeds are used: Pioneer, DeKalb, Stine, and Wyffels and are all purchased through a dealer.

The dealer comes out to the farm to take the farmers order for the season. The corn comes packaged in paper bags and the soy beans in boxes –both products are delivered. The farmer is using neonicotinoid treated seeds to control rootworm, corn borer, armyworm, and maggots.

Handling Process

Seeds arrive the first week of April and are planted within three weeks. Corn in paper bags arrive plastic wrapped to wooden pallets. A 12-row planter is used to plant corn. The seed bags are manually loaded into the planter boxes. To plant the soy beans the auger on a seed tender pulls the seed out of the boxes and into the seed tender. The same auger is used to pull the seed from the seed tender into the planter. Excess seed is used to fill in poor areas after initial planting.

Farm Summary

The farms that participated in the study had no more than three full-time employees and no more than two part-time employees. All the farms plant both corn and soy beans. Farm D was the only farm to use a cover crop, alfalfa is planted during the off season. Only Farm A and B picked up some of their seeds from dealers; all the farms had some or all their seed delivered to their location. The majority of the seed came packaged the same way, therefore, all the farmers had similar exposures to seed treatments.

All the farms interviewed planted corn and soybeans and used almost no PPE, one farmer reported wearing gloves while handling treated seeds. Two main methods of planting the seeds was using a seed tender or a planter. The seed tender was either filled before being brought back to the farm or filled at the farm using an auger. The planter is filled by manually dumping the bags into the row boxes. Excess seed is either stored for next season or used to replant areas that do not germinate after the initial planting.

Table 3. Farm Questionnaire Responses

Farm	Farm A	Farm B	Farm C	Farm D	Farm E
Employees: full time	2	3	1	3	1
Employees part time:	0	2	0	0	1
Type of Crop	Corn & soy	Corn & soy	Corn & soy	Corn & soy Alfalfa = cover crop	Corn & soy
Seed/ Company	Pioneer, Wyfells, Becks, Merschman	Pioneer & Wyfells	AgriGold, Big country seeds	LG seeds, Pioneer	Pioneer, DeKalb, Stine, Wyffels
Delivered or Pick Up	Delivered & Pick Up	Delivered & Pick Up	Deliver	Deliver	Deliver
Packaging	Corn in bags, Soy in boxes	Corn in boxes, Soy in bags	Corn in bags, Soy in totes	Corn and soy bags	Corn in bags, Soy in boxes
Seed Storage	Stored in shed until next season if unused	Stored 4-6 weeks	Corn: 3 weeks Soy: 6 weeks	3 months: End January to beginning of April	3 weeks
PPE	None	None	Gloves	None	None

DISCUSSION

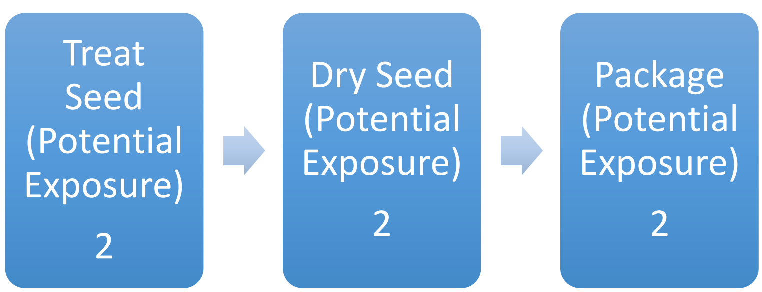
General Exposure Opportunities

The exposure opportunities are the same between corn and soy bean treatments. The only difference that exists between the two seed types is that corn goes through two cleaning steps at the facility that is treating it, while all soy bean seeds arrive at the facility cleaned.

Exposure to neonicotinoids may occur during treatment, drying, and packaging. Controlling these hazards exposures is a fundamental way to protect employees. A preliminary hazard analysis (PHA) was conducted on the results from the manufacturing process. A PHA is a qualitative analysis used to determine probable incidents that may lead to injury, illness, or a near miss. A PHA is conducted by inspecting the equipment, workers interactions, and the process flow diagram to identify hazards. A risk code is derived from two factors severity and probability. Severity has a scale ranging from one being minor, two is major, three is critical, and four is catastrophic. The probability scale is classified alphabetically from A being frequent, B is probable, C is Occasional, D is remote, E is improbable, and F is impossible.

Figure 17 depicts the risk code determined by combining the severity and probability of exposure. Risk codes range from three to one, one being the most hazardous. A ranking of three determines the operation is permissible, while two needs a limited-time waiver/management approval, and one is unacceptable and the risk must be reduced. Seed treatment was determined to have a risk code of two because the severity would be critical and the probability occasional. Critical severity means a failure in the system would result in personnel being exposed to hazardous chemicals which may result in minor injury. Occasional probability means system failure is likely to occur during the systems life cycle. During the drying process the risk code was determined to be two because the severity was major and the probability probable. Major severity is defined as a failure in which employees experience a low-level exposure. Probable probability means system failure is likely to occur several times during the systems life cycle. Finally, the packaging process risk code was determined to be two because similarly to the seed drying process the severity was major and the probability was probable.

Figure 17. Preliminary Hazard Analysis



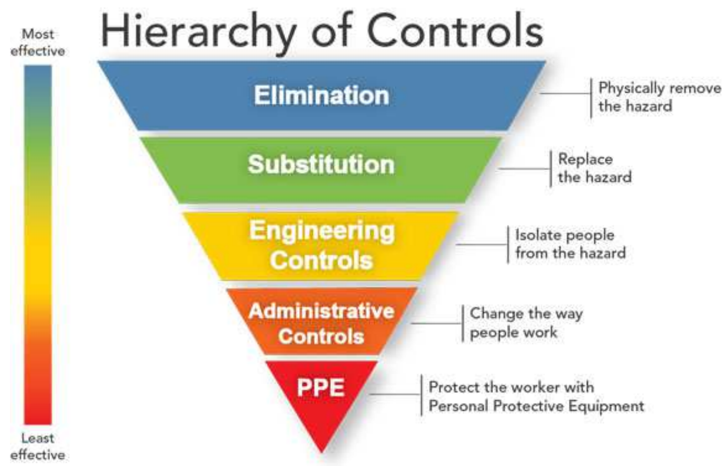
A variety of controls were seen by manufacturers and distributors in order to protect employees during these processes. Manufacturer A uses engineering controls to protect their employees by using a dust collection system and automated bagging. Manufacturer B engineering controls to protect their employee by using a chemical storage room to isolate the chemicals from the employees and a ventilation system. Manufacturer C uses administrative policies and PPE. Manufacturer D uses engineering controls, isolation by using chemical storage room and having an enclosed treatment area that is monitored by cameras, and PPE. Manufacturer E uses engineering controls (closed-system), administrative policies, and PPE to protect their employees.

Distributor A was excluded from the Table 4 and the summary because they do not conduct on site commercial seed treating. Distributor B uses only PPE. Distributor C uses engineering controls (closed-system), administrative policies, and PPE to protect their employees. Distributor D uses administrative policies. Finally, Distributor E uses no controls. The National Institute of Occupational Safety and Health created the Hierarchy of Controls (Figure 18) to depict the effectiveness of controls. Elimination being the priority, which would be to remove the hazard from the process entirely. The least effective method of control is personal protective equipment [51].

Table 4. Controls for Potential Exposures

Facility	PPE	Administrative	Engineering
Manufacturer A	No	No	Yes
Manufacturer B	No	No	Yes
Manufacturer C	Yes	Yes	No
Manufacturer D	Yes	No	Yes
Manufacturer E	Yes	Yes	Yes
Distributor B	Yes	No	No
Distributor C	Yes	Yes	Yes
Distributor D	No	Yes	No
Distributor E	No	No	No

Figure 18. NIOSH Hierarchy of Controls [51]



Manufacturer Synopses

Manufacturer size varied; within the study full-time employees ranged from four to approximately 70. Manufacturers employed few employees who work only during seed treatment season (typically from March to beginning of June). Only three seasonal employees were reported among all manufacturer sites, although two respondents were unsure of the number at their facility. Therefore, it is presumed that employees who are likely to be exposed are full-time.

The seed treating process had many similarities and differences between the manufacturers. There were observed opportunities for exposure at facilities of all ages. However, the technology used within the facility seemed to contribute to the potential for exposure in the facility. Manufacturers had either closed or open treatment systems. In a closed system, once the pesticide drum is attached to the hose, the process is enclosed so that there is theoretically no potential for exposure to the pesticide again. Once the seeds are finished in the treatment system, staying in a closed system with no access to the work environment, they are automatically packaged. In contrast, in an open system, there are opportunities for exposure after the pesticide drum is attached to the hose. Another opportunity in an open system is when the seeds are treated in an open cylinder; therefore, dust inhalation is a potential exposure. Lastly, when the seed is being packaged. During this process the seed is poured either from an auger or a bin into its final container. The movement of the seed can potentially cause dust to form creating an inhalation hazard.

Manufacturers using open system technology (A-D) had more risks of exposure than manufacturers with a closed system. At each of these locations there was evidence that colorant had been spilled in the past because it stained the floors. These workers have a potential to be exposed when mixing the pesticides and other products through dermal and inhalable routes. In addition, at manufacturer B, the seed is checked by hand, without gloves, occasionally throughout the day to ensure dryness. The interviewee admitted that their hands tend to dye because the colorant from the seed is not dry at this stage. They then proceed with washing their hands. This presents an opportunity for the worker to be contaminated through dermal contact with the insecticide. In manufacturer A and B, there was also potential of exposure through inhalation immediately after treatment because the seeds empty into an open machine for further sorting. Manufacturer D avoided this exposure at this stage by using a camera system. Once the products are mixed, the seeds go through a system which is followed by cameras so no worker must be in the room during operation. If a machine were to fail, the system would be shut down and the employee can go into the room and manage the problem. The cameras are always watched during operation.

Closed systems (E) had two points of exposure. During the beginning of the process, uncapping the chemical drum and attaching a pump. This is a quick process typically completed within one minute. The other chance of exposure is from leaks. While every facility reported that there had been no such occurrence there was visible colorant stained on the floors. In manufacturer E, it was seen on the second floor where the mixing occurs. There were many hoses connecting to the mixer, therefore it is not clear which chemicals had spilled in the past but the occurrence was evident.

Colored dust was also noticed at manufacturer A and B. Although both facilities had ventilation for dust, the dust was still noted at each facility on and around equipment adding another area for potential inhalation.

Personal protective equipment (PPE) and safety policies varied greatly between manufacturers ranging from no PPE or policies to facilities that wore gloves, hard hats, goggles, reflective vest, and ear protection and had emergency action plans (EAPs), standard operating procedures (SOPs), lock out tag out (LOTO), extensive training prior to working with equipment and chemicals, readily available safety information for equipment at each machine.

Chemical storage for the manufacturers was relatively similar in that the areas were climate controlled and protected from spillage. Only one did not have spillage protection.

Distributor Synopses

Distributor size varied greatly, ranging from five to 120 employees. Typically, however, only a few (between one and three) employees treated seed. However, one Co-Op that operates four locations had 45 employees whom conduct seed treating. Every distributor that participated in the study not only sold seed, but treated it as well. One distributor was unique in this aspect because they treated small quantities of seed for research purposes. They send the treated seed to a large company whom runs tests on it. None of their treated seed is sold to the public.

Safety policies seemed to vary notably within this group. One distributor had an EAP for the entire company, but no EAPs existed specifically for the seed treating warehouse. However, one Co-op had EAPS, SOPs, and annual training sessions which encompassed seed treating best practices. Their seed treating equipment is recalibrated at the start of each season for precision purposes to ensure proper amounts of each chemical are being placed on each seed and to guarantee each machine is working efficiently, that way maintenance can be conducted before the season begins, if need be.

Personal protective equipment differed between the distributors. It ranged from none to closed toed shoes, aprons, gloves, and safety glasses. The Co-op whom had employees wear the most protective equipment uses closed system technology to treat their seeds and have a policy that while the system is operating employees must remain 25 feet away from the equipment.

As with manufacturers, distributors also treat seeds and therefore have more opportunity to be exposed than previously thought. Co-ops appear more likely than companies to enforce safety in the workplace. Companies wore less PPE and had fewer safety policies than co-ops.

The exposure opportunity is very similar to the seed treatment facilities, since essentially they are doing the same tasks. All of the distributors used an open system to treat their seeds.

Farmer Synopses

All the farms that participated in the study had between one and three full-time employees. Therefore, Occupational Safety and Health Administration does not enforce safety policies at these locations. Every farm studied produced corn and soy beans during the spring, and one planted alfalfa as a cover crop in the fall. The majority of seed was delivered to the farm –corn was mainly packaged in bags and soy beans in boxes.

Farmers are exposed very similarly because most of them receive their seeds packaged the same way and use the same type of equipment to plant their seeds. When opening the seed corn bags, each farmer had a very similar method. They rip open the bag and then pour the seed into row boxes or into one large container on their planter. The boxes and container are around four feet high, therefore this process is taking place very close to the farmers face where inhalation exposures may occur. Soy beans provide much less exposure opportunity because they arrive packaged in boxes and an auger pulls the seed directly into the planter, therefore, the farmer does not have the exposure to every bag like they do with corn.

LIMITATIONS

A limitation of this study is the small sample size (N=15). However, there is little research regarding neonicotinoid treated seed handling and processing in the United States. Participants self-selected to take part in the study which may have resulted in selection bias. The interviewee was able to tailor their response to what they believed was a preferred response by the researcher creating bias. Observer bias may have occurred because the experimenter was aware of the hypothesis under investigation and had through background knowledge of safety and health practices when dealing with pesticides and machinery. Since the participants were asked questions regarding past experiences recall bias may have also been present. In order to minimize selection bias in future studies incentives can be used to entice companies who are hesitant to participate in the study. The majority of the research took place in the off season, so few systems were seen in action.

CONCLUSION

Manufacturers and distributors had very similar experiences conducting seed treatment. Their exposure opportunities were nearly identical. The only unique exposure being Manufacturer E because of their use of an entirely closed system. Using a closed system prevented the employees from potential exposures during seed treatment and packaging. However, all employees had the same potential exposure when attaching the pesticide blend to the required hose. Personal protective equipment use varied greatly varied among sites. However, co-ops were more likely to have stricter policies on PPE use. Farming techniques were similar for all sites; therefore, it is presumed they experience similar potential exposures. Future research should focus on open system exposures and developing interventions to create safety policies at all facilities.

CHAPTER III: FUTURE RESEARCH AND PUBLIC HEALTH RELEVANCE

FUTURE RESEARCH AND NEXT STEPS

This study collected information on neonicotinoid-treated seed handling practices at treatment plants, distributors, and on farms. Study sites showed a variation in types of equipment used, which suggests the potential for some worksites to have higher exposures than others. In addition, the companies' focus on PPE and training varied, which could contribute to different levels of exposure among the workforce.

The interview and tour approach used to conduct this research was an effective way to collect qualitative data. The questionnaire allowed respondents to provide detailed information as well as shorter responses. The site tour was vital in understanding the methods and equipment used to complete each process. However, visiting the sites during operation was particularly informative. Photographs taken at the site visits provided a visual representation of the variation between facilities and equipment used.

The findings of this study suggest that both engineering and administrative controls are important to protect the workers from potential exposures. In the hierarchy of controls engineering modifications are prioritized compared to administrative enforcements. This study shows that closed system treating processes appear to reduce potential exposures. However, it appears that administrative controls are vital in preventing exposures as well. Places of employment that put administrative controls, such as housekeeping and training, as a priority can also reduce opportunity of exposure. In this study, manufacturers and distributors had a wide variety of approaches to safety policies for their employees. Farmers had no on-farm safety policies for their employees.

Further research is needed to determine the health effects of neonicotinoids and their exposure limits. Also, future research should be conducted to investigate aerosol and dermal exposures during seed treatment, especially on facilities not using a closed system, to determine what quantity of neonicotinoid insecticide workers are exposed to. Novel interventions could implement new administrative and engineering controls at facilities not currently taking advantage of the combination and evaluating exposure reductions. Another area of research could compare aerosol and dermal exposures at companies without administrative policies verses co-ops with extensive policies, since it appears the majority of co-ops have strict administrative policies.

RELEVANCE TO PUBLIC HEALTH

Neonicotinoids are a new chemical and there has been little research on humans and even less on occupational exposures. With the use of neonicotinoids consistently increasing each year, it is vital to determine the amount of risk these employees are in. An employee should exit the work place as healthy as they entered. This qualitative study provided formative data that will contribute to determining where and how workers are exposed to neonicotinoids throughout the lifecycle. There is evidence that workers potentially are experiencing dermal and inhalation exposures to neonicotinoids through treated seeds. Researchers now have a foundation to start quantitative research in this area to determine the true extent of exposure.

CONCLUSION

This study used qualitative data to provide new information on where and when workers are exposed to neonicotinoids. Simply addressing that there may be an exposure is not enough. A significant need for quantitative data exists, to ensure workers are adequately protected. This study showed that there is a potential exposure risk in all stages of the neonicotinoid lifecycle.

This study also identified common themes within each population. Seed treatment facilities are likely to have full-time employees who are continually exposed to the same factors during treating season. Co-ops were more likely to have strict administrative controls such as PPE use and training policies. Farmers all had similar exposure opportunities when unloading seed into the planter. Where and how workers are potentially exposed to neonicotinoids is clear, however, future research is essential in determining if neonicotinoid exposure is occurring and if it is detrimental to human health.

Appendix A

Manufacturing Questionnaire:

1. What is manufactured at the facility?
    a. What percentage of product is neonicotinoid?
2. How many people work on premise?
3. How many employees work in neonicotinoid manufacturing area?
4. Please talk me through the manufacturing process of neonicotinoid pesticides?
5. Where do neonicotinoid processes occur?
    a. How many employees handle neonicotinoids directly?
    b. What tasks are involved?
    c.
        i. How many people preform this task, how frequently do they do the task, and how long does it take?
        ii. Are there any engineering controls in place?
        iii. Are safety policies in place? (Administrative controls)
        iv. PPE?
        v. Have there been any incidents such as dermal contact or inhalation exposures?
            1. If so, how often does that happen?
        vi. Is any waste produced?
            1. If so, how is the waste handled? And have there been any releases to the environment?
    d.
        i. How many people preform this task, how frequently do they do the task, and how long does it take?
        ii. Are there any engineering controls in place?
        iii. Are safety policies in place? (Administrative controls)
        iv. PPE?
        v. Have there been any incidents such as dermal contact or inhalation exposures?
            1. If so, how often does that happen?
        vi. Is any waste produced?
            1. If so, how is the waste handled? And have there been any releases to the environment?
    e.
        i. How many people preform this task, how frequently do they do the task, and how long does it take?

ii. Are there any engineering controls in place?
iii. Are safety policies in place? (Administrative controls)
iv. PPE?
v. Have there been any incidents such as dermal contact or inhalation exposures?
    1. If so, how often does that happen?
vi. Is any waste produced?
    1. If so, how is the waste handled? And have there been any releases to the environment?

f.
    i. How many people preform this task, how frequently do they do the task, and how long does it take?
    ii. Are there any engineering controls in place?
    iii. Are safety policies in place? (Administrative controls)
    iv. PPE?
    v. Have there been any incidents such as dermal contact or inhalation exposures?
        1. If so, how often does that happen?
    vi. Is any waste produced?
        1. If so, how is the waste handled? And have there been any releases to the environment?

g.
    i. How many people preform this task, how frequently do they do the task, and how long does it take?
    ii. Are there any engineering controls in place?
    iii. Are safety policies in place? (Administrative controls)
    iv. PPE?
    v. Have there been any incidents such as dermal contact or inhalation exposures?
        1. If so, how often does that happen?
    vi. Is any waste produced?
        1. If so, how is the waste handled? And have there been any releases to the environment?

6. Do employees ever have direct contact with neonicotinoids? How often does this occur?
    a. How often does this occur?
    b. When was last incident?
7. (only if product is in an inhalable form) Have there been any accidental inhalations?
    a. How often does this occur?

b. When was last incident?

8. Where are chemicals stored?
9. How are chemicals stored?
10. How long are chemicals stored at location?

Distributor Questionnaire:

1. How many employees on premise?
2. How many employees handle neonicotinoids directly?
    a. What tasks require direct handling?
    b. How long does it take for an employee to complete each task?
3. Have there been any accidental releases into the environment?
4. Have there been any accidental releases?
    a. When did last release occur?
    b. How often does this occur?
5. Have there been any accidental dermal contact?
    a. When did last incident occur?
    b. How often does this occur?
6. Have there been any accidental inhalations?
    a. When did last incident occur?
    b. How often does this occur?
7. Are there any specific safety policies in place that focus on neonicotinoid handling?
8. Are there any safety policies in place in general?
9. Are there any engineering controls in place?
10. Where are chemicals stored?
11. How are chemicals stored?
12. How long are the chemicals stored at location?

Farmer Questionnaire:

1. What type of crops are you planting?
2. What seed do you use?
3. What company are the seeds from?
4. Where/ how do you purchase the product?
5. How do you get it from purchaser to home?

6. How is it packaged?
7. How do you open the package?
8. Where do you store it?
    a. For how long do you store it?
9. What pests are you trying to control?
10. Can you describe the process you go through between opening of the package to the planting of the seeds?
    a. How many people handle seeds on the farm?
    b. What do they do with them?
11. What do you do with excess seeds?

Appendix B

Cruiser Maxx Corn 250:

Active Ingredients:

- Thiamethoxam
- Fludioxonil
- Mefenoxam
- Azoxystrobin
- Thiabendazole

User Safety Recommendations:

- Wash thoroughly with soap and water after handling.
- Wash hands before eating, drinking, chewing gum, using tobacco, or using the toilet.
- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

Multiple Task Workers must wear:

(Multiple task workers perform multiple tasks in one day such as mixing, bagging/ filling seed containers, product application, bag sewing, and clean up)

- Chemical resistant gloves Chemical-resistant gloves: barrier laminate, butyl rubber ≥14mils, nitrile rubber ≥14 mils, neoprene rubber ≥14 mils, polyvinyl chloride (PVC) ≥14 mils, or Viton ≥14 mils

- Chemical-resistant coveralls over long sleeved shirt and long pants
- Shoes plus socks

Crusier Maxx Beans: Unavailable

User Safety Recommendations:

- Wash thoroughly with soap and water after handling.
- Wash hands before eating, drinking, chewing gum, using tobacco, or using the toilet.
- Remove clothing/PPE immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

Applicators and other handlers must wear:

- Long-sleeved shirt and long pants
- Chemical-resistant gloves: barrier laminate or butyl rubber or nitrile rubber or neoprene rubber or polyvinyl chloride (PVC) or Viton
- Shoes plus socks
- Protective eyewear: faceshield, goggles, or safety glasses

Merschman Seeds:

Composition:

- Rancona V 100 Pro FS
- Belmont 2.7 FS
- Attendant 480
- Thiabendazole 4L ST
- Agrocer Red 48:2B
- Agrocer Polymer 321

Appendix C

Cleaning: Cleaning is a step completed in seed treatment. The main goal is to keep the correct size and shape seed and discard the rest. Seeds are original sorted for shape by a screen, that way waste seed falls through and the right shape continues to the next step. The second step of cleaning is conducted on a declining and angled machine that vibrates the seed so that the denser seeds shift to the top of the machine while the lighter seed falls to the bottom. The dense seed is what is kept while the lighter seed is discarded.

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