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Comparison of Ammonia and Particulate Matter Air Sample Concentrations at Task-Locations within Swine Confinement Buildings.

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Comparison of Ammonia and Particulate Matter Air Sample Concentrations at Task-Locations Within Swine Confinement Buildings

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by

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ABSTRACT

Comparison of Ammonia and Particulate Matter Air Sample Concentrations at Task-Locations Within Swine Confinement Buildings

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Introduction: A task-associated analysis of ammonia and particulate matter concentrations was conducted on swine farms in breeding and gestation barns. The purpose of this study was to determine if specific tasks performed by workers increase concentrations of ammonia and particulate matter exposure.

Methods: An exploratory, descriptive design was used to determine if swine confinement workers have increased ammonia and particulate matter exposure when performing assigned tasks in breeding and gestation barns. A convenience sample of 8 workers volunteered from among all breeding and gestation workers (n=24). Data collection occurred in the morning at each of the 8 farms and continued until tasks were completed (~4 hrs). Analysis of covariance (ANCOVA) was computed to determine if the type of task or type of barn was related to workers' exposure to ammonia or particulate matter.

Results: Ammonia levels were below the sensitivity of the instrument (<0.1) except on 1 morning when the ammonia concentration was recorded at 8 ppm. However, concentrations above 0.1 ppm lasted for less than 5 minutes. Consequently, this variable was not included in the analysis. Correlation analysis was used to answer the 1st research question. The results suggested a statistically significant decrease in particulate matter as the number of operating fans increased.

Analysis of covariance (ANCOVA) was used to answer the last 2 research questions. The results suggested a significant interactive effect between the type of confinement barn and the type of tasks workers were performing. The barn types differed by the number of exhaust fans and the type of animal waste disposal system.

Conclusions: Occupational health nurses can use study results to implement interventions to minimize worker exposures. These results indicate that understanding the relationship between building design and type of work tasks along with the importance of proper ventilation may minimize worker exposure to harmful particulate matter in SCBs during the summer months.

DEDICATION

I dedicate this manuscript to the many workers who have worked and continue to work in swine confinement buildings. Their efforts to produce high quality protein at an affordable cost are honorable and appreciated.

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CONTENTS

Page

Page

Page

Page

Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

Figure Page

CHAPTER 1

INTRODUCTION

The agricultural workforce represents over 40% of the world's 3 billion workers or approximately 1.2 billion principal operators, nonwage family members, and wage earning employees or farm workers (ILO, 2004). According to the Bureau of Labor Statistics (2008), the United States (U.S.) has approximately 2 million workers employed full-time in agriculture, fishery, and forestry (excluding logging) occupations. Of these 2 million workers, U.S. agricultural workers held approximately 834,000 jobs in 2004 (Bureau of Labor Statistics, 2008). Sixty-six percent of all U.S. agricultural workers are engaged in crop and livestock production (Bureau of Labor Statistics, 2008). The remaining 34% are employed in agribusiness and other enterprises that directly support agriculture (Bureau of Labor Statistics, 2008).

Approximately 250,000 workers are currently employed in swine-raising operations (Swine, 2000). In 2007, five states led the nation in pig inventory and marketing: Iowa, North Carolina, Minnesota, Illinois, and Nebraska (NASS, 2009). Iowa and North Carolina together marketed more pigs than the sum of the next eight swine-producing states. An illustration of concentrated production from the agricultural statistics board was published in the December 2007 issue of the *Quarterly Hog and Pigs Report*.

Hazards of Farming

The National Safety Council (2004) reported that agriculture is one of the most dangerous occupations, second only to mining. The Worker Health Chartbook (2004) confirms this danger with worker fatality rates in the two industries, i.e., 22.7 fatalities per 100,000 workers in agriculture and 23.5 per 100,000 miners. The third industry, construction, follows with a substantially less 13.3 deaths per 100,000 workers.

Agricultural workers and their families are at risk for occupational illnesses and injuries for several reasons (Frank, McKnight, Kirkhorn, & Gunderson 2004; Rautiainen, Lange, Hodne, Schneiders, & Donham 2004; Reed, 2004). First, farms are one of the few work sites in which the entire family participates. Families live, play, and work in environments with many potential health hazards. Second, farms are often exempt from government regulation because Occupational Safety and Health Administration (OSHA) regulations are only applied to farms or farming operations that employ more than 10 full-time workers excluding family members. Third, Rydholm and Kirkhorn (2005) reported that agricultural workers have less access to formal safety and health education and surveillance programs than workers in other industries. Finally, when workers sustain injuries, they often delay treatment due to the distance between farms and the nearest health care provider or emergency department and the cost of care (Kirkhorn & Schenker, 2002).

Farm workers are at risk for injuries from power equipment operation, heavy lifting, loud noises, and livestock encounters. A variety of farm-related diseases is caused by chemical and biological exposures and stress (Langley, McLymore, Meggs, & Roberson, 1997). Kirkhorn and Schenker, (2002) determined these exposures result in toxicities, zoonotic diseases, musculoskeletal disorders, hearing loss, respiratory illnesses, and psychosocial disorders.

Changes in swine production over the past 25 years have resulted in hundreds of animals receiving food, water, and care in small confined areas within a single building. Within these confined areas, animals deposit solid and liquid waste resulting in poor air quality (Donham, 1989). Biological breakdown of these waste products releases contaminants into the confined environment air. Workers are subjected to this environment inside the swine confinement buildings (SCBs) at least 8 hours a day, often 6 to 7 days each week. They are also responsible for removing waste that does not fall through the slatted floor. During this scraping procedure, workers breathe air high in contaminants, potentially damaging their lungs.

Research and Regulation

Considerable research has been conducted to identify the air contaminants in swine confinement buildings. Several chemical and physical irritants including ammonia, hydrogen sulfide, methane, and particulate matter have National Institute for Occupational Safety and Health (NIOSH) exposure limit recommendations. NIOSH recommends these limits based on scientific studies. The Occupational Safety and Health Administration is responsible for promulgating standards from these scientific studies and enforcing exposure limits. However, current OSHA limits have not been modified in the past 20 years or more. New knowledge generated by NIOSH has yet to be translated into OSHA regulations.

Occupational Health Nursing

Occupational health nurses practice in a variety of workplace settings. During the last 2 decades, occupational health nurses' roles have expanded into agriculture (Randolph & Migliozzi, 1993). One of the primary goals for occupational health nurses is the prevention of workplace injuries and illnesses. Occupational health nurses are needed in the agricultural industry because of the high incidence of accidents and resulting injuries as well as work-related illnesses.

The roles, tasks, and scope of practice for occupational health nurses in various industries differ because of company expectations and needs. Companies have diverse perspectives regarding the contribution of occupational health nurses to their profit margin. Often, the company's philosophy and relationship to employees determines the latitude granted occupational health nurses. Work-related injuries are on the rise and this creates financial burdens for the company as well as workers and their families due to lost productivity and revenue (BLS, 2008; Thomas et al., 2006). For instance, when a company wants to ensure the health of their employees, the occupational health nurse may be responsible for health promotion, screening, injury and illness prevention, and safety programs leading to a reduction in injuries and resulting increased productivity. However, if the company wants to maintain reporting requirements as directed by OSHA, then the focus is on injury prevention and treatment on site with a resulting decrease in recordable incidents due to corrective action.

Significance of Study

In the swine industry, production methods began to change in the mid 1980s (Donham, 1993). These new production methods were more cost efficient, reducing the amount of feed to produce a pound of pork. These new methods shifted production from a few animals on many farms to many animals in confinement buildings on few farms. The result of the shift in production concentrated not only animals but waste products as well.

Concentration of waste created an environment laden with biological airborne contaminants and gases that affect the respiratory systems of animals (Hamilton et al., 1999) as well as workers who spend up to 8 hours a day 6 to 7 days a week in the environment (Donham, Cumro, & Reynolds, 2002). Several contaminants, e.g. ammonia, hydrogen sulfide, carbon dioxide, methane, total particulate matter (dust), endotoxins, and bioaerosols, have been shown to cause respiratory changes among swine workers (McDonnell, Coggins, Hogan, & Fleming, 2008). Although many other gases have been identified in swine confinement buildings (SCBs), most are present in trace amounts and have not been linked to respiratory disorders in workers (Sigurdarson, O'Shaughnessy, Watt, & Kline, 2004). On the other hand, ammonia, hydrogen sulfide, and particulate matter have been determined to cause acute and chronic respiratory conditions in swine confinement workers (Schiffman, Studwell, Landerman, Berman, & Sundy, 2005). Particulate matter has been shown to cause bronchial inflammation in humans exposed to SCBs (Von Essen & Romberger, 2003)

Ammonia is an irritant gas with a sharp odor, a key intermediary in the nitrogen cycle in nature. This gas is released into the atmosphere of SCBs from the breakdown of urea in the urine of the animals. Once in the environment even at levels well below OSHA limits ammonia may cause eye, sinus, and skin irritation, coughing, wheezing, chest tightness, and other upper and lower respiratory discomforts. (Sundblad et al., 2004).

Particulate matter (dust) contains proteinaceous material ranging in size from less than 2 microns to 50 microns in diameter (Donham, Scallon, Popendorf, Trehaft, & Roberts, 1985a). Fecal particles are small and constitute the major alveolar burden in the lung (Donham & Gustafson, 1982). Grain dust is usually large particles and forms the major airway burden for workers (Donham, Yeggy, & Dague, 1985b). Other components present in dust include animal dander, broken bits of hair, insect parts, bacterial endotoxins, pollen grains, and fungal spores. Dust also absorbs ammonia and other toxic or irritating gases that may be affixed to respirable particles that can be drawn deep into the respiratory systems of workers and increase irritation or inflammation (Donham, Haglind, Peterson, Rylander, & Belin, 1989; Ivanov, Palmberg, Venge, Larsson, & Linden, 2005; Senthilselvan et al. 1997).

Epidemiologic studies reveal the most common respiratory symptoms manifested by workers in swine facilities are coughing, mucus production, bronchitis, wheezing, chest discomfort, organic dust toxic syndrome, airway hyperresponsiveness, and reduction in pulmonary function (Donham, Merchant, Lassise, Popendorf, & Burnmeister, 1990; Mueller-Anneling, O'Neill, & Thorne, 2006; Von Essen & Banks, 2009). Several cross-sectional studies have also demonstrated an increased number of respiratory disorders related to the indoor environment of swine confinement workers (Donham et al., 2007; Dosman et al., 2004; Preller, Heederik, Boleij, Vogelzang, & Tielen, 1995a; Radon et al., 2002; Wing & Wolf, 2000). Agricultural health nurses must safeguard workers' exposure to these respiratory hazards. Unfortunately, this particular problem has not been adequately addressed by the nursing profession due in part to limited specialty education in agricultural health nursing (Reed & Wachs, 2004).

Work Tasks

Production specialization and size of farms determines the number of workers employed on a farm. Farrowing-to-wean (FW) farms with 2,000 sows will typically employ seven workers. Farm managers coordinate work tasks to maximize animal production, provide husbandry training, order medications, maintain records and reports, and assist workers as needed to meet farm goals.

Farrowing house attendants, usually three, assist sows with the birthing process, feed sows, and take care of baby pigs. Pigs that are 3 days old must be processed, a cluster of treatments including two vaccinations, an iron injection, tail docking (cut off to 1 inch), and tattooing to identify the farm of origin. Male pigs are castrated and the incision site is sprayed with a disinfectant. Other farrowing house attendant duties include cleaning empty farrowing rooms after pigs are weaned, washing aisles, moving sows, and loading pigs onto trucks.

Three workers are assigned to the breeding and gestation barns. Their assignments include feeding, scraping behind sows, sweeping aisles, and breeding animals in estrus (heat). These tasks take most of each morning but time varies depending on the number of animals that have to be bred. Afternoon work includes loading sows into the farrowing rooms if needed, checking sows that have been bred for 35 days for pregnancy with a Doppler ultrasound machine, cleaning barns, and moving sows. Some farms require additional help in the farrowing rooms and workers are expected to assist as needed. It is common practice for all workers to arrive at work about the same time and remain on the job until all farm tasks are completed.

Research Questions

The first question posed for this research was "Is there a relationship between the work tasks of swine confinement workers and the exposure concentrations of ammonia and particulate matter?" Additionally, "Does the design of swine confinement barns affect the concentrations of ammonia and particulate matter?" During the summer months fans cycle on and off to keep the animals cool and remove moisture. Because of this phenomenon, another question seemed appropriate, "Is there a relationship between the number of fans running and concentrations of ammonia and particulate matter in swine confinement barns?"

Conceptual Framework

The researcher developed a model, a visual aid, of exposures that occur in SCBs and their effect on workers. The outer ring indicates the contaminants present inside the SCBs and discussed in literature (see Chapter 2) as agents that can affect the respiratory function of swine confinement workers. Along the bottom of the outer ring are four variables that may have an influence on contaminant concentrations: building design, temperature, relative humidity, and seasonal effects. According to O'Shaughnessy, Achutan, and Karsten, (2002), contaminant concentrations are relatively higher during winter months as compared to other seasons. In addition, variations were identified during the day as outside temperatures increased and warmer inlet air was drawn into the SCBs (Kim et al., 2007). Figure 1 shows the relationship of the occupational exposures swine confinement workers experience and how these exposures may alter workers' health.

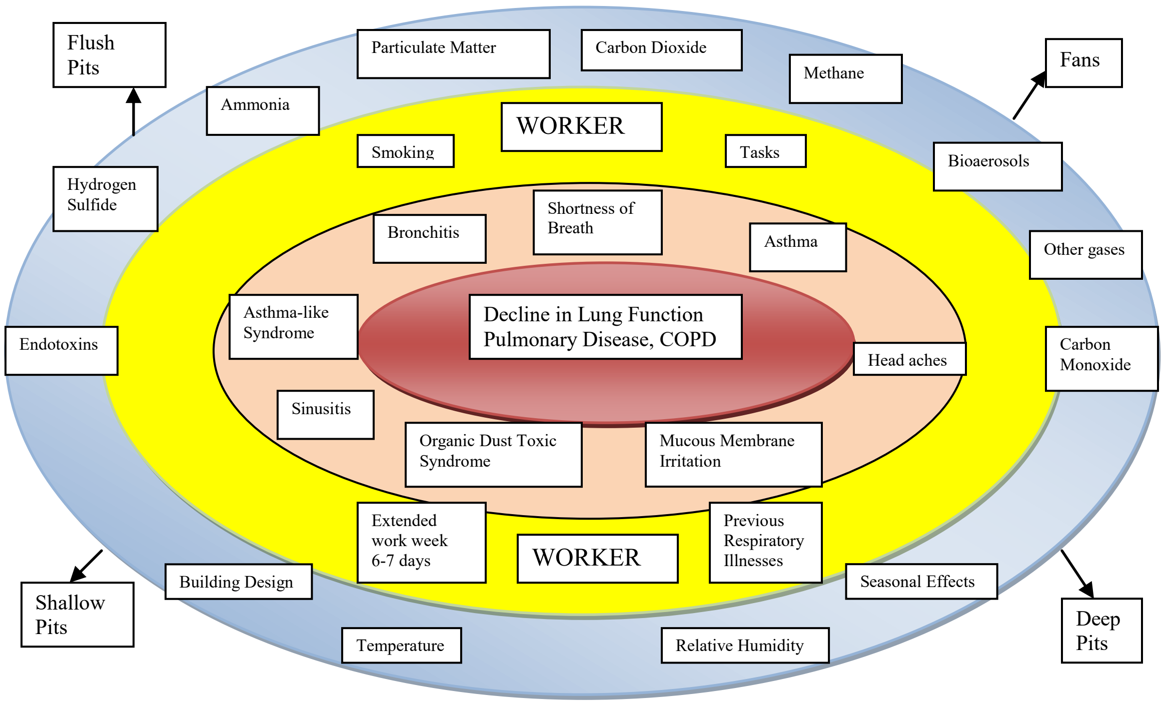

Figure 1. Swine Confinement Occupational Exposure Model

Building design is listed as a factor that affects the concentration of contaminants because the design may enhance or impede the exchange of internal air. Also, the building design determines the number of fans installed in the building and the number of animals housed in SCBs. As the inside temperature of the SCBs increases, the number of fans running also increases because the number of fans running determines the air exchange rate. Contaminant concentrations are inversely related to air exchange, i.e., contaminant concentrations increase as air exchanges decrease (Kim et al., 2007a). Therefore, fans are represented by an outward arrow indicating that fans can remove contaminants from the SCBs. The manure handling system, flush pits, shallow pit or deep pit, also affect the concentration of contaminants in SCBs (Patni & Clarke, 1991).

Relative humidity has also been documented in the literature as a key factor in the concentration of PM (Wing et al., 2008). Air sampling instruments are also affected by relative humidity. Instrument specifications indicate that relative humidity greater than 50% may decrease the accuracy of the instrument.

Building design is thought to affect contaminant concentrations within the SCBs. Each building design has a specific number of fans, size of fans, tunnel-ventilation system, and number of cool cells. However, the exact effect building design has on each contaminant is not reported in the literature.

The next level involves workers who can be exposed to any or all of the contaminants in the SCBs. The risk of contaminant inhalation is determined by contaminant concentration, length of exposure and respiration rate. The effect of these contaminants on workers' respiratory systems may also be related to their past health history, e.g., history of smoking, asthma, or other respiratory complications. This researcher suggests that tasks performed inside SCBs influence workers' exposure to ammonia and particulate matter.

Worker exposure may result in one or more acute illnesses listed in the next inner level. The ability of workers to tolerate changing acuity levels may determine how long workers stay employed in the swine industry. If workers are unable to return to work or illnesses persist then chronic disease develops, which may warrant workers leaving their jobs. Several researchers have documented that decline in lung function will occur over time (Iversen & Dahl, 2000; Radon et al., 2001; Senthilselvan et al., 1997; Vogelzang et al., 2000)

Definitions of Terms

Air exchange rate: the time it takes for the internal air to be completely exchanged with new air from the outside environment. The rate is influenced by fan design and number of fans running.

Auger system: a way of moving feed within a tubular pipe from the outside storage bin to the individual feed hoppers for each animal inside the swine confinement building.

Breeding barns: building where animals are placed for breeding and to ensure pregnancy.

Curtain-sided buildings: a construction design with open sides (for cross ventilation of the buildings) which can be closed with plastic curtains that are rolled up and down as needed to control the internal temperature of the barns.

Demographics: age, gender, length of employment in swine facilities, previous respiratory diagnosis.

Estrus: period of time when female animals are receptive to breeding.

Exposure threshold limits: the highest level of exposure considered safe for workers.

Farrow-to-feeder: farms that breed and farrow sows and retain the pigs at weaning. The pigs are sent to an on-site nursery and kept for about 8 more weeks or until the animals average 50 pounds.

Farrow-to-finish: these farms produce pigs and have several specialized barns that accommodate growing pigs; nursery, grower, and finisher barns. Pigs are raised to a market weight of 250 pounds and are shipped to slaughter plants directly from these farms.

Farrow-to-wean (FW): farms that specialize in the production of pigs until they are weaned from the sows. Pigs are usually 4 to 10 pounds and an average of 18 days old when they are shipped to an off-site nursery. This method of production is believed to control disease in young pigs.

Gestation barns: buildings where animals are placed after they have been checked to ensure they are bred. Sows usually stay here until 5 days prior to farrowing.

Heat checking: the process used to determine if animals are bred or are having another estrus cycle. This process is performed in the breeding and gestation barns daily.

Open-pit systems: waste storage areas that vent back into the SCB environment.

Partially slatted floor: a combination floor system, solid concrete at the front half of the animals and aisles and slatted areas at the rear of the animals. This design allows fecal matter and urine to fall through openings and collect under the flooring.

Particulate matter (PM): airborne dust and other aerosol components within swine confinement buildings that may be inhaled into the respiratory systems of animals and humans.

Pit flush system: a slightly sloping system for handling waste that allows animal excretions to fall through a slatted floor and be periodically flushed to an outside holding area using large amounts of water.

Retention pit system: a system that uses a partially slatted floor design through which urine and fecal matter fall into a water-filled pit. The pit with a water depth of 3 feet to 8 feet is regularly unplugged and allowed to wash outside to a holding lagoon.

Shallow recharge pit systems: 18 inch deep pits are located under the slatted floors. Water fills the pit to allow for the dissolution of waste products and is discharged once a week to once a month to an open lagoon outside the buildings.

Swine confinement buildings (SCBs): specially designed barns that house swine in individual crates or group pens. The size of these barns varies depending on the size of the farm and the number of animals that need to be housed.

Task-location: specific locations within the SCB in which specified tasks are completed.

Tunnel ventilation: the process of moving air through a building from the lower elevation end of the barn to the higher elevation end of the barn. This process requires the use of several fans at the higher elevation end. Air is drawn over a radiator cooling system at the lower elevation end of the barn to decrease air temperature and cool animals.

Summary

Agriculture is a dangerous occupation with many hazards that affect workers' health. Changes in animal production over the last 3 decades created a unique environment that increases worker exposure to hazardous chemical, biological, and physical agents. The purpose of this study was to elucidate task-associated ammonia and particulate matter concentrations in the SCBs to determine if specific tasks increase health hazard exposures for workers. Identification of ammonia and particulate matter exposure associated with individual tasks could direct recommendations for engineering or administrative controls or the need to wear personal protective equipment to reduce exposure.

CHAPTER 2

LITERATURE REVIEW

This chapter presents study-associated literature to better understand the effects of swine production on workers' respiratory health. An overview of the agriculture industry and common swine industry hazards are presented and swine production changes are acknowledged as generating new exposures that can adversely impact workers' health. Several contaminants in SCBs have been linked to respiratory diseases; however, this study focuses on two specific contaminants documented to affect workers' respiratory health in SCBs: ammonia and particulate matter. The relationship between tasks performed by swine confinement workers and potential exposure to ammonia and particulate matter is explored.

The Agriculture Industry

The agriculture industry, including farming, is one of the most dangerous in the United States with consistently high rates of work-related injuries and deaths (National Institute for Occupational Safety and Health, 2007). The farming workforce includes the operator (farmer) and family members, permanent employees, seasonal workers, migrant workers, and other contract employees (International Labor Organization, 2007). The farming workforce has been described as unique because their workplace is often also their home. Consequently, the farmer, family members and residential workers may be continuously exposed to agricultural hazards.

National Institute for Occupational Safety and Health (NIOSH) surveillance data from 2007 estimated that children and adolescents under the age of 20 who lived on, worked on, or visited farms experienced over 22,000 agriculture-related injuries. Youth who lived on farms accounted for more than 70% of all these injuries with 34% of the injuries attributable to work-related tasks. Youth are often injured when their job assignments exceed their development skills (Little et al., 2003).

Interestingly, two regions of the United States, the South and Midwest, accounted for almost 80% of all fatal farm injuries. Farm workers, including youth, are exposed to hazards such as machinery, tractors, grain storage bins, ponds, manure pits, and livestock that cause fatalities (Sprince et al., 2003). It is common for young and elderly workers as well as primary farm operators to perform simultaneous work assignments. According to Little et al., (2003), most youth are injured attempting to perform tasks beyond their developmental maturity or they lack the experience to consistently complete tasks successfully. The most frequent injuries are most often associated with youth and livestock interactions (Browning, Westneat, Donnelly, & Reed, 2003). Elderly workers have age-related sensory and musculoskeletal system decline that increases their risk for injury (Engler, 2002). Women are also at increased risk of injury as they are more involved with farming operations today than in previous generations and many are primary operators (Dimich-Ward et al., 2004).

Agriculture hazards can be categorized in four groups: physical, biological, psychological, and chemical. Within each category, several specific hazards are addressed in the literature. Farm work is diverse and includes: building construction, electrical repairs, mechanics, field repair of machinery, and a multitude of tasks associated with livestock and crop production. Versatile employee skills reduce the cost of repairs but may present additional hazards for workers.

Physical Hazards

Physical hazards may prompt visions of amputations, lacerations and trauma from rotating machinery, tractor rollovers, and grain accidents. Physical hazards in the farming environment also include noise, vibration, heat and cold, machinery, and livestock (Donham & Thelin, 2006).

Noise and Noise-Induced Hearing Loss. Hearing loss naturally occurs over the lifespan; higher frequencies (4000-6000 Hz) disappear first. Occupational hearing loss among farmers is a consequence of long-term exposure to noise in excess of 85 dB, resulting in a characteristic threshold shift to no more than 60 Hz (Holgers, Eelandsson, & Barrenas, 2000). Machinery used on the farm, including power chain saws, power posthole diggers, grinders, and other shop tools can affect hearing. McBride, Firth, and Herbison (2003) indicated that improvements in machinery design may lessen hearing loss among farmers. Choi (2005) also determined that noise acts as a stressor affecting job performance and increasing injury risk. Furthermore, farmers are more likely to hunt. The explosive noise from a gunshot is a significant risk factor for developing hearing loss (Donham & Thelin, 2006). Unfortunately, no treatment is available to reverse noise-induced hearing loss (NIHL).

Vibration and Injuries Related to Vibration. Whole body vibration (WBV) causes other health problems such as lower back pain and neurological disorders (Lings & Leboeuf-Yde, 2000). Tractors are a primary source of WBV and workers in feed grinding facilities have reported WBV neuropathy (Peplonska & Szeszenia-Dabrowska, 2002). According to Seidel (2005), long-term exposure to WBV can promote physiological changes in the spine that contribute to increased prevalence of low back pain among farm workers.

Hand-arm vibration syndrome (HAVS) is associated with the use of hand tools. Studies reveal that farmers who use high pressure washers and other machinery that vibrate can experience white finger syndrome (Raynaud syndrome), intermittent blanching of fingers, and hand blanching from vascular spasms of the arteries (Palmer et al., 2001a). The use of vibration tools is also believed to increase the incidence of carpal tunnel syndrome (Badger, O'Donnell, Sherigar, Connelly, & Spence, 2008; Hagberg, Morgenstern, & Kelsh, 1992; Palmer, Griffin, Syddall, Cooper, & Coggon, 2001b).

Heat and Cold. Few studies have been published related to heat and cold stress at work and almost none have focused on farmers. However, farmers are exposed to variations in weather that put them at risk for health complications. Heat exposure may result in heatstroke, an emergency that occurs when the body can no longer cool itself and body temperature elevates rapidly (Argaud et al., 2007). Additionally, less serious effects of heat are cramps, exhaustion, skin rashes, and syncope. Prolonged heat exposure can decreased sperm viability and result in male infertility (Jensen, Bonde, & Joffe, 2006; Yaeram, Setchell, & Maddocks, 2006).

Prolonged exposure to cold can result in hypothermia, body temperature less than 35º C. At this temperature, the muscular system initiates shivering to generate heat. Work capacity and oxygen absorption decrease due to depleted muscular energy (Wang, Ke, & Lin, 2005). As physical exhaustion increases, confusion, apathy, and hallucinations may occur. Below 33º C, cardiac depolarization is slowed reducing cardiac output that can result in loss of consciousness. Localized hypothermia of extremities can cause frostbite and tissue death (Roche-Nagle et al., 2008).

Hazards Causing Work-Related Musculoskeletal Disorders. Farmers lift heavy fertilizer, feed, seed, and chemical bags from ground level to overhead, increasing strain on shoulders as well as back muscles (Voaklander, Umbarger-Mackey, & Wilson, 2009). Due to strenuous work on farms, chronic joint pain, including the joints of the lower back, is common (Rosecrance, Rodgers, & Merlino, 2006; Walker-Bone & Palmer, 2002). Neck injuries may result from trauma, repetitive reaching overhead, or whiplash from collision of farm equipment and motorized vehicles. Shoulder injuries often result from repetitive motion and excessive force required during farm tasks (Nonnenmann, Anton, Gerr, Merlino, & Donham, 2008). The elbow, wrist, and hand can develop nerve impingement, i.e., carpal tunnel syndrome and tennis elbow from repetitive motion (Palmer et al., 2001b). Farmers also have an increased prevalence of osteoarthritis in the knees and hips compared to the general population (Holmberg, Thelin, Stiernstorm, & Svardsudd, 2005; Walker-Bone & Palmer, 2002).

Animal handling incidents can result in multiple ligament and cartilage injuries of the upper and lower extremities. When animals are restrained in chutes for treatment and identification tag insertion, they move precipitously causing injuries to workers. Injuries can be mild, i.e., soft tissue injuries, to severe, i.e., fractured bones (Mariger et al., 2008).

Psychosocial Hazards

Stress. Mental health is a particular concern for farmers. Holmberg, Thelin, Stiernstorm, and Svardsudd, (2004) discovered that a larger percentage of farmers live alone than workers in other occupations who have supportive spouses and positive family dynamics that tend to reduce stress. Modern agricultural practices have altered the historic perception that all family members work together on the farm. Due to technological changes in farming over the past 3 decades, many farmers now till large acreage by themselves and spouses work off the farm (Martin, 2001). Isolation can also result in depression and cause stress within the family. Working off the farm can adversely impact day-to-day communication; spouses have difficulty understanding each other when they try to share their work experiences. Women who work off the farm often feel obligated to assist with farm chores and assume primary responsibility for children and the house, compounding their stress (Martire & Schulz, 2007; Stohs, 2000).

Governmental regulations related to farming have also increased over the past few decades resulting in compliance issues and potential penalties, another source of stress (Booth & Lloyd, 2000). The media have highlighted inhumane treatment of animals and toxic chemical application spills that affect societal perceptions of how farmers handle animals and their concern for the environment, another stressor (Thorne, Ansley, & Perry, 2009). Farmers believe a cultural gap exists between urban and rural residents due to misunderstandings and a lack of trust (Booth & Lloyd).

Depression. According to Levi and Levi (2000), chronic stress can exacerbate health problems such as cardiovascular diseases, diabetes, obesity, and depression. The etiology of depressive symptoms in farmers has been linked to acute agricultural crises (Lovelace, 2005). When animals have to be slaughtered to prevent the spread of disease with no financial compensation, farmers experience additional stress. This situation was reported in the mid 1990s when the porcine influenza respiratory syndrome (PIRS) virus caused third trimester abortions in gestating swine. The swine farmers could not avoid the virus that infected herds all across the United States. Prolific animals that normally farrowed 10 to12 live pigs were producing only half that number of live births. Overhead costs remained the same, but production was insufficient to cover operational costs. Despite farmers' attention to detail, one new virus altered the profitability of entire swine operations.

Suicide. The suicide rate among farmers is higher than comparable populations in urban settings (Woo & Postolache, 2008). Thomas et al., (2003) reported high risk of suicide among farmers in Britain. Increased mental health morbidity in rural settings has been attributed to decreased availability of mental health professionals (Sawyer & Lambert, 2006). In addition, many farmers find it impossible to leave the farm for an appointment with a healthcare professional, especially during planting and harvest times. Every daylight hour must be spent in the fields or on the farm working. Finally, farmers often have access to firearms, the most common means of suicide among farmers (Booth, Briscoe, & Powell, 2000).

Biological Hazards

Zoonotic Diseases. Acha and Szyfres (2003) defined zoonotic diseases as infections common to animals and humans. According to the World Health Organization (WHO), zoonoses are infections that are naturally transmitted between nonhuman vertebrate animals and humans (Marano & Pappiaoanou, 2004). Over 200 animal diseases exist worldwide; however, only about 40 are of concern to agricultural workers (Donham, 1985). Zoonotic diseases are categorized according to their etiological agent (see Table 1).

Table 1

Zoonotic Infection and Causative Agents, Adapted from Donham & Thelin (2006)

Zoonotic Infections	*Bacterial*	*Viral*	*Parasitic*	*Fungal*	*Protein Particle*
Disease Examples (Common names)	Anthrax Brucellosis Colibacillosis Lyme Disease	Hantaviruses Rabies Hepatitis E	Echinococcosus Trichinosis Tape Worm	Histoplasmosis Dermatophytosis Blastomycosis	Variant Creutzfeldt Jacob Disease Mad Cow disease

Pharmaceuticals. Modern livestock production uses antibiotics, immunizing agents, and other therapeutics to promote growth, prevent disease, and maintain animal health (Lathers, 2001). Use of antibiotics in feed poses several risks for workers. During the feed grinding process, antibiotics can come in contact with workers' skin or aerosol can be inhaled by workers.

Additionally, many antibiotics are injected into livestock and handlers can inadvertently inject themselves. In both cases, workers sensitive to antibiotics can experience severe reactions (Schmidt, 2002). Surface bacterial growth of some fruit crops is reduced by spraying antibiotics (Teale, 2002). The widespread use of antibiotics has resulted in increased antibiotic-resistant organisms that amplify health risks for agricultural workers (Larson, 2007; Padungton & Kaneene, 2003; Sengelov et al., 2003).

Chemical Hazards

Pesticides. Pesticides are chemicals that kill specific undesirable species that are economically, socially, or healthwise detrimental to humans. According to Farahat et al., (2003), pesticides contain 675 active ingredients and over 16,000 formulations are marketed for a wide variety of applications. Insecticides, herbicides, and fumigants pose health risks to agricultural workers (Reeves & Schafer, 2003).

As with many occupational illnesses, incidence and prevalence of pesticide poisonings are only estimates (Litchfield, 2005). Pesticide poisoning may not be reported because it is mild and often dismissed by farmers as simply a cold or influenza. Second, most agricultural workers do not seek health care unless it is a serious illness, especially during planting and harvest time. Third, farm workers who are undocumented fear authorities will deport them or the language barrier may prohibit effective communication with health care providers. Fourth, a diagnosis of pesticide poisoning by health care providers may be overlooked because symptoms are vague and mimic other diseases and illnesses (Calvert, Plate, & Das, 2004; Mage et al. 2000)

Dosemeci et al., (2002) developed an algorithm of 6 factors that could lower the chronic pesticide exposure of farmers. Closed mixing systems reduce the chance of spills in the environment and on personnel. Proper equipment, i.e., tractors with enclosed cabs and charcoal air filters, protect farmers during pesticide application. Limiting the washing of equipment can minimize the risk of splashing pesticides on workers. Finally, appropriate hygiene, increased frequency of bathing, handwashing, and changing clothes and gloves are essential after spills.

Acute toxic exposures have three consistent causes (Mage et al., 2000). The most common cause of exposure is failure to follow labeled instructions. However, sometimes instructions are not written in workers' languages or workers need training to ensure proper handling and storage of pesticides. Sometimes unanticipated situations occur such as hoses rupturing or pesticides accidentally spilling, contaminating workers (Mage et al.).

Respiratory Hazards. Farmers are exposed to a wide variety of agents harmful to the respiratory system; exposures vary depending on the type of agricultural operation. Some workers may be exposed daily to substances originating from soil, exhaust fumes from machinery, pesticides, fertilizers, animal waste and waste by-products, and plant decay or fermentation residues (Kern et al., 2001; Lee et al., 2006). Table 2 summarizes sources of agriculture exposures that could lead to respiratory disease and the primary causative agents.

Table 2

Sources of Respiratory Contaminants, Adapted from Donham and Thelin, (2006)

Animals	Plants	Insects	Pesticides	Feed Additives	Microbes Metabolites	Infectious agents	Gases & Fumes
Dander Dried fecal material Hair follicles	Grain dust Tannins Glucans Plant particles	Insect parts Feces of mites and roaches	Fumigants Insecticides Residues	Antibiotics	Endotoxins Mycotoxins	Bacteria Fungi Viruses Rickettsia	Anhydrous ammonia Hydrogen sulfide Welding fumes Animal waste

Many factors contribute to individuals' respiratory responses to inhaled gases, infectious agents, and particulate matter (dust). According to Singh and Davis (2002), exposure to complex mixtures, chemical concentrations, workers' genetic susceptibilities, smoking history, and duration of exposure are key factors in determining the incidence of respiratory diseases.

Agricultural dusts are complex mixtures of organic matter. Farmers exposed to dust exhibit a cluster of respiratory symptoms including mucous membrane irritation, non-allergic asthma-like conditions, and acute bronchitis (Rylander, 2004). Genetic variations also affect individuals' responses to agriculture dust inhalation (Kline et al, 2004). However, characteristics of specific dusts may increase the respiratory responses of particular individuals (Mathisen, Von Essen, Wyatt, & Romberger, 2004). Dust exposure causes farmers' lung (FL), organic dust toxic syndrome, bronchitis, and airway obstruction and may prompt asthma attacks in susceptible individuals (Schenker, 2005).

Farmers who produce and use silage can be exposed to nitrogen oxides when filling and emptying silos or silage bunkers. Inhalation of nitrogen oxide at low levels may illicit mild symptoms such as fatigue, nausea, vertigo, or vomiting. With prolonged exposure, symptoms last for weeks. Additionally, pulmonary edema can develop within 30 hours of exposure to high levels of nitrogen oxide. Without proper health care and observation, workers can develop acute respiratory distress.

The Swine Industry

Changes in swine production have created poor worksite air quality. Hundreds of animals are placed in one building and receive food, water, and care in small confined areas. Within these areas, the animals also deposit solid and liquid waste with a foul odor and contaminants are released into the enclosed environment (Osterberg & Wallinga, 2004). Farmers work in this environment at least 8 hours a day 6 to 7 days a week. Part of the workers' responsibility is to remove waste that does not fall through the slatted floor. During this time, workers are breathing air high in irritants, potentially damaging their lungs.

Human Health

Considerable research has focused on contaminants found in confined animal feeding operations (CAFOs) (Donham, 1993; Donham & Gustafson, 1982; Donham, Hagland, Peterson, Rylander, & Belin, 1989; Heederik et al, 2007; Kirkhorn & Schenker, 2002). Swine confinement buildings have been found to be contaminated with over 300 volatile organic compounds and fixed gases (Palmberg, Larsson, Malmberg, & Larsson, 2002; Schiffman, Bennett, & Raymer, 2001). Most of these gases are present in low amounts and contribute to the characteristic odor identified with swine operations. Several contaminants including ammonia, hydrogen sulfide, methane, carbon dioxide, carbon monoxide, and dust have exposure limits established by the Occupational Safety and Health Administration (OSHA) based on research from the National Institute for Occupational Safety and Health (NIOSH). However, OSHA standards and NIOSH guidelines often differ. NIOSH makes recommendations for standards based on scientific studies. The Occupational Safety and Health Administration promulgate standards with exposure limits based on NIOSH research but also taking into account economic "feasibility". Thus, many limits have not been modified for more than 20 years. Therefore, new knowledge that has been generated by NIOSH has yet to be implemented.

OSHA standards are designed to minimize occupational hazards and only minimally affect production. Ammonia and PM levels are rarely found in excess of established limits; yet the prevalence of agricultural-related diseases is well documented in the literature (Donham, Merchant, Lassise, Popendorf, & Burnmeister, 1990; Iversen & Dahl, 2000; McDonnell, Coggins, Hogan, & Fleming, 2008). Questions still remain about the prevalence of respiratory complications among workers in SCBs.

An exhaustive search of relevant literature including dissertation abstracts revealed few research studies addressing health hazards associated with specific tasks routinely performed in SCBs. A knowledge gap regarding workers' use of personal protective equipment when performing specific tasks or if specific tasks increase worker exposure was found.

The swine industry provides a unique set of agricultural hazards including exposure to odors, noise, trauma, fires, explosions, electrocution, thermal stress, accidental poisoning, pathogens encountered in manure and water, drowning, volatile compounds, dust, heavy lifting, musculoskeletal injuries, and emotional and financial distress (Day et al, 2009; Frank, McKnight, Kirkhorn, & Gunderson, 2004). Swine industry hazards were for consistency grouped into four categories: (1) physical, (2) psychosocial, (3) biological, and (4) chemical. In an effort to reduce redundancy, only hazards specific to swine confinement workers are discussed.

Physical Hazards

Noise and Noise-Induced Hearing Loss. In the morning as workers arrive, sows are eager to eat. The animals squeal and are conditioned to continue squealing until feed drops. The high pitched sound of 850 animals squealing at one time can affect hearing if workers do not wear hearing protection. Humann, Donham, Jones, Achutan, and Smith (2005) indicated that when animals hear employees arriving at the farm, noise ranges from 61 to 78 dB; once animals begin to eat, the noise level increased to more than 100 dB. This level is well above the OSHA exposure limit of 85 dB; prolonged exposure to 85 dB or louder is hazardous to workers' hearing. Hearing loss usually affects frequencies between 4000 Hz and 6000 Hz initially. As time goes on, loss of hearing impairs individuals' ability to hear the higher pitches of human speech (3000Hz). Combined with presbycusis (normal aging changes in hearing), workers can experience communication disability. Associated with noise-induced hearing loss, workers also report tinnitus or ringing in the ears (Humann et al., 2005)

Vibration and Injuries Related to Vibration. Pressure washing the breeding and gestation barns exposes workers to hand vibration. Hand-arm vibration syndrome resulting from high pressure washer systems similar to those employed in SCBs was reported by Cooke, House, Lawson, Pelmear, and Wills, (2001). The extent of damage that may occur is related to the amount of vibration and duration of exposure. It is noted that most washing occurs during the warmer months to avoid additional thermal stress to the animals. Some workers who use high pressure washers experience vibration-related injuries while others seem to be unaffected.

Work-Related Musculoskeletal Disorders. The sows and boars on a farrowing operation usually weigh 450 pounds or more and have the potential to cause serious damage to employees' feet and toes if the pigs step on workers' feet. When animals are turned out of the gestation crate, they have a tendency to run down the 3-foot wide aisles and collide with workers causing injury. These physical injuries are usually not devastating but some result in fractures of the ribs, lower extremities, arms, and shoulders and may require the orthopedic correction of joints (Gordon & Rhodes, 1996). The crates where the animals are housed are made of metal and a double-hinged gate is at the front and back of the crate. This design allows for ease in moving animals because they only have to walk forward, an easier way to handle large animals. Long metal rods hold the gates on the crates. Removing and replacing the safety pins sometimes causes pinching injuries to workers. These injuries may not result in lost work time but frequent adverse health outcomes have been documented (Frank et al., 2004). Pinching injuries also occur when performing machinery maintenance on the farm.

Lacerations can occur when animals bite workers. Biting injuries are usually difficult to suture and wound healing is sometimes slow due to an inoculation of bacteria from the animal. Workers should not be allowed back into the barns until the wound has totally closed, which may take weeks. Several articles have been written recently documenting the presence of methicillin-resistant staph aureus (MRSA) in SCBs (Selbergeld, Graham, & Price, 2008).

Not all physical injuries result in lost work time. Many employees with physical injuries can be assigned to modified duty for a short period to complete recovery from the injury.

Psychosocial Hazards

Stress. Swine confinement workers experience stressors similar to those in nonfarm employer-employee relationships. However, Loboa and Stofferahn (2007) suggested that odor and noise in SCBs are precursors to stress reactions in agricultural workers. Perceptions about industrial farming are detrimental causing additional stress for swine confinement workers and owners. Workers may also be concerned about possible infections from animals, loss of employment, and even legal status.

Biological Hazards

Swine require several vaccinations during the course of their lives. Hundreds of animals must be vaccinated in a short time period during which workers are usually moving with such rhythm that at times they may inject or vaccinate themselves before they can stop their motion. According to Mousel, Leed, White, and Herrmann-Hoesing (2008), needle sticks are common in livestock husbandry. Needles are not changed between animal injections, needles are not sterilized, and multiple organisms are present on the skin of animals including fecal organisms. Another concern is that needles used to inject swine are usually large bore needles (16-14 gauge) and because of repeated use are not sharp. When these needles enter human flesh they create a more severe injury at the injection site; larger trauma sites and injected organisms may slow the healing process (Plumb, 2002).

Chemical Hazards

Pesticides. Swine workers are exposed to particular pesticides that vary depending on the size of the farm. In larger companies, a pesticide specialist may handle all the outside pesticides because of regulations and licensure requirements associated with them. Inside the SCBs, swine workers may have to spray insecticides to control spiders and roaches. Additionally, rodenticides are required inside SCBs because feed attracts mice and rats. Flies are a chronic problem; however, the shallow recharge pit system reduces fly populations.

Hydrogen Sulfide. Hydrogen sulfide is one of the most dangerous gases arising from the storage, handling, and decomposition of animal wastes. Continuous exposure to hydrogen sulfide can affect workers' ability to detect the rotten egg smell, producing shortness of breath, cough, eye and nasal irritation, headache, nausea, rapid loss of consciousness, lactic acidosis, and even death (Mitloehner & Schenker, 2007). Most deaths associated with hydrogen sulfide toxicity are workers entering confined spaces under slatted floors to clean the pit or individuals trying to rescue an unconscious worker in the absence of a compliant confined space entry program with permits, purging, harnesses, and fitted respirators.

Endotoxins. As gram-negative cell walls are destroyed, endotoxins are released. Considerable research over the last 10 years has documented the role of endotoxins in the inflammatory response of exposed workers' respiratory systems (Charavaryamath & Singh, 2006; Charavaryamath, Janardhan, Townsend, Willson, & Singh, 2005; Heederik et al., 2007; Kirkhorn & Garry, 2000; Madsen, 2006). Endotoxins attach to dust particles and are inspired into the lungs. Dust particle size determines the depth of inhaled endotoxin deposition. The respiratory distress response may be mild to severe depending on the amount of lung tissue involved (Mathisen, Von Essen, Wyatt, & Romberger, 2004; Romberger, Bodlak, Von Essen, Mathisen, & Wyatt, 2002; Wyatt, Sison, Von Essen, Poole, & Romberger, 2008). Vogelzang et al., (1998) emphasized that several studies have reported endotoxin exposure associated with decline in lung function; however, researchers have been unable to isolate the effects of endotoxins alone. Specialized testing assays are required to measure the concentrations of endotoxins; this research project did not have the monetary resources or skilled personnel to determine endotoxin concentrations in SCB dust.

Ammonia. Ammonia is an irritant gas with a sharp odor, a key intermediary in the nitrogen cycle. This gas is released into the air of swine confinement buildings after the breakdown of urea in the urine of animals. Once in the environment, ammonia may cause irritation of the eyes, sinuses, and skin, as well as coughing, wheezing, chest tightness, and other upper and lower respiratory symptoms.

According to Takai et al., (2002), ammonia can affix to dust particles that are then inhaled by workers. Inhaled dust ranges from 1 to 6 µg per mg in swine houses and the ammonia content is equivalent to 1000 to 6000 ppm on a weighted basis. Respirable dust was found to have even higher ammonia contamination at 7000 ppm. Respirable dust can deposit in alveoli tissue in the lower part of the lung. The ammonia on the dust particle is easily vaporized in the presence of water causing lung damage.

Particles deposited in the nose may also contain ammonia capable of desensitizing the olfactory organ and affecting the perception of odor. Ammonia irritates the mucus membranes of the nasal tract and initiates a cascade inflammatory response (Brautbar, Wu, & Richter, 2003; McDonnell et al., 2008; Sundblad et al., 2004). Some of the ammonia-associated symptoms reported in the literature are scratchy throat, runny nose, cough, and burning eyes (Lacey, Redwine, & Parnell, 2003; Smeets et al., 2007).

Particulate Matter. Particulate matter (PM) is a complex mixture of potentially hazardous compounds. Feed dust, animal dander, dry feces, molds, pollen, insect parts, and hair follicles are primary constituents of PM found inside SCBs (Donham, 1989; Donham & Gustafson, 1982; Donham & Popendorf, 1985). Sigurdarson, O'Shaughnessy, Watt, and Kline, (2004) suggested that ammonia and perhaps other toxic gases affix to dust particles. Combinations of respiratory irritants sometimes produce a synergistic effect. Donham, Cumro, and Reynolds, (2002) suggested that the synergy of ammonia and dust could produce 2 to 4 times the respiratory airway hyperreactivity of a single exposure of dust or ammonia. Additionally, dust may contain antibiotic residues that can cause hypersensitivity reactions in SCB workers (Cole, Todd, & Wing, 2000; Hamscher, Pawelzick, Sczesny, Nau, & Hartung, 2003).

A cluster of symptoms in swine workers have been identified in the literature over the past 15 years. Symptoms in order of prevalence include cough with or without sputum or phlegm, scratchy throat, runny nose, burning or watering eyes, headaches, chest tightness, and shortness of breath (Donham, 1993). These symptoms are more common and severe in individuals with a history of respiratory risk factors, i.e. asthma or smoking.

Besides acute reactivity, longitudinal studies have reported a decline in respiratory function, FEV1 and FVC, among farmers that is not attributable to normal aging (Cormier, Israel-Assayag, Racine, & Duchaine, 2000; Radon et al., 2001; Senthilselvan et al., 1997; Vogelzang et al., 2000). Some researchers have suggested that respiratory reactivity to swine barn dust may produce a "healthy worker" effect; workers who experience respiratory reactivity resign from their jobs due to repeated respiratory complications so only health workers are left (Chenard et al., 2007; Preller, Heederik, Krombout, Boleij, & Tielin,1995b). Donham (1991) suggested that three groups of workers explain the "healthy worker" effect. In group 1, workers are so reactive to the SCB environment that they do not maintain employment for even 1 year. The second group continues to work in SCBs but, after 6 years, respiratory symptoms increase in frequency and these workers are unable to continue working in animal production. The last group has symptoms but they are not severe enough to change jobs.

Summary

Over the last 30 years, researchers have identified contaminants within the SCBs. Studies delineate worker responses to contaminant exposures. Information has been gathered to explain the respiratory and immune responses to the contaminants, both acute and chronic. However, few studies have identified tasks within the SCBs that increase worker exposure to the aforementioned hazards. This study was conducted to quantify the association between tasks and exposures to determine if the tasks performed contribute to the occupational hazards of swine confinement work.

CHAPTER 3

METHODOLOGY

Chapter 2 highlighted published research studies about potential health hazards within swine confinement buildings and workers' responses to these contaminants. However, a knowledge gap was found related to the effect of task-associated exposures for swine confinement workers. Thus the research questions, Is there a relationship between the work tasks of confined swine farm workers and the concentrations of ammonia and particulate matter to which workers are exposed?, Is there a relationship between number of fans running and concentrations of ammonia and particulate matter in SCBs?, and Does the design of SCBs affect the concentrations of ammonia and particulate matter?, remain unanswered.

Chapter 3 describes the research design and the rationale for choosing a quantitative descriptive correlational method. Sample selection, instrumentation, data collection procedures, ethical considerations, and data analysis methods will also be described.

Pilot Study

The aim of the pilot study was to determine if specific tasks performed during routine work in the SCBs increased respiratory irritancy and if agricultural workers could identify where in the SCB ammonia and particulate matter were in highest concentration. The pilot study was a first step in identifying task locations within SCBs that could promote respiratory responses in SCB workers.

The initial research question, "Does irritancy reported by swine confinement building (SCB) workers' in specific task-locations correlate with air contaminant concentrations of ammonia and particulate matter?" guided the chosen research design, quantitative descriptive correlational design. The pilot study was nonexperimental and used observation to describe and document situations as they naturally occurred. The investigator had no control over the independent variable and did not manipulate the environment. This method is particularly appropriate when little existing knowledge about a particular problem area exists (Polit & Beck, 2008). The pilot study delineated respiratory irritancies experienced and reported by swine workers at specific task-locations while performing routine work.

Pilot Setting

The pilot study was conducted on a 2000-head farrow-to-wean (FW) sow farm because it was representative of swine confinement operations throughout the United States and the farm owner was willing to allow the researcher to collect data on the farm. Several family members were involved in day-to-day operation of the farm, although additional workers were needed to complete all tasks in the swine operation. External appearance of the farm indicated a well organized and clean operation. Resources were located in designated areas and grounds were free of trash and well maintained.

The farm had two breeding and gestation barns, a farrowing and office barn, and a workshop. Each of the breeding and gestation barns housed approximately 800 animals. Typically, five workers are employed on a farm of this size, i.e., a manager and owner, two breeding and gestation workers, and two farrowing house attendants. The manager maintains production reports submitted to the central office each week and assists with animal care 50% of the time.   Breeding and gestation workers are responsible for daily breeding of sows in estrus, feeding animals, heat checking for recycling animals, moving sows, cleaning barns, and assisting farrowing house attendants as needed. Farrowing house attendants sort and move piglets as needed to ensure viability, castrate piglets, feed sows, and clean the farrowing house.

Workers begin their work days at varying times. During week days, workers arrive at 0700 except on Wednesday when pigs are weaned and all workers report at 0500 to assist with shipping. On the weekend, three workers care for all farm animals and begin work at 0600. Workers are scheduled to work 12 consecutive days before a 2-day weekend off. However, if a worker is unable to work, an employee scheduled off may be required to work. Consequently, the work week may be longer than 12 days.

Access to facilities is restricted to prevent introduction of disease to the breeding herd. Permission from the owner must be obtained prior to entry. The policy requires that visitors have had no contact with other swine in the past 30 days. To restrict introduction of bacteria, workers are required to shower in and out of the facility.

Barn Characteristics. Barns were 60' wide and 320' long, curtain-sided, and tunnel ventilated with insulated tin roofs. Inside the barns, aluminum ceilings were installed to conserve animal heat during colder months. A partially-slatted floor system allowed animal excrement to fall through small openings into a pit flushed periodically by four 250-gallon flush tanks located at the high end of the barn. Effluent from an outside lagoon was used to fill the tanks and every 4 hours two of the four gutters were flushed. The gutters under the slatted floors have a 0.5% slope allowing gravity to encourage the flow of waste. At the lower end of the barn, several 50 foot, eight-inch diameter polyvinyl chloride (PVC) pipes move the discharge to the lagoon. Most animals were in individual crates.

Barn 2 was designed like Barn 1 except for the flush system. In Barn 2 under the slatted floors was a holding pit that collects feces and urine. The pit was about 2 feet deep and water is held in the pit for 10 to 14 days. To remove the collected excretions, three stoppers are removed simultaneously and the discharge is allowed to flow to the lagoon. After draining, the pit is refilled with one foot of water. The pit system is designed so that overflow can move into the top of the pipes if the system is not drained during the 2-week period. This safeguard prevents the effluent from backing up inside the barn.

Barn 1 was located about 75 feet from a wooded area and at a lower elevation than Barn 2. On the west end of Barn 1, a farm workshop blocked most of the northern winds, resulting in a warmer barn than Barn 2. Barn 2 was located at a 15 to 20 foot higher elevation with pasture on the south, east, and west sides. Part of the increased elevation was necessary to accommodate the retention pit system associated with the building design. The office and farrowing unit was located on the north side of this barn.

Ventilation System. Each barn had 7 fans on the lower end of the building toward the lagoon. The center fan, called the minimum ventilation fan, runs continuously to provide fresh air for the animals and workers regardless of the temperature inside the barn. If inside temperature reaches 68º F, a second fan is activated. With each 2ºF increase, another fan is activated. At 78ºF, all fans should be running. However, if the temperature continues to increase to 80ºF, the cool-cell system is activated and water drips over radiator-type coils to cool air as it enters the internal environment. In tunnel ventilated buildings, air is drawn from the upper end of the building through an opening covered by course paper designed like a radiator in a car. If the barn temperature exceeds 80º F, a pump in the reservoir circulates water over the paper grids and air is cooled as it flowed through the system. Moist air and substantial airflow cools the barn. Because swine have no sweat glands, it is imperative that internal barn temperature be controlled to maximize animal productivity and comfort.

All fans in this facility were four foot fans (50") and had the potential to move 20,100 cubic feet of air per minute. Several factors can alter the efficacy of the fans including dust accumulation on the internal louver and fan blades and external factors such as wind speed and direction, rain, fog, and outside temperature.

Sample

Because the entire population of swine confinement workers could not be accessed due to cost and time constraints, a convenience sample of workers willing to participate in the pilot study was selected. Convenience sampling can result in atypical participants from the population appropriate for the study (Polit & Beck, 2008). For example, some eligible participants may elect not to participate in the study because they have current respiratory symptoms or complications, i.e. bronchitis, asthma, or sinusitis. Minimal exclusion criteria increased the number of eligible participants for the study.

Participant Recruitment. Recruitment for the pilot study began after securing consent from the sow farm owners and East Tennessee State University Institutional Review Board. Initial information about the study was presented at the monthly managers' meeting and a flyer asking for volunteers was distributed for posting on each farm. Contact numbers on the flyer allowed participants to contact the researcher directly.

Criteria for Participants. Study participants must have worked in the SCBs for at least 1 year and assigned to either the breeding or gestation barns as their primary barn location. Only swine confinement workers over the age of 18 and able to speak and write in English were included. Participants unable to answer questions or complete the survey were also excluded. Other exclusion criteria included cognitive impairment and recent changes in health status as indicated by short-term or long-term disability.

The researcher personally asked each worker to participate in the study and explained the consent form including workers' right to withdraw from the study at any time. After a worker consented to participate in the study, demographic data were recorded for each participant during face-to-face interviews. Each participant was assigned a study identification number and no names were recorded to protect participants' identities. Workers of both genders were encouraged to participate in the study; however, only two workers from this farm were included in the pilot study although each worker who met the inclusion criteria had the opportunity to volunteer.

Instrumentation

Questionnaire. A questionnaire was designed by the researcher to collect demographic data and report any previous respiratory symptoms (Appendix A). Demographic data included age, gender, smoking history, education, number of years employed in SCBs, and any previously diagnosed respiratory diseases. Items 8 and 9 specifically asked workers to identify any respiratory symptoms they had experienced and indicate the task-locations that elicited the reported symptoms. The questionnaire was completed through a face-to-face interview in an isolated area to protect the confidentiality of worker responses and ensure that the questionnaire was understood. Workers were prompted to ask questions or make comments. One of the items on the questionnaire asked workers if they had experienced respiratory symptoms while working in the SCBs. This information was transferred to the Bembry Task Analysis Worksheet (Appendix A). Reported symptoms were indicated in the appropriate symptom column "R". Any symptom that occurred while the data were being collected in the gestation and breeding barns was recorded at the time of occurrence in the column labeled "O".

Bembry Task Analysis Worksheet. The task analysis worksheet was generated by the researcher from study data collected at the University of Iowa (2009). University of Iowa researchers asked swine confinement workers to record routine tasks performed on farms during their regular work week. From these data, the researchers categorized 200 items into several categories that included all tasks performed on swine farms. The Bembry Task Analysis Worksheet is specific for tasks performed in the breeding and gestation barns. The horizontal axis identified tasks: feed drop, feeding, scraping slatted floors behind sows, sweeping feed aisles, breeding, completing breeding cards, heat check, refilling feed lines, and walking along back aisles or pens. The vertical axis identified the most prevalent respiratory symptoms documented in the literature (Donham & Thelin, 2006): cough with and without sputum or phlegm, scratchy throat, runny nose, burning or watery eyes, headache, chest tightness, shortness of breath, wheezing, and muscle aches and pain. Subdivisions indicated on the vertical axis were used to record symptoms reported ("R") by workers and symptoms observed ("O") by the researcher.

Air Sampling Instruments. The Aeroqual Series 500 monitor was used to measure ammonia content in parts per million (ppm) (Kanomax USA Inc, Andover NJ). This instrument has a detectable sensor head that measures ammonia concentration in the air at task-locations and is equipped with a data logger. The data logger measures, records, and stores ammonia concentrations that can be later be downloaded to a computer for analysis. Time intervals for sampling can be adjusted. For the purpose of this study, air ammonia samples were collected every minute. The internal clock was set to indicate real-time so observed symptoms could be correlated to data collected on the Bembry Task Analysis Worksheet. The instrument was zeroed prior to entering the farm in an ammonia free environment.

Particulate matter was measured using the Model pDR-1000AN personal/dataRAM (Thermo Electron Corporation; Franklin, MA). The pDR-1000AN is a passive air sampling monitor that allows air to freely access the sensor element. Measurements of particulate matter were recorded in mg/m^3. This monitor has a data logger system that records particulate matter in the air and is downloadable to a personal computer. The particulate matter monitor is capable of reading particle sizes of 0.1 to 10 µm. The monitor can calculate an average concentration depending on the data point time interval. The instrument was zeroed in a clean air environment before entering the farm.

Data Collection Procedures

The pilot study was conducted in the month of December. The researcher had 20 years experience in the swine industry and had worked in swine confinement operations for several years. Previous experience suggested that the concentrations of ammonia and particulate matter were highest in the swine confinement barns during the early morning; thus the researcher decided to collect study data in the morning. The researcher believed the ammonia concentration would be in the range of 5 ppm to 25 ppm and particulate matter in the range of 15 mg/m^3 to 25 mg/m^3. However, the findings from the pilot study were actually quite different than hypothesized.

Data collection began at the start of the work day and continued for 4 hours or until the chosen tasks were completed. The air sampling instruments were zeroed prior to arrival at the farm in a clean environment. Data were collected from each of the SCBs' nine task-locations: feed drop, feeding, scraping behind sows, sweeping feed aisles, breeding, completing breeding cards, heat check, refilling feed lines, and walking along back aisles or pens. Workers were asked to report any of the following respiratory symptoms: scratchy throat, runny nose, burning eyes, headache, chest tightness, shortness of breath, or muscle aches and pain that occurred during the data collection period.

At the end of data collection each day, data were downloaded to a password-protected personal computer and instrument memory was cleared in preparation for air sampling the next morning. In an effort to keep the time of collection consistent, only one barn was sampled each day.

Ammonia Air Samples. The ammonia air sample instrument was carried in the chest pocket of workers' coveralls. The instrument was secured with straps that prevented the instrument from dislodging when workers bent forward. Care was taken to minimize occlusion of the sampling head. Despite this effort, the head dislodged during data collection and recording of ammonia concentrations ceased for a time in the second barn. This problem was not discovered until the researcher downloaded the data.

Particulate Matter Samples. The particulate monitor did not fit in workers' coveralls so it was secured to a belt around each worker's waist. This type of equipment is called a passive air monitor; air must flow in the front orifice and out the back of the machine for accurate results. Efforts were made to ensure adequate airflow through the machine. The monitor was set to sample and record every 15 seconds.

Ethical Considerations

The East Tennessee State University Institutional Review Board approved the pilot study prior to data collection (Appendix A). The study was explained to each participant by the researcher. Participants willing to be part of the study signed the informed consent and received a copy for their records. No known risks associated with the study were identified. Possible study benefits included identification of task-locations that may require personnel protective equipment to protect workers' respiratory systems from known irritants such as ammonia and particulate matter. Additionally, discussing health symptoms associated with specific task-locations may improve participants' awareness of occupational health risks. Over the long-term a better understanding of contaminant exposure could lead to improved ventilation and housekeeping.

Data Analysis

A correlational analysis was used among and between task locations, work-tasks and respiratory symptoms reported by workers and ammonia and particulate matter levels (Polit & Beck, 2008).

Pilot Study Results

Figure 2 shows the actual findings for ammonia during the feed drop and feeding times in Barn 1. Animals stood up and squealed as workers entered the barn for the feed drop. After animals received their feed, most would defecate and urinate. The peak in ammonia concentration (1.4 ppm) was associated with animal urination, volatility of urine ammonia over time, and mixing of waste remaining in the pits. The researcher also noted that only one fan was on during the feeding process. At 0604, the second fan activated and ammonia concentrations decreased. Fan 2 turned off at 0617 and another peak in ammonia concentration was noted.

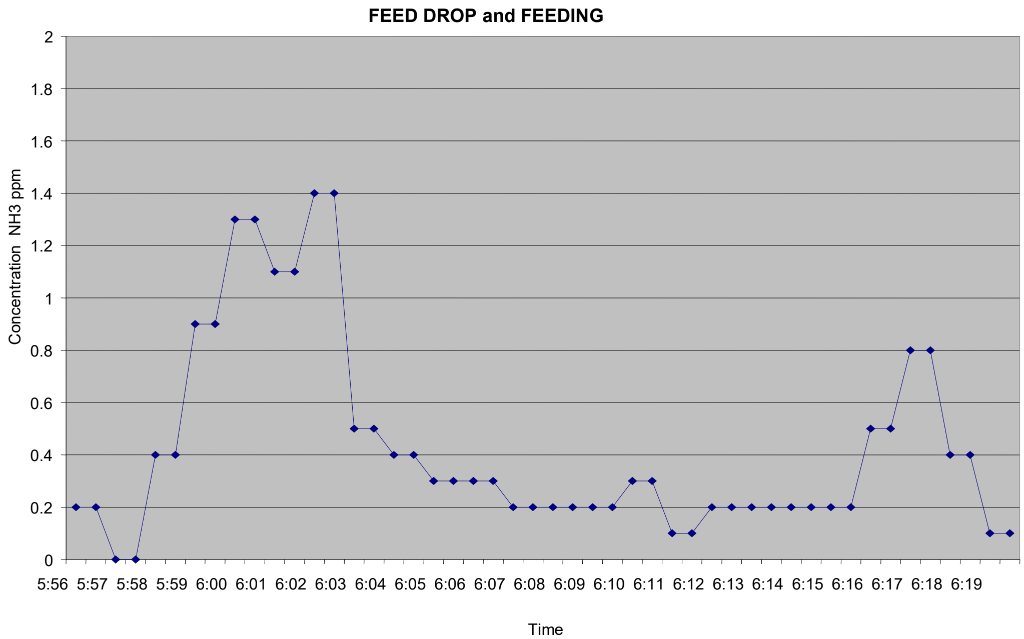

Figure 2. Ammonia Concentrations During Feed Drop and Feeding (Barn 1)

In Figure 3, ammonia concentrations peaked at 0.7 ppm at 0625. It was determined that this peak represented animals standing up again after finishing eating and urinating. However, it is uncertain if this is the only reason for the increase in ammonia concentration because one fan turned off at 0620. Therefore, the increase in ammonia may have been due to a decrease in air flow. The second fan activated at 0640 and continued to run for 20 minutes before cycling off.

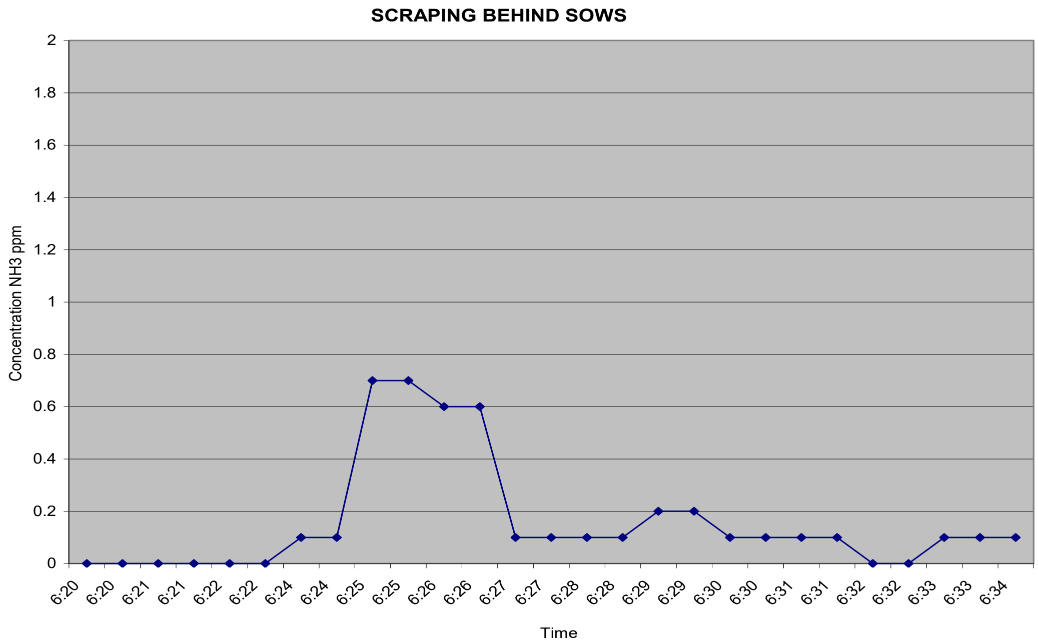

Figure 3. Ammonia Concentrations During Scraping Behind Animals (Barn 1)

During the breeding task, animals are palpated and stimulated to check for estrus. Ammonia concentrations during this task ranged from 0.1 to 1 ppm. It was hard to determine how many sows in the barn were standing and the frequency of urination that occurred during this time. Noteworthy, many animals actually urinate either prior to or after the breeding procedure. Additionally, the fans were cycling according to internal temperature. Another factor that may have contributed to the ammonia increase was the volatility of ammonia from the pits as flush tanks operated. All contributing factors considered, this was one of the longest time intervals with elevated ammonia concentrations. Workers were coughing and reported throat and eye irritation. Figure 4 displays the variations in ammonia levels during the breeding task.

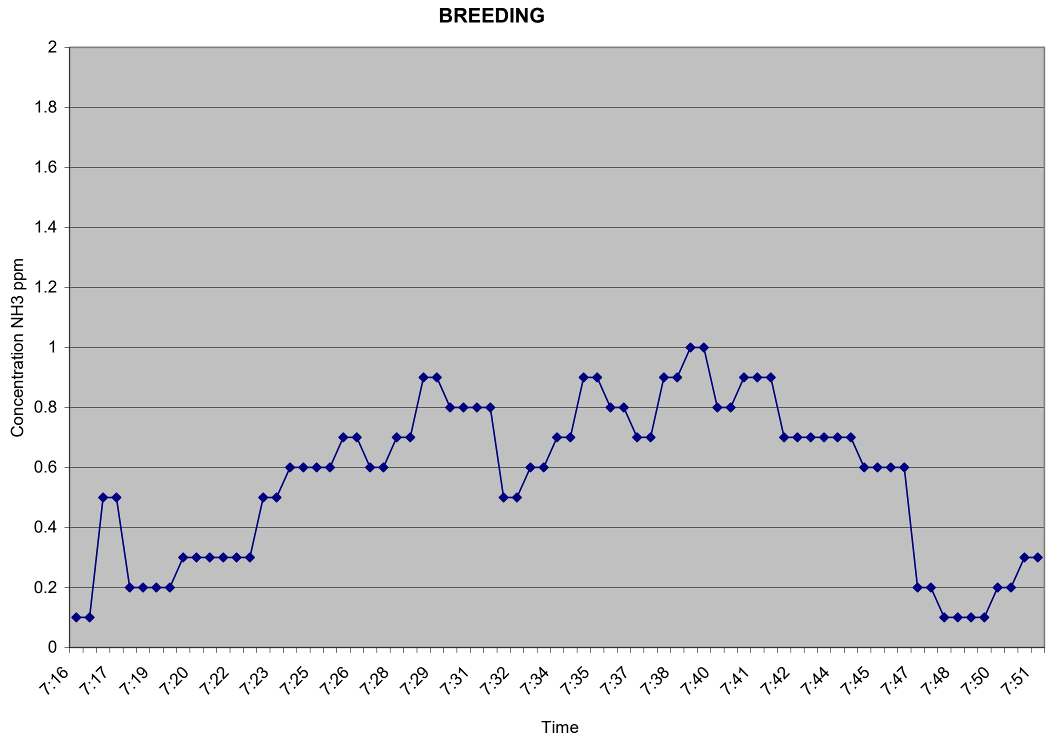

Figure 4. Ammonia Concentrations During Breeding (Barn 1)

After the breeding task was completed, the worker documented the date of breeding and completed breeding cards. Documentation on the breeding cards informed the manager when the animal was bred, to which group the sows were assigned, of the sire's identify, and when to expect farrowing. As the worker documented the breeding information, the outside temperature began to increase and warmer air entered the barn. Consequently, as more fans were activated, the internal air was exchanged more rapidly. Figure 5 shows the effect that the number of fans operating had on the concentration of ammonia.

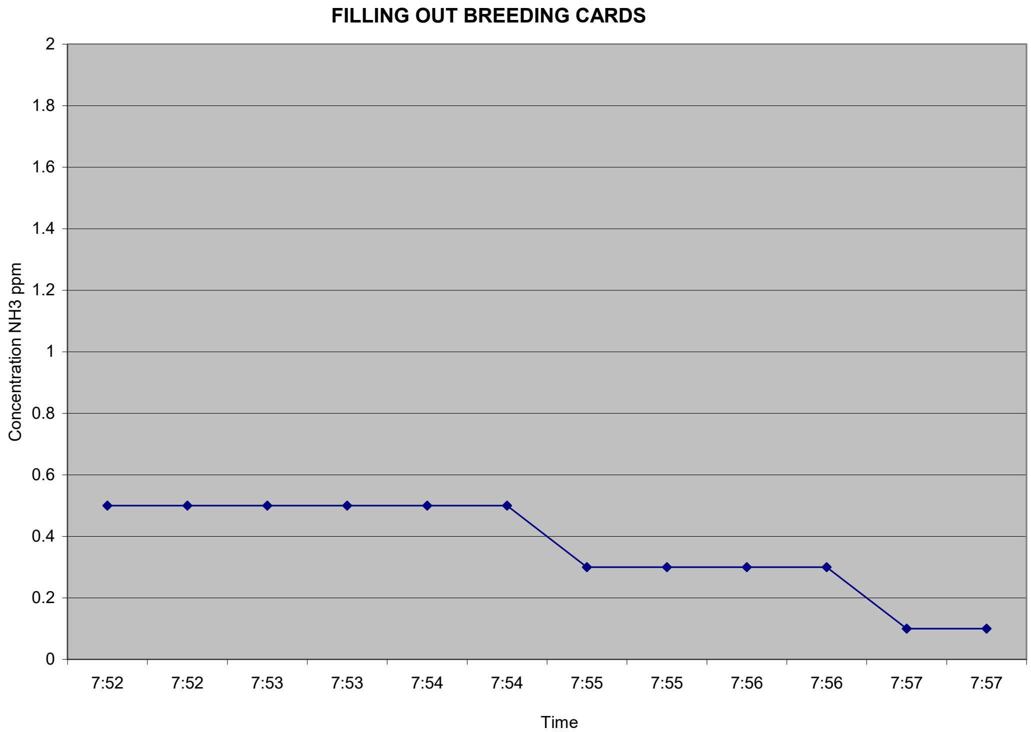

Figure 5. Ammonia Concentrations While Completing Breeding Cards (Barn 1)

Heat check lasted from 0811 until 0933. One high concentration of 0.5 ppm occurred but most of the ammonia levels were below 0.3 ppm. This peak could have been due to the cycling of fans at this particular time of day. As warmer air was drawn into the barn, internal temperature increased and activated an additional fan. Figure 6 shows the range of concentrations during the heat check task.

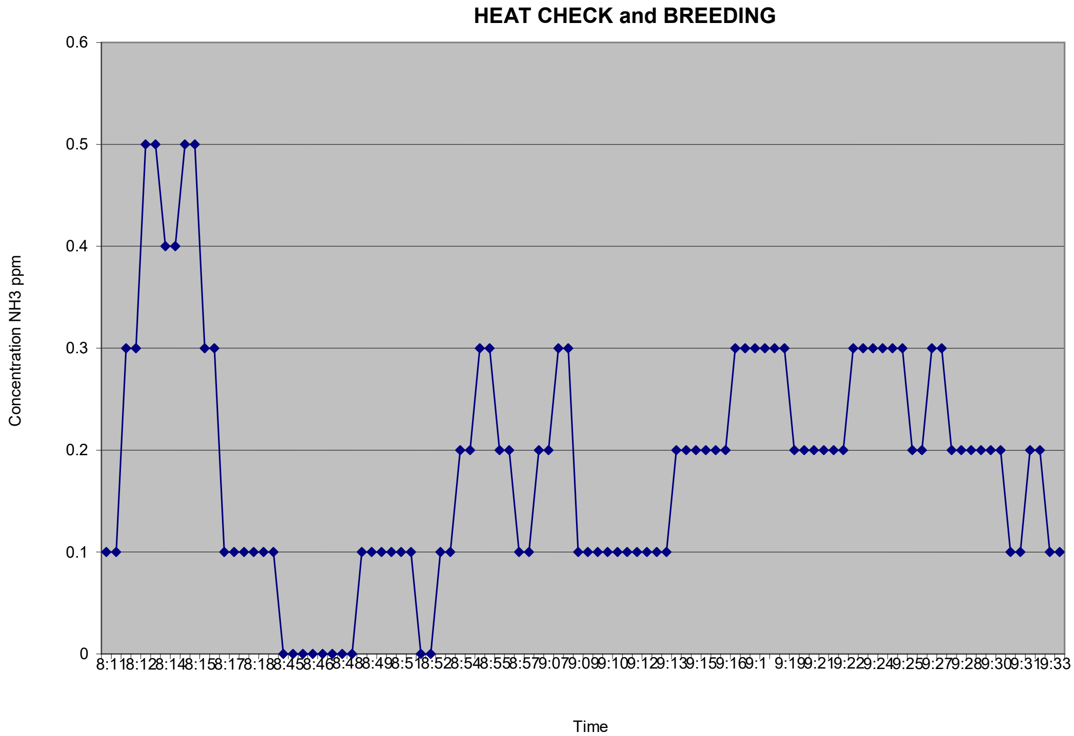

Figure 6. Ammonia Concentrations During Heat Check and Breeding (Barn 1)

The following graphs indicate the particulate matter recorded during each task. The actual feed drop from feed lines created a peak in particulate matter of 2.9 mg/m³ at 0625. The barns were designed with four feed lines, each dropped independently. Animals in open pens were hand fed by workers. Each animal received a five pound scoop of feed. The worker hand feeding may have increased exposure due to feed dust in the immediate area. As Figure 7 shows, concentrations greater than 1mg/m³ were experienced for more than 10 minutes. Only one fan was running and any particulate matter in the air was not exhausted quickly. The minimum fan moves 10,100 cubic feet of air per minute. Based on building dimensions, the inside of each barn had 162,000 cubic feet of air space.

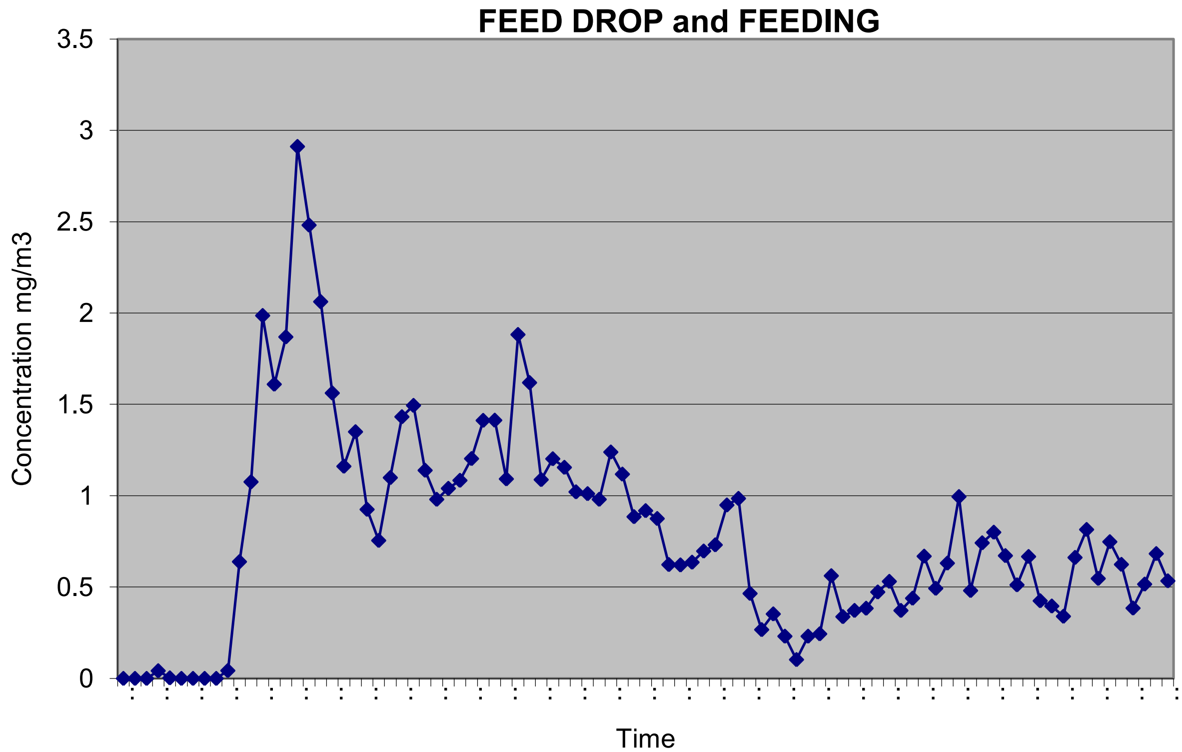

Figure 7. Particulate Matter Concentrations During Feed Drop and Feeding (Barn1)

The only significant peak in particulate matter during scraping behind the sows was at 0659 with a concentration greater than 3 mg/m³. Other concentrations during this task were relatively low (see Figure 8).

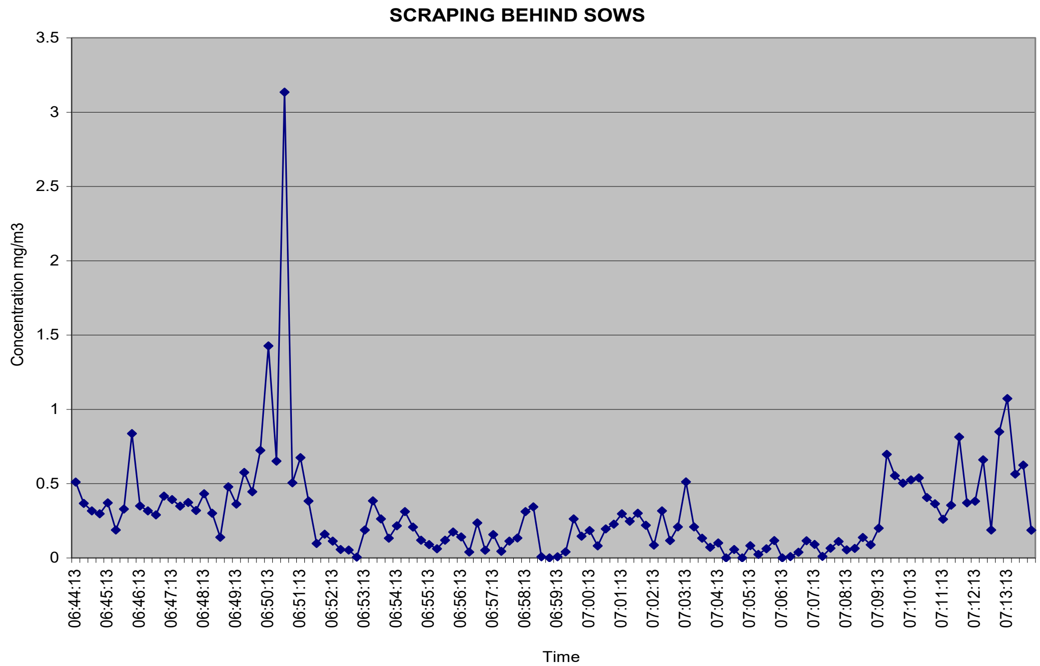

Figure 8. Particulate Matter Concentrations When Scraping Behind Sows (Barn 1)

After animals consume most of the feed dropped, the center aisles were swept. This task places feed back into the trough after sows have rooted the feed into the aisle beyond their reach. Some animals are less messy and little feed is in the aisles. Particulate matter was greater than 0.5 mg/m³ for most of the period between 0714 and 0730 when a higher concentration of 1.5 mg/m³ was recorded. The second fan was activated at 0731 and this may account for the rapid decline in particulate matter concentration (See Figure 9).

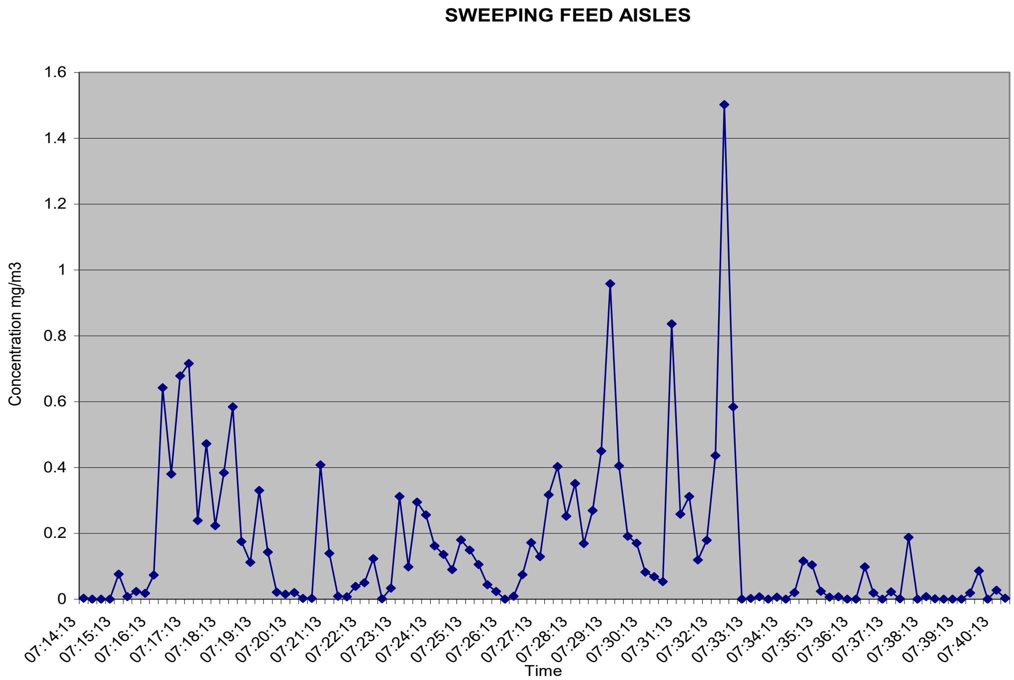

Figure 9. Particulate Matter Concentrations When Sweeping (Barn 1)

Breeding and heat check showed a wide range of variability in the concentrations of PM over time, variability that could be related to physical handling of the sows. Animals thought to be in heat were palpated and workers actually sit on the animals to see if they stand for breeding. The location of the monitor may have incurred increased dust during this time when workers physically entered the individual sow crates. The researcher was not clear how many fans were actually running or when fans turned on or off during the air sampling shown in Figure 10 and Figure 11.

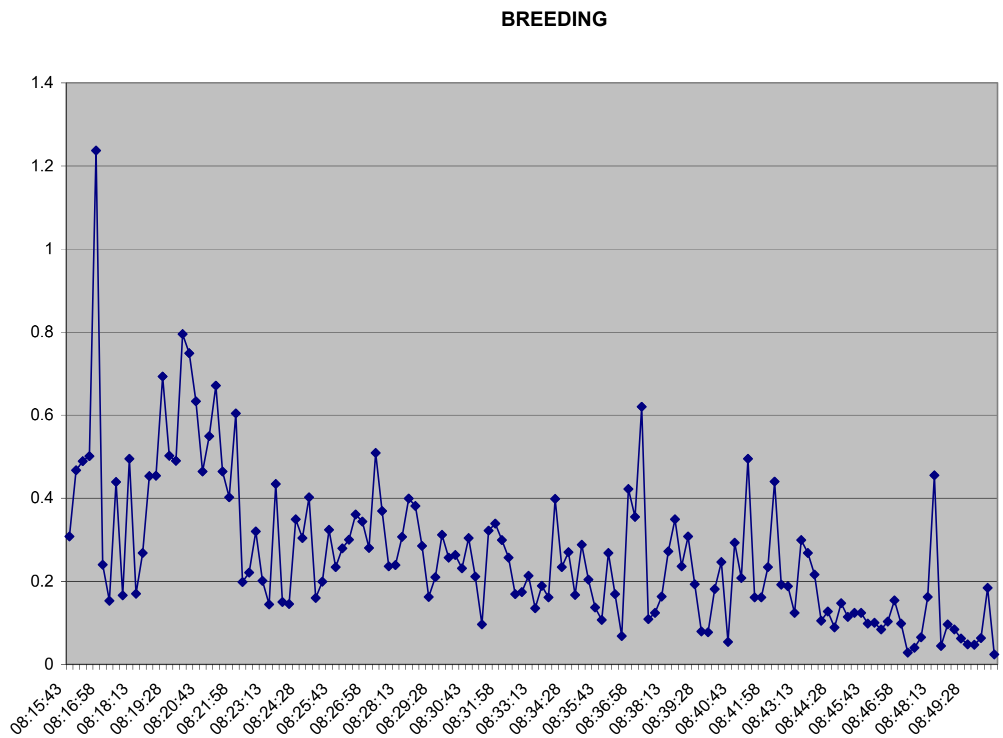

Figure 10. Particulate Matter Concentrations During Breeding (Barn 1)

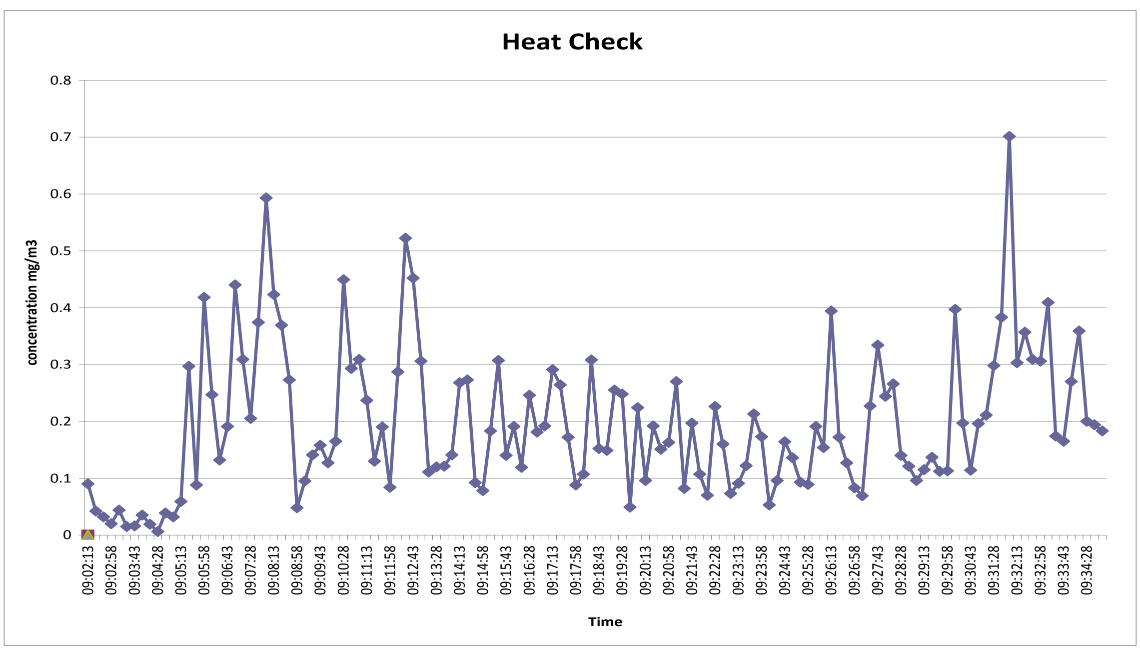

Figure 11. Particulate Matter Concentrations During Heat Check (Barn 1)

Only ammonia data were collected for Barn 2 because the particulate monitor's memory was full, a situation not realized until data were downloaded. In addition, the head on the ammonia monitor dislodged from the sensor and data were not recorded after breeding. However, these errors were easily prevented once the researcher understood the instrument limitations and how to minimize instrument errors during the dissertation study.

A 30-minute delay in ammonia concentration peak in Barn 2 compared to Barn 1 was observed. This difference is believed to be related to urine and feces falling into a water solution where it dissolves and takes a period of time to vaporize into the atmosphere. However, the relative concentrations of ammonia were similar between Barn 1 and Barn 2, 1.4 ppm and 1.5 ppm, respectively. This delay in peak ammonia concentrations could inform a change in policy: allow workers time to check animals and then exit the barn, preventing exposures after feeding the animals. Figure 12 displayed the time delay.

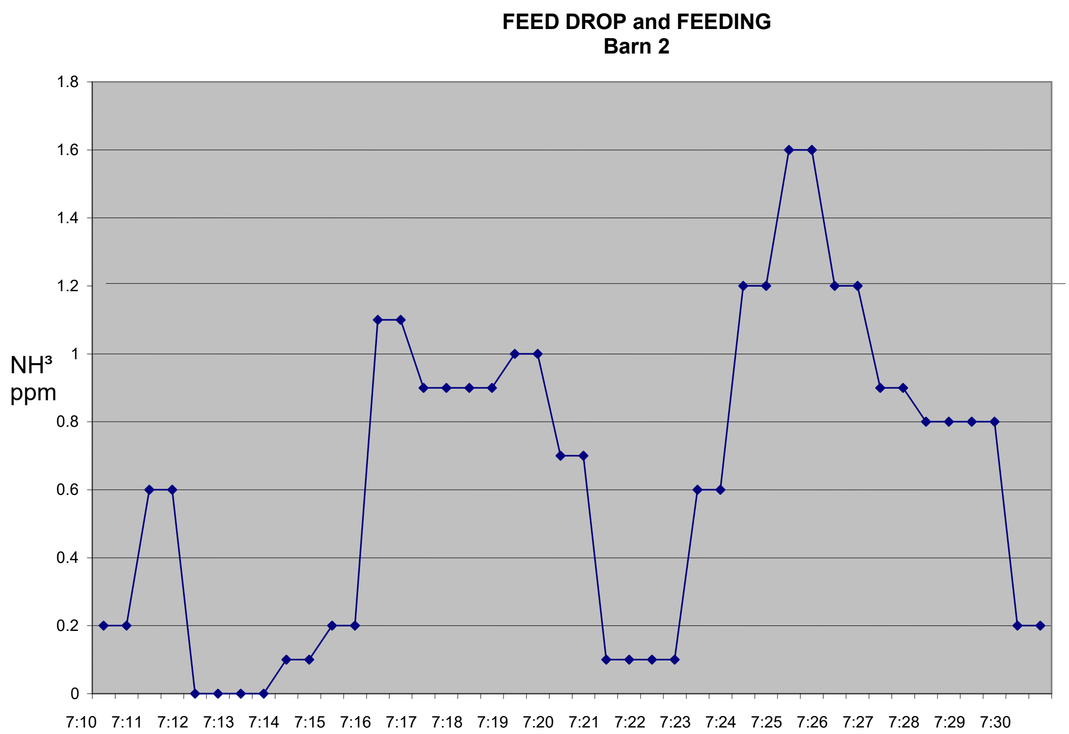

Figure 12. Ammonia Concentrations During Feed Drop and Feeding (Barn 2)

Comparison of Barn 1 (Figure 4) and Barn 2 (Figure 13) show marked differences. Barn 1 had a higher ammonia concentration for a longer time period than Barn 2. In Barn 1 the ammonia concentration was 0.6 ppm or greater for a period of 22 minutes with several concentrations at 0.9 ppm. The maximum concentration for Barn 1 was 1 ppm. In comparison Barn 2 had a maximum ammonia concentration of 1.3 ppm but it lasted only 2 minutes. Overall, task time had concentrations below 0.5 ppm except as noted in the previous example. By reducing the exposure, workers' exposure to high ammonia concentrations was reduced by 20 minutes. Assuming that employees work 12 days in a 2-week period, they would experience 240 minutes with less exposure or about 4 hours less time at concentrations of 0.6 ppm or greater. The clinical significance of this is unknown but should be investigated to see if building design plays a significant role in reducing worker exposure.

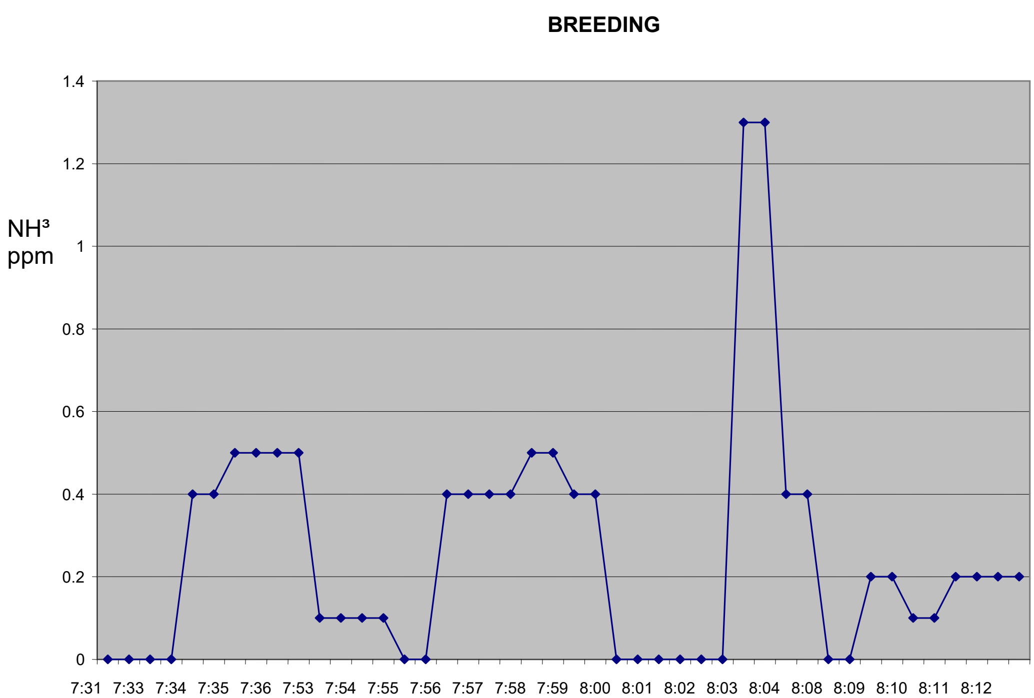

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Figure 13. Ammonia Concentrations During Breeding (Barn 2)

Modifications from Pilot Study

Based on experiences during and findings of the pilot study, the ammonia monitor was adjusted to ensure that the head did not become dislodged during sampling. Additional laboratory experiments were conducted with other ammonia monitoring instruments to ensure proper readings from the personal monitor.

After the data were gathered in the pilot study, the researcher asked workers why they did not report any respiratory symptoms. Workers stated they experienced no more symptoms in the barns than outside the work environment. The researcher decided to provide workers with further study explanation before completing the questionnaire to highlight worker privacy and confidentiality of the data.

Changes were also made to the task worksheet because not all tasks were performed on a daily basis, i.e., in the winter, barns are washed only once a month, sows were not treated unless the animals were sick, and sows were only moved once a week. Because of the dissertation study site method of management, breeding, completing breeding cards, and conducting heat checks were combined into one task.

It was clear from the pilot study that the researcher needed to pay closer attention to fan activation because fans appeared to explain some variation in particulate matter and ammonia levels. Also, the researcher decided to meticulously record task time intervals. Date and time on the monitors were synchronized for ease of comparison to task time intervals.

Time intervals for sampling particulate matter and ammonia were set at 1 minute in the dissertation study for sampling consistency. Analysis of PM data during the pilot study indicated no statistical difference between sampling at 15 seconds and sampling at 1 minute. Therefore, the change to PM sampling at 1 minute intervals would not miss relevant data.

Another concern was the placement of the particulate matter monitor; it should be placed closer to the breathing zone of the workers instead of at the waistline. However, this placement was inconvenient and cumbersome for workers. The investigator purchased two mesh hunting vests to hold monitoring equipment as workers performed their daily tasks. These vests allowed adequate airflow for passive air sampling and were designed to secure the instruments. Pockets on the vests were at the waistline of workers which was approximately one meter from the floor. Workers confirmed wearing the vest did not interfere with job performance.

Dissertation Study

Research Design

The aim of the dissertation study was to determine if ammonia and particulate matter concentrations differed by specific tasks performed during routine work in the SCB. This study was a first step in identifying task locations at which workers may benefit from the use of personnel protective equipment (PPE). Three research questions were posited for the dissertation study. The first question was "Is there a relationship between number of fans running and concentrations of ammonia and particulate matter in swine confinement barns?" Second, "Does the design of swine confinement barns affect the concentrations of ammonia and particulate matter?" Third, "Is there a relationship between the work tasks of swine confinement workers and the exposure concentrations of ammonia and particulate matter?" A quantitative descriptive correlational design was chosen to answer the research questions. The study was nonexperimental and described, compared, observed, and documented situations as they naturally occurred. The investigator had no control over the independent variable and did not manipulate the environment. This method is particularly appropriate when existing knowledge about a particular problem area is not well developed (Polit & Beck, 2008).

Research Setting Restrictions

To gain access to a large corporate farm, the researcher negotiated with management to design a study that would meet company's needs and also remain true to the intent of the research study. Along with anonymity, company officials set the following restrictions.

Questionnaire. The research site management team requested that questions 8 through 10 be omitted from the questionnaire used in the pilot study. Company officials were concerned that these questions could suggest possible occupational health hazards to workers and promote unnecessary concern about their safety while working in the SCBs. The deleted questions asked workers to indicate any respiratory symptoms they had experienced while performing routine work tasks in the SCBs. The questions correlated with reported symptoms on the Bembry Task Worksheet (BTW). Thus, only observed symptoms were recorded on the BTW.

Research Question. The original research question, "Do swine confinement building (SCB) workers' reported task-location specific pulmonary irritancy correlate with air contaminant concentrations of ammonia and particulate matter?" was modified because the researcher could not ask workers if they had experienced any respiratory symptoms while working. In addition, neither pilot study participant reported experiencing any respiratory symptoms at work. Therefore, the new research question addressed concentrations of ammonia and particulate matter during specific work tasks in the SCBs.

Data Collection. Data collection was restricted to one compound of eight farms. The company chose the compound and informed employees that they would have an opportunity to be part of a research study if they wished to volunteer. Strict biosecurity was enforced to prevent the spread of disease between farms. Entrance into the farm required showering and farm coveralls. No "street" clothes or footwear could be worn on the farm unless it was new and in the manufacturer's package. Rubber boots were provided for employees and visitors to wear inside the farms. The company required that the vest used to hold the instruments be disinfected and allowed to dry for 24 hours prior to use on another farm. This requirement was met by purchasing two vests and alternating their use. The compound manager also determined the order in which the farms were visited. All eight farms were included in the study.

Study Settings

The company allowed the researcher to collect data in one compound with 8 farms in two series, 1200 and 1900.

Barn Characteristics. The 1900-series farms were 2000 head farrow-to-wean (FW). The breeding and gestation barns were curtain sided and tunnel ventilated. Each barn was 72' wide and 360' long with an insulated tin roof. Inside the barns, aluminum ceilings were installed to retain animal heat during colder months. Barn floors were partially slatted with shallow recharge pit systems. The recharge pit was drained and refilled weekly with effluent from the lagoons. Usually each barn housed about 750 grown sows with an average weight of 450 pounds. Animals were in individual crates except cull sows, sows that were going to slaughter, and newly received gilts, females that replace cull sows but are still too young to breed.

Farms designated as 1200-series were 1200 head FW facilities. Barns were designed the same as the 1900-series but were slightly smaller than the 1900-series breeding and gestation barns. Barns were 60' wide by 240' long with insulated tin roofs. The barns were curtain sided and tunnel ventilated. Inside the barns the same insulated metal ceilings had been installed. Barn floors were partially slatted with shallow recharge pit systems in breeding and gestation Barn 1. The recharge pit was drained and refilled weekly with effluent from the lagoons. Breeding and gestation Barn 2 had a flush pit system for removing animal waste. Tanks were set to flush every 4 hours.   Each barn housed about 600 head of grown sows with an average weight of 450 pounds. The sows lived in individual crates except cull sows and newly received gilts.

Ventilation Systems. The 1900-series barns had ten 50” fans located at the lower end of the barn facing the lagoon. The center fan operated continuously and the other nine fans staged on depending on the inside temperature. At 70º F, the second fan turned on. When the inside temperature reached 72º F, fans three and four were activated. Two additional fans activated for each 2 degree increase in inside temperature. All 10 fans were set to run when the internal temperature reached 78º F. If the inside temperature continued to increase, cool cells were activated at 80º F.

The 1200-series barns were narrower and shorter; the ventilation systems were designed differently from those in the 1900-series barns. The 1200-series barns had only six fans. The 36 inch minimum ventilation fan ran continuously. The remaining five fans were all 50” fans. The staging for activation of subsequent fans was similar to the 1900-series except only one additional fan came on at a time. Inside temperatures in excess of 80º F activated the cool cells; tunnel ventilation through water soaked coils prevented temperatures from exceeding 88º F inside the barns. Temperature control is essential to reduce heat stress on pregnant sows. Table 3 shows a comparison of 1900-series barns to 1200-series barns.

Table 3.

Barn Design Comparison

Farms	*Width*	*Length*	*# Fans total*	*Size of minimum ventilation fan (1)*	*Size of additional fans (# fans)*	*Manure handling system*
1900-series	72'	360'	10	50"	50" (9 fans)	Shallow recharge pit(18")
1200-series Barn 1	60'	240'	6	36"	50" (5 fans)	Flush tank pit System
1200-series Barn 2	60'	240'	6	36"	50" (5 fans)	Shallow recharge pit (18")

Sample

To participate in the study, workers must have worked in the SCBs for at least one year, have been assigned to the breeding and gestation barns as their primary work location, have been at least age 18, and speak and write in English. The researcher personally asked each worker to participate in the study and explained the consent form including worker's right to withdraw from the study at any time. Demographic data were recorded for each participant who volunteered during the face-to-face interview. Each participant was assigned a study identification number and no names were recorded on the questionnaire to protect workers. Workers of both genders were encouraged to participate in the study. No more than one worker from each farm was included in the study, but each worker who met the inclusion criteria had the opportunity to volunteer.

Participants who were unable to answer questions or complete the survey were excluded. Additionally, other exclusion criteria included cognitive impairment and recent short-term or long-term disability due to a change in health status. However, no participants met these exclusion criteria.

Participant Recruitment. Recruitment began after securing a modified study approval from the ETSU IRB and consent from the company production manager and vice president of swine operations. Initial information about the study was presented to the vice president of human resources, production manager, and vice president of swine operations for the company. After consent was given by the vice president, the researcher met with the compound site manager to discuss the intent of the research project and answer any questions. The compound site manager informed workers on each farm that they would have the opportunity to participate in a research study if they worked in the breeding and gestation barns. Other employees were informed that future research would focus on workers with farrowing assignments, but this study would not include the farrowing environment. Contact numbers were provided to potential participants so they could contact the researcher directly.

Instrumentation

Questionnaire. The questionnaire was designed by the researcher to record demographic data and documented any diagnosis of asthma or respiratory problems in the previous 6 months. Demographic data included age, gender, smoking history, education level, number of years employed in SCBs, and any previously diagnosed respiratory diseases (Appendix A). The questionnaire was completed through a face-to-face interview in an isolated area to protect worker privacy and confidentiality of responses and ensure the questionnaire was understood. The workers were prompted to ask questions or provide comments. Questionnaires were coded so workers could not be identified to maintain confidentiality.

Air Sampling Instruments. The Aeroqual Series 500 monitor was used to measure the ammonia content in the barns (Kanomax USA Inc, Andover NJ). This was the same instrument used in the pilot study with adjustments made to ensure the sensor head did not dislodge. Ammonia was measured in parts per million (ppm). Data were downloaded to a password-protected personal computer after completion of daily air sampling. The instrument was zeroed prior to entering the farm in an ammonia free environment.

Particulate matter was measured using the Model pDR-1000AN personal/dataRAM (Thermo Electron Corporation; Franklin, MA). Measurements of particulate matter were recorded in mg/m^3. The monitor had a data logging system that was reset to record particulate matter each minute instead of every 15 seconds as was done in the pilot study. Data were downloaded to a password-protected personal computer after completion of daily air sampling. The instrument was zeroed in a clean air environment prior to arriving at the farm each morning.

Data Collection Procedures

The dissertation study was conducted in the month of July. Data collection began at the start of the work day and continued until the four selected tasks were completed. Data were collected from each SCBs task-location: feed drop and feeding, scraping behind sows, sweeping feed aisles, and breeding and heat check. Workers were asked to report any of the following respiratory symptoms: scratchy throat, runny nose, burning eyes, headache, chest tightness, shortness of breath, or muscle aches and pain if they occurred during the data collection period.

At the end of data collection each day, information was downloaded to a password-protected personal computer and instrument memory was cleared in preparation for the next day's work. In an effort to keep the time of collection consistent, only one barn was sampled each day.

Ammonia Air Samples. The ammonia instrument was carried in a netted vest to facilitate passive air flow. The pockets on the vest were at waist height, approximately 1 meter from the floor. The instrument was secured with straps that prevented it from falling out when the worker leaned over crates or climbed over pens. The sensor head of the instrument was secured to the monitoring base with duct tape. Care was taken to minimize the occlusion of the ends of the sampling head. The ammonia instrument was set to display readings and record concentrations in parts per million (ppm) each minute.

Particulate Matter Samples. The particulate monitor was placed in another pocket on the vest, approximately 1 meter from the floor. Inspections were made periodically during sampling to ensure the vest was not occluding the instrument inlet. The recording on the monitor was set to sample and record every minute and concentrations were recorded in mg/m^3. Data were downloaded to a password-protected personal computer each night and the instrument was zeroed in a dust free environment.

Ethical Considerations

East Tennessee State University Institutional Review Board approved the dissertation study after the researcher submitted a study modification form (Appendix A). The study was explained to each participant and participants willing to be part of the study signed the informed consent and received a copy for their records. No known participant risks were identified. Possible benefits included identification of task-locations that may require use of personnel protective equipment to protect workers' respiratory systems from known irritants such as ammonia and particulate matter. Additionally, health symptoms related to task-locations may have improved participants' awareness of occupational health risks and their own health.

Data Analysis

Data were graphed according to task performed, feed drop and feeding, scraping behind the sows, sweeping feed aisles, and breeding and heat check. Concentrations of particulate matter were depicted on the primary Y-axis and number of fans on the secondary Y-axis. The X-axis for all graphs was time. Continuous sampling was conducted and recorded at 1-minute intervals until all four task were completed. Ammonia concentrations were below the sensitivity (< 0.1 ppm) of the instrument except on one occasion which lasted 5 minutes. Therefore, ammonia concentrations were not included in the analysis.

Data were analyzed using SPSS (Version 17) to answer the research questions. During the time workers were not in the barn, the PM monitor was still recording. Out-of-barn (OOB) breaks and other recordings not inside the breeding and gestation barns were not used in the data analysis. Some data were outliers, greater than five standard deviations (SD) from the mean. A decision was made to exclude data points that were greater than 4 SD from the mean. Based on this decision, six data points of high concentration were not included in the data analysis. One data point was 18 standard deviations from the means. This decision was applied to all analyses involving PM concentrations.

The first research question was, "Is there a relationship between the number of fans running and concentrations of ammonia and particulate matter in swine confinement barns?" The number of fans running was treated as continuous variable (0 to10) and a Pearson product-moment correlation was used to determine if a relationship existed between the number of fans running and the concentrations of ammonia and particulate matter.

The second and third research questions, "Is there a relationship between the work tasks of swine confinement workers and the exposure concentrations of ammonia and particulate matter?" and "Does the design of swine confinement barns affect the concentrations of ammonia and particulate matter?" were analyzed together using analysis of covariance (ANCOVA) to determine if the task the workers' performed and the type of barn design (1200-series Barn 1, 1200-series Barn 2 and 1900-series) was related to PM concentrations while holding the number of fans constant. It was decided to hold the numbers of activated fans constant as the fans are not controlled by management or workers but rather by the temperature inside the barn.

Summary

The pilot study provided insight into study procedures and instrumentation that could affect dissertation study findings. Instrument testing and protocol modifications resulted from the experiences gained in the pilot study that strengthened the dissertation study design and results. Modifications requested by the company were necessary to promote collaboration between the researcher and industry. These changes did not alter the research focus. Consequently, research findings should be easily incorporated by the company because allowances were made to accommodate their interests.

CHAPTER 4

RESULTS

The purpose of this study was to answer the original research question: "Do swine confinement building (SCB) workers' reported task-location specific pulmonary irritancy correlate with air contaminant concentrations of ammonia and particulate matter (PM)?" As discussed in Chapter 3, dissertation study farm officials restricted the questions the researcher could ask workers including if they had experienced any respiratory irritancy symptoms during specific work tasks in the SCBs. In addition, the pilot study suggested that workers might not report any respiratory problems. Thus, the research question was revised to include these three questions:

1. Is there a relationship between number of fans running and concentrations of ammonia and particulate matter in SCBs?
2. Is there a relationship between the work tasks of SCB workers and the concentrations of ammonia and particulate matter to which workers are exposed?
3. Does the design of SCBs affect the concentrations of ammonia and particulate matter?

This chapter presents the results of the data analyses to render a clearer understanding of the research presented.

Demographics

Eight participants volunteered to be part of the dissertation study. Seven were male and one was female (n=8). Four participants were in the age range of 30 years to 40 years, three were between 41 and 60 years, and one was over 60 years old. Participants had worked in SCBs from 2 years to 24 years; two participants had worked between 2 and 10 years, three between 11 and 15 years, two between 16 and 20 and one had worked for 24 years. Six participants had completed high school, one had a college degree, and one had not received a high school diploma. All eight participants denied a history of asthma or any respiratory complications within the last 6 months. In regard to smoking history, two participants denied ever smoking, three were current smokers, and three were former smokers.

Descriptive Findings

In the SCB, several factors can change the concentration of PM. Feed is dry and has dust particles that are easily released during the morning feed drop. Sweeping of the aisles provides an opportunity for dust to float into the atmosphere. However, feed is not the only source of PM. Animal dander, hair follicles, dried feces, mold, and pollen are just a few components of the complex dust mixture found in confined animal feeding operation dust (Donham, 1989; Donham, 1991; Donham et al., 2002).

1900 Series Farms. During the day, as fans cycled on and off, PM concentration inside SCBs changed. For instance, if the inside volume of the 1900-series SCB was 194,400 cubic feet (72' X 7.5' X 360') and all 10 fans ("50") were running, then the entire internal atmosphere was exchanged every minute. However, if only the minimum number of fans was operating, it took 10 minutes to exchange the inside volume of air; therefore, dust particles had an opportunity to settle on crates and other structures within the SCB. Those settled particles could easily become airborne again during heat checking, breeding, or moving animals, increasing the potential for instantaneous PM exposure among workers in the immediate area.

Feed Drop. Each 1900-series barn had four feed lines from which feed was dropped independently. After feed drop was completed, workers hand-fed animals in back pens. Hand feeding increased particulate matter concentration to 0.6 mg/m^3 (Figure 14). Also, noteworthy was that at 0642 in Barn 1 8 of the 10 fans were already running. Other barns in the 1900-series had similar concentrations throughout the task sampling period (Appendix B). Equipment malfunction occurred in farm P19B; therefore no PM data were recorded for that sample day.

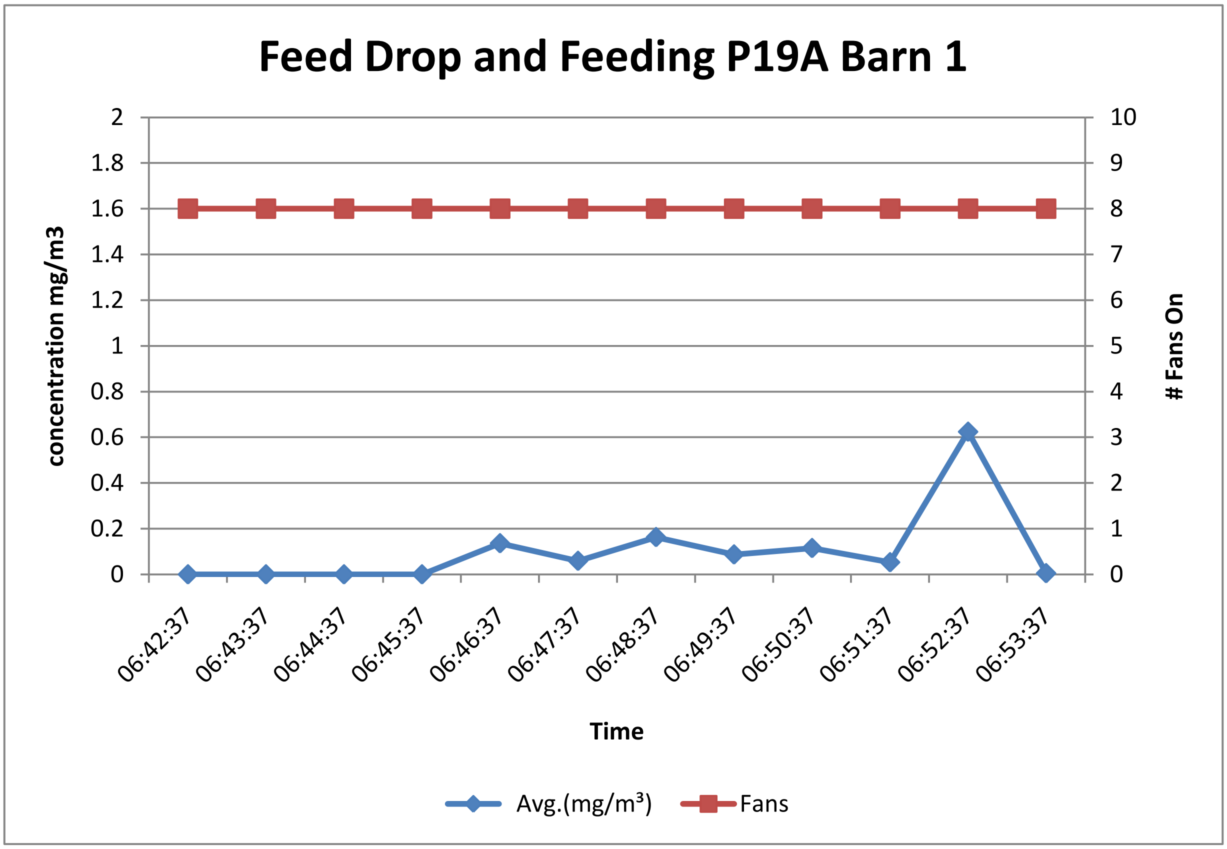

Figure 14. Particulate Matter Concentrations During Feed Drop and Feeding

Scraping

When animals stood up to eat, it was essential that feces be removed from behind the sows. During the scraping task, the worker also observed for any animals that were not eating, an indicator of animal sickness. Concentrations of PM during this task were less than 0.1 mg/m³. A slight increase in PM occurred at 0658, but when the next group of fans activated the concentration returned to almost zero. Figure 15 shows the usual pattern of PM when fans were running. The effect of fans cycling on and off can be seen in Figure 16. In P19D-Barn1, the PM concentrations increased for about 4 minutes before readings decreased to less than 0.1 mg/m³. Appendix C highlights PM concentrations on other 1900-series farms during the scraping task.

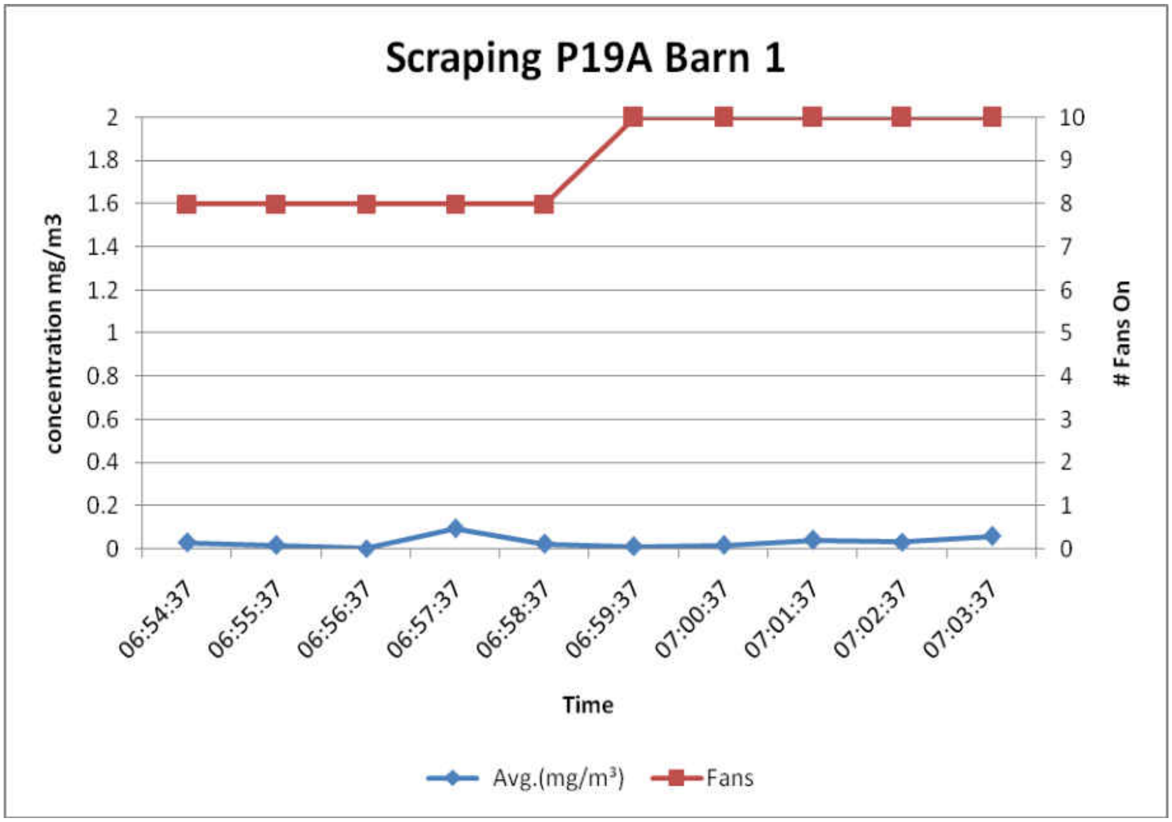

Figure 15. Particulate Matter Concentrations During Scraping on Farm P19A, Barn 1

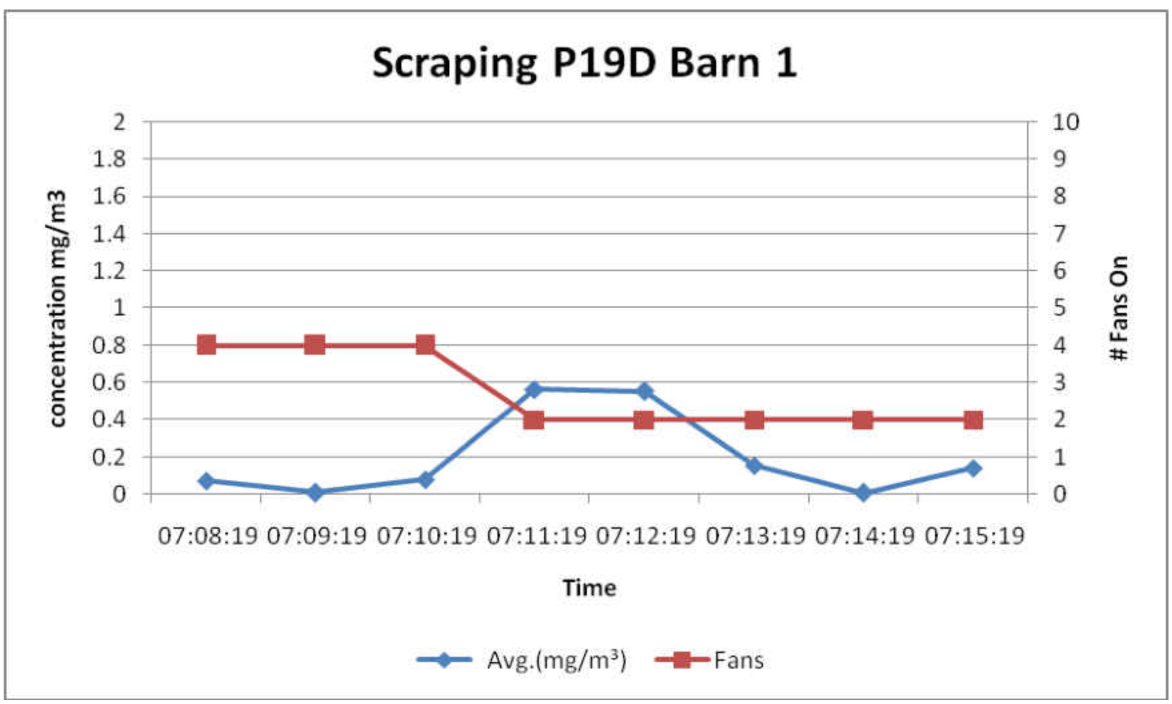

Figure 16. Particulate Matter Concentrations Over Time During Scraping on P19D Barn 1

Sweeping

Swine normally engage in a "rooting" motion of the head when eating that causes some of the feed to come out of the trough and out-of-reach of the animals. After the sows had eaten for about 30 minutes, the feed aisles were swept and feed returned to the trough so the animals could finish eating. The amount of feed in the aisles varied substantially. However, feed was in pellet form and easily swept back into the trough. Figure 17 displays PM concentrations during the sweeping task. For the 1900-series, concentrations were similar and appear in Appendix D.

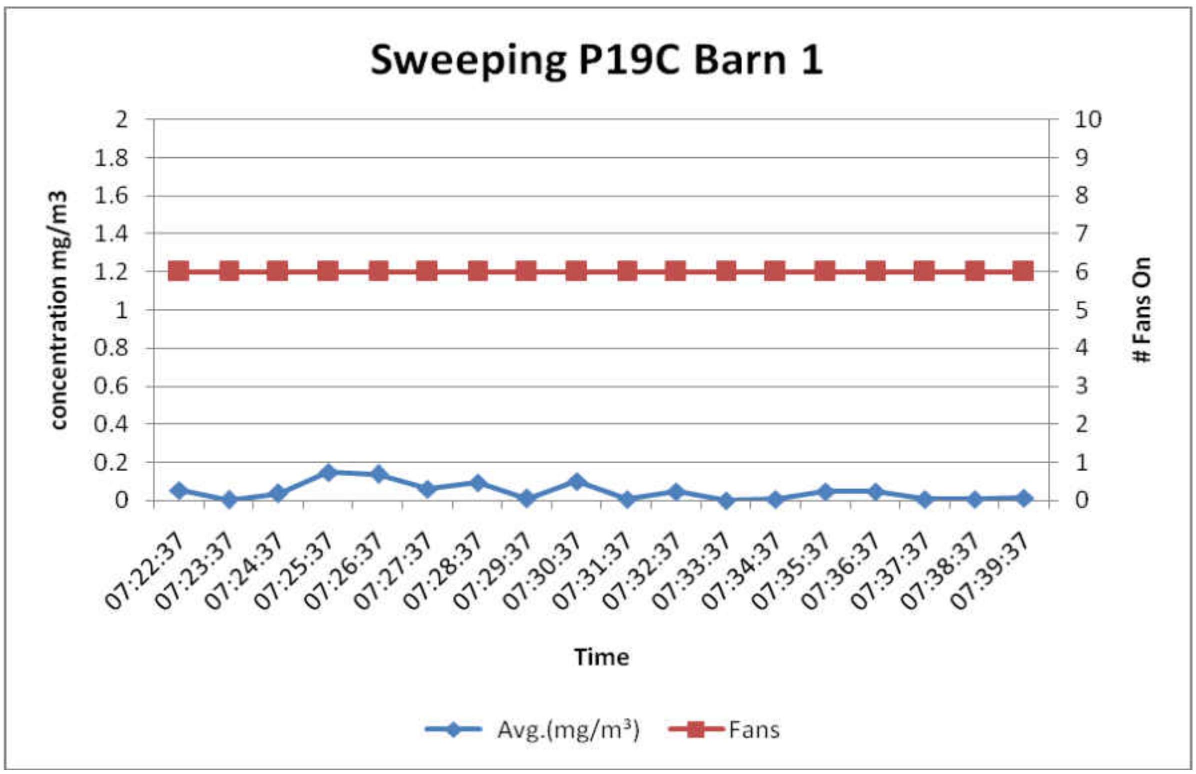

Figure 17. Particulate Matter Concentrations During Sweeping on Farm P19C, Barn 1

Heat Check and Breeding

High concentrations of PM were recorded during heat check and breeding tasks in Farm P19D-Barn 1. During the first 6 minutes of the heat check and breeding task, the PM concentration was 1 mg/m³ with six fans running. At 0855, two more fans came on and the PM concentration decreased to 0.2 mg/m³. Eight fans continued to run for 30 minutes until the inside temperature dropped below 76 degrees. As shown in Figure 18, the PM concentration stayed below 0.2 mg/m³ until the tasks were completed and monitoring terminated at 0952. Other 1900-series farms had recorded PM concentrations below 0.2 mg/m³ during the entire heat check and breeding task (See Appendix E).

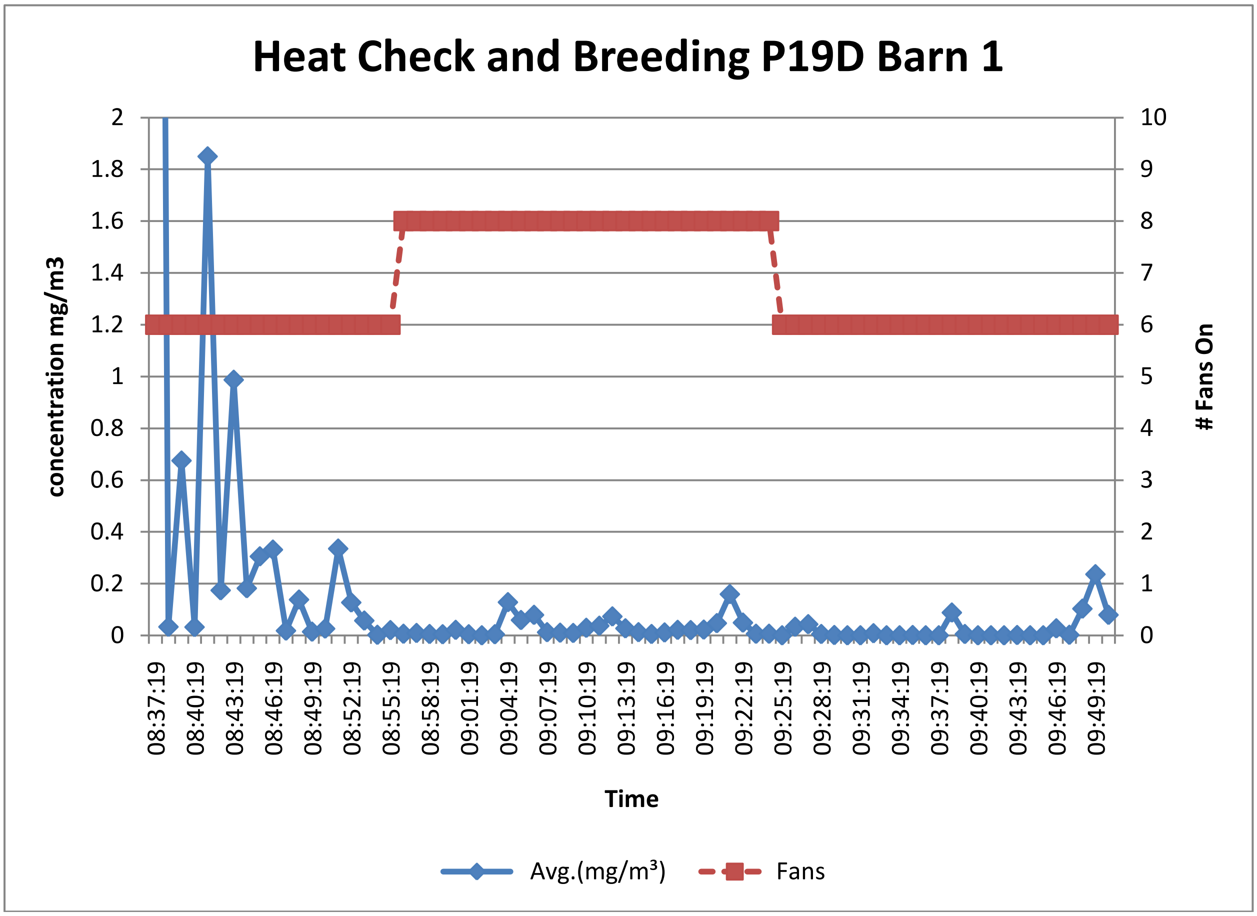

Figure 18. Particulate Matter Concentrations During Heat Check and Breeding

1200 Series Farms

Feed Drop. Farm P12D-2 (Figure 19) had the greatest increase in PM concentration during the feed drop task. This was also the farm sampled at the earliest time of the morning.

Workers reported early on the data collection day to ship pigs from that farm to other farms. At 0448, three fans were running in the breeding and gestation barns. Three minutes later, at 0451, a fourth fan activated and rapidly decreased PM concentration to less than 0.4 mg/m³. Other 1200-series barns were sampled approximately 2 hours later in the day. Each of those barns had five to six fans running and measured less than 0.2 mg/m3 of PM. Refer to Appendix F for all 1200-series feed drops.

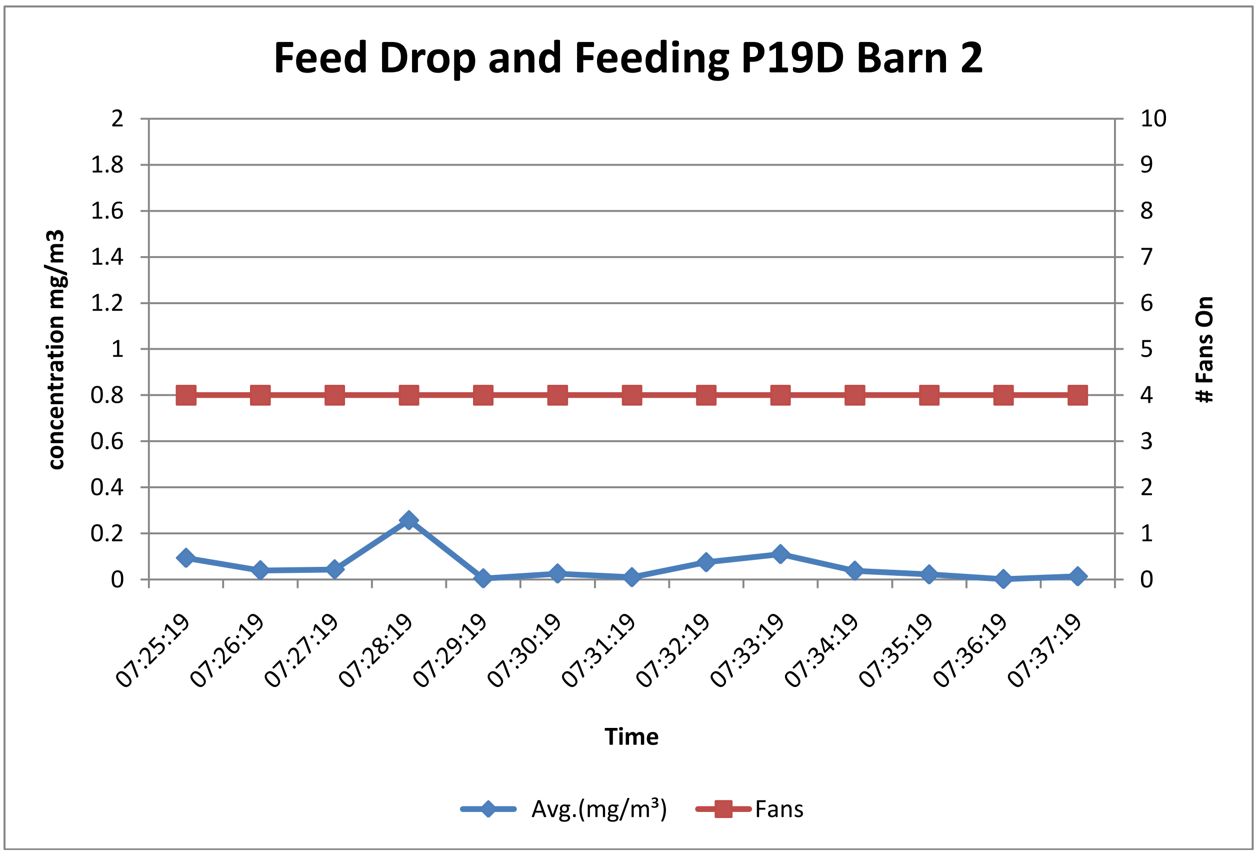

Figure 19. Particulate Matter Concentrations During Feed Drop and Feeding (P12D Barn 2)

Scraping

All but one farm had PM concentrations less than 0.4 mg/m³. Farm P12B-1 particulate matter concentration increased to 1.2 mg/m³ at 0724 but returned to levels below 0.4 mg/m³, representative of other farms in this group. Six fans were running at the beginning of the work day and the inside temperature was 78º F when workers entered the barn. Figure 20 shows the variations noted on farm P12B-1. Additional sampling results can be found in Appendix G.

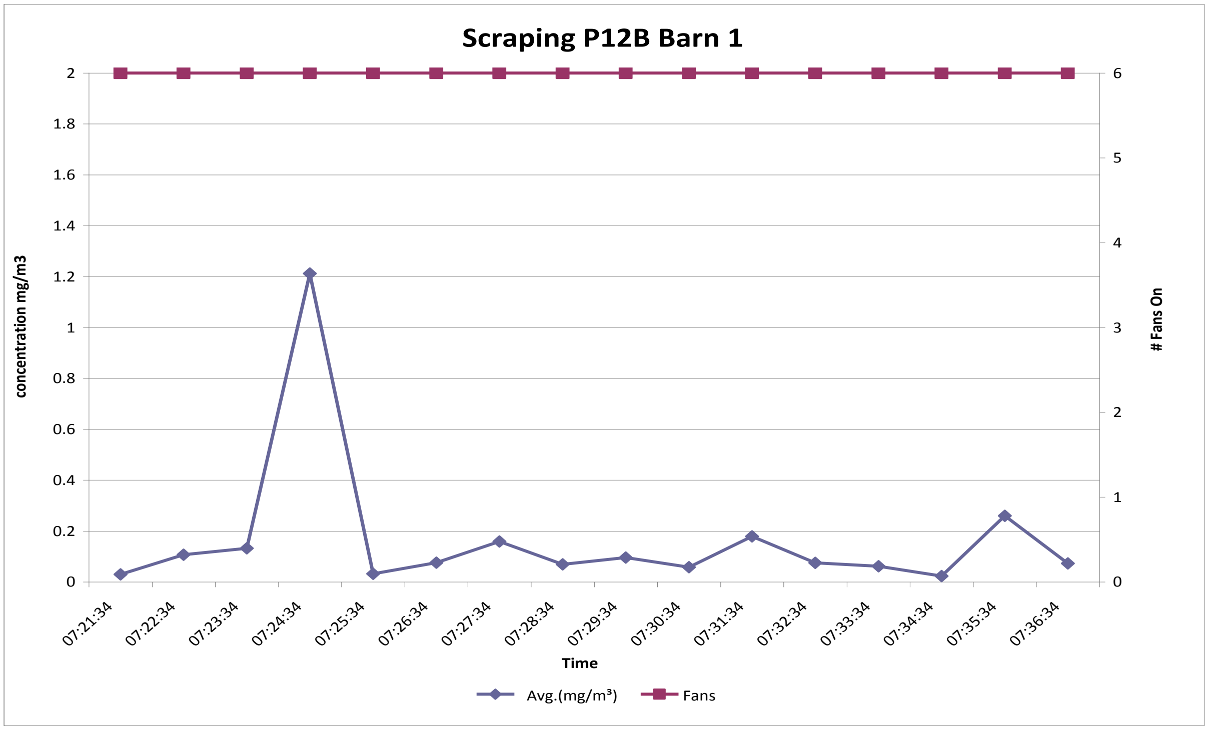

Figure 20. Particulate Matter Concentrations During Scraping (P12B Barn 1)

Sweeping

During the sweeping task, variations were expected because some sows "rooted" more feed into the aisle than others. This task yielded interesting concentrations of PM. In farm P12B-1, the PM concentration was 1.6 mg/m³ at 0749. All fans (6) were running during the entire task. Other farms had fewer fans running during the sweeping task but none recorded concentrations as high as those recorded on farm P12B-1. Appendix H shows the findings from all 1200-series farms for sweeping and Figure 21 illustrates results from farm P12B-1.

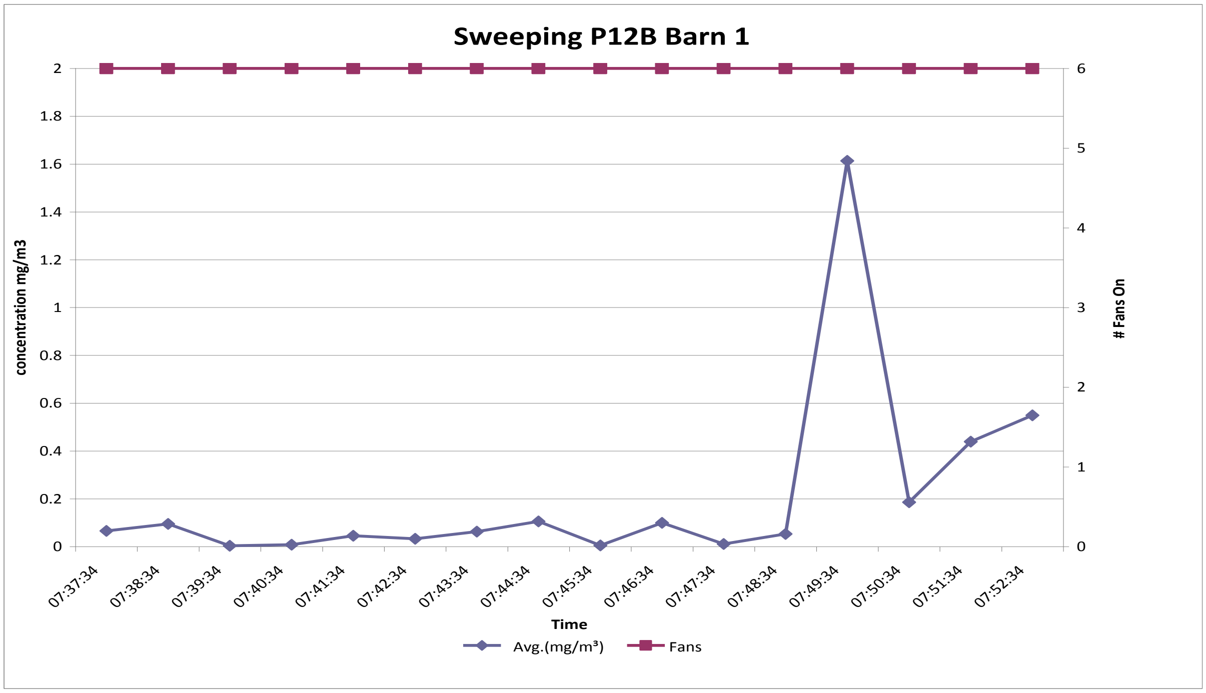

Figure 21. Particulate Matter Concentrations During Sweeping (P12B Barn 1)

Heat Check and Breeding

During heat check and breeding, workers were required to physically palpate sows to determine readiness for breeding. Dust often became dislodged from metal crates when the worker entered individual crates. Animal dander and hair follicles were also displaced in the course of manually checking sows. During the heat check and breeding task, several readings were greater than 0.4mg/m^3 on two particular farms, P12D-1 and P12A-2. The other barns in the 1200-series farms had PM concentrations less than 0.4 mg/m^3. Figures 22 and 23 illustrate the changes in PM concentration in P12D-1 and P12A-2. Other graphs for heat check and breeding can be found in Appendix I.

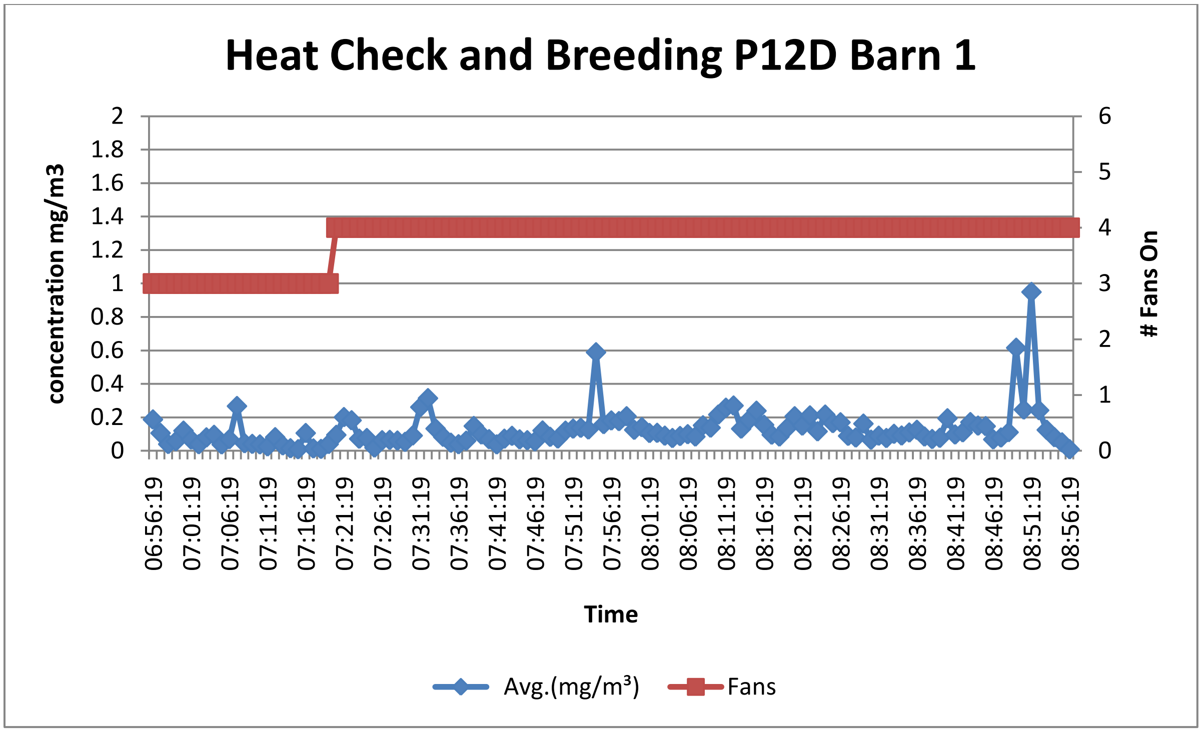

Figure 22. Particulate Matter Concentrations During Heat Check and Breeding Time in P12D-1

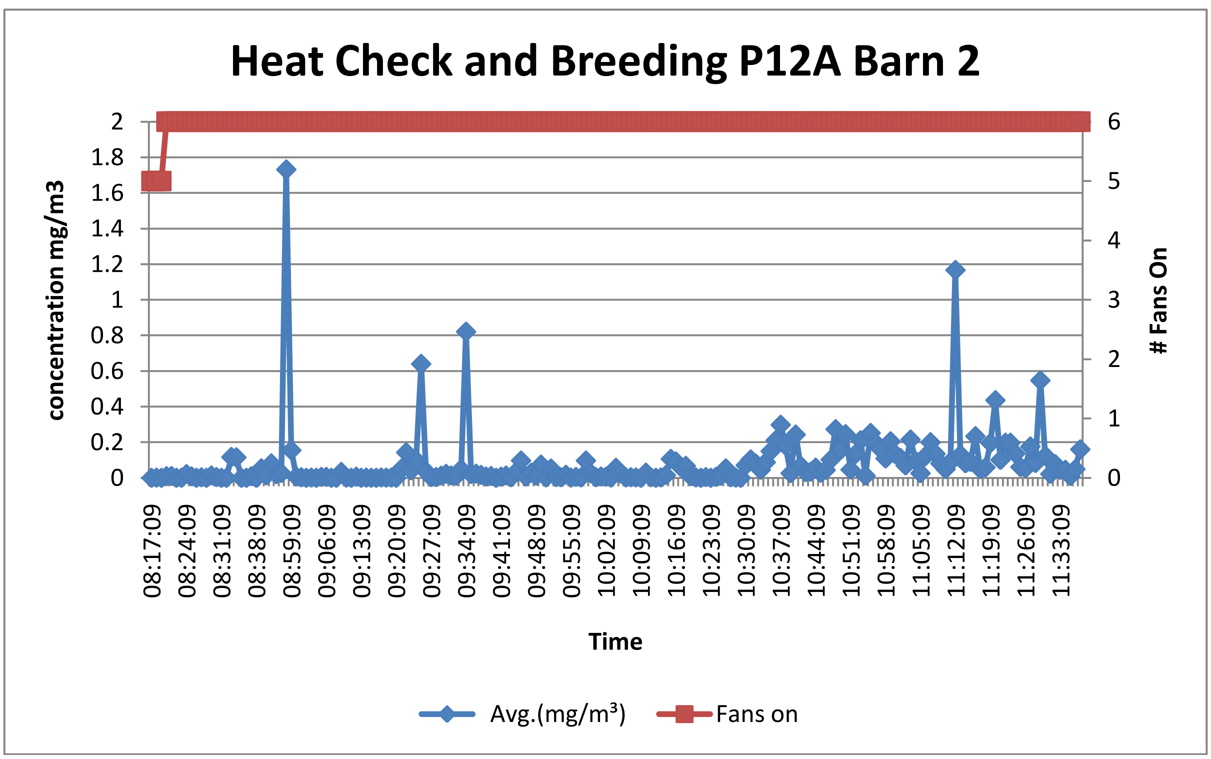

Figure 23. Particulate Matter Concentrations During Heat Check and Breeding Time in P12A-2 *Barn Comparison*

In the 1200-series farms two different building designs were used for the breeding and gestation barns. All Barn 1's were flush-tank barns that used 250 gallon tanks to flush water under the slatted floor and wash animal waste to the lagoon. Barn 2 was a shallow-recharge pit system. In that system, pits were filled with recycled water from the lagoon and held in the pit for 1 week, then drained. Most SCBs constructed after 1992 are the shallow-recharge pit design. The 1900-series barns on all farms had shallow-recharge pits.

Comparison of the flush pit to the shallow-recharge pit was made to determine any differences in PM among the 1200-series barns. Figure 24 shows the concentrations of PM over time in Barn 1 and Barn 2. An interesting observation was the increased concentration of PM in Barn 1 compared to Barn 2. Figure 25 shows PM concentrations for all barn 1's feed drop/feedings.

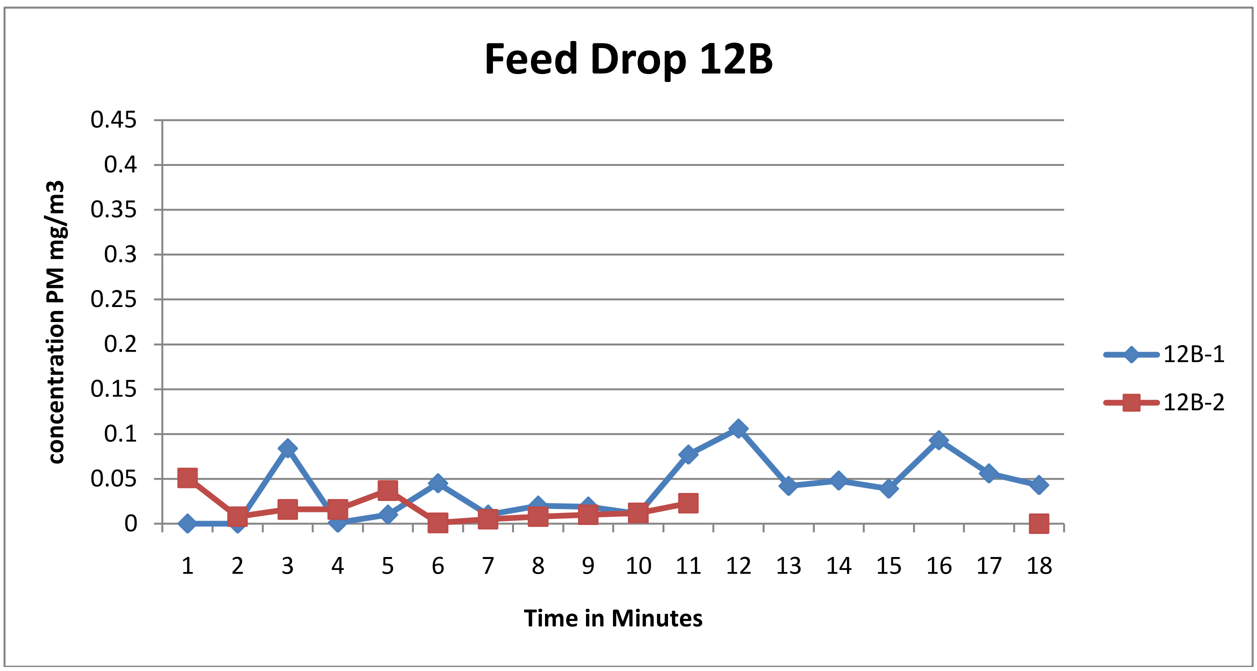

Figure 24. Particulate Matter Concentrations During Feed Drop (P12B, Barns 1 and 2)

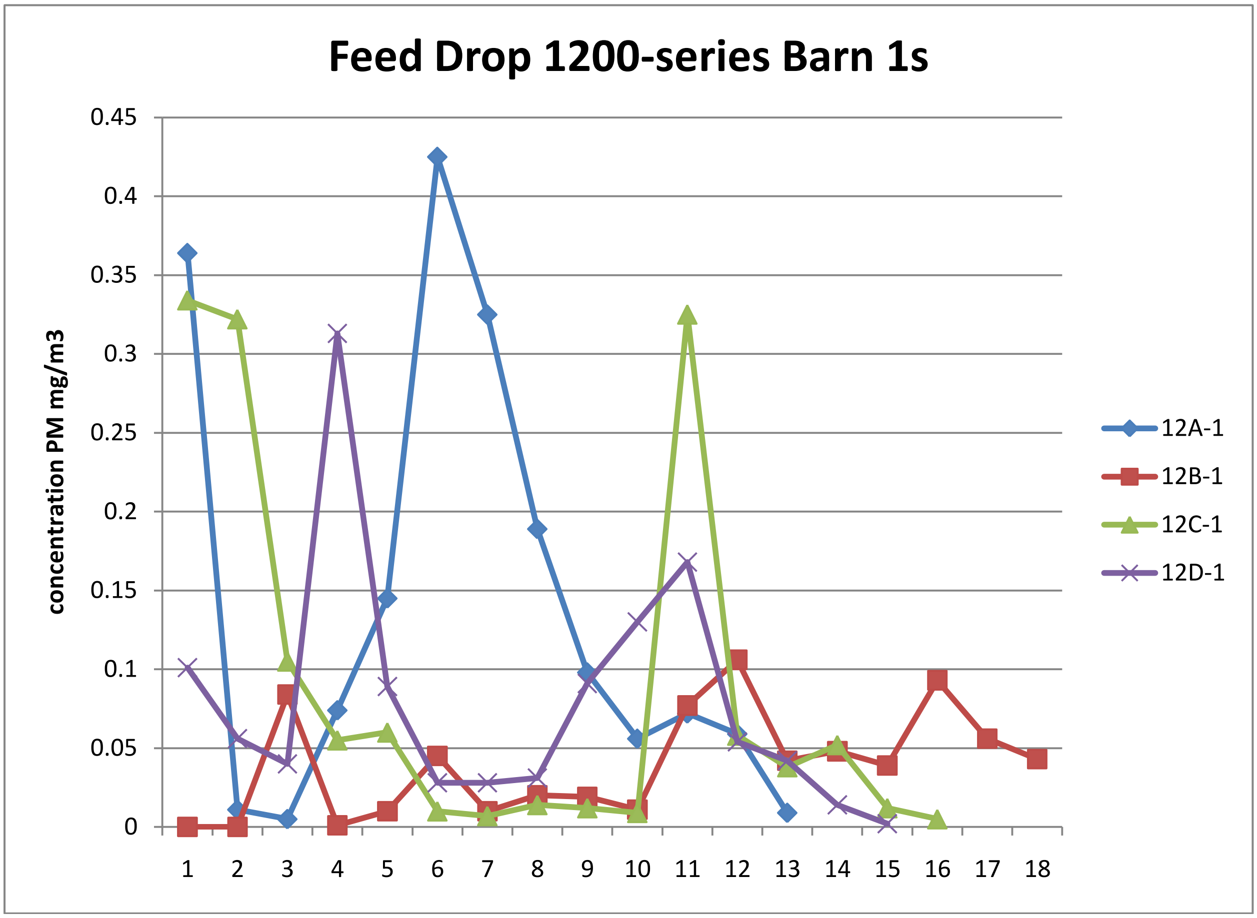

Figure 25. Particulate Matter Concentrations During Feed Drop (1200-series Barn 1s)

Concentrations of PM were higher in some 1200-series Barn 2 but averaged less than the concentrations in 1200-series Barn 1. Figure 26 provides an overview of the concentrations in Barn 2, A, B, C, and D during feed drop sampling. Other tasks performed in Barn 2 had similar results.

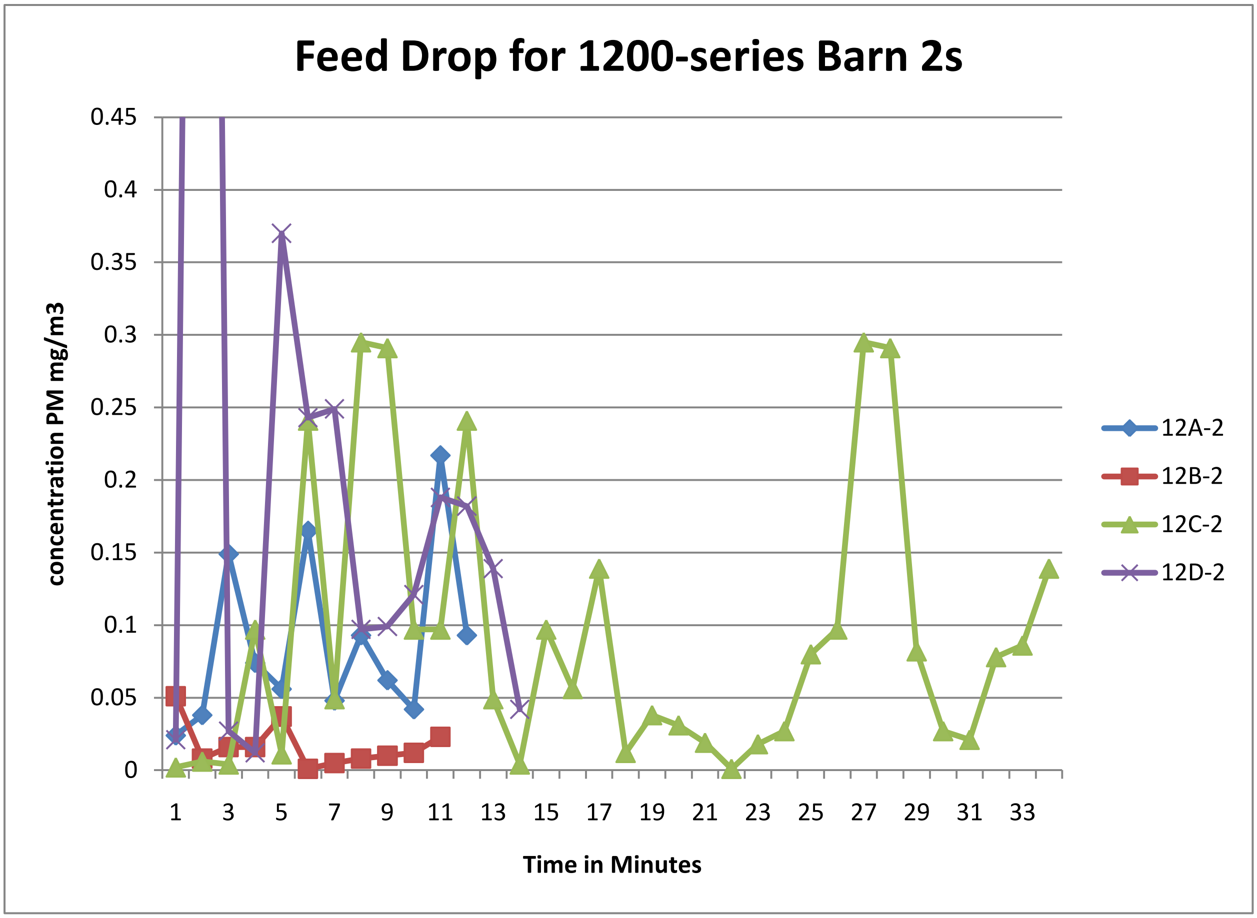

Figure 26. Particulate Matter Concentrations in1200-series Barn 2s During Feed Drop and Feeding Time

Ammonia

The pilot study was conducted in December. During the winter, temperatures ranged from 25ºF to 55ºF outside and 55 ºF to70 ºF inside the SCBs. Fans were set to run if the internal temperature was higher than 68 degrees; therefore, most of the day, especially in the morning, only one fan ran continuously. If the outside temperature registered below 30 ºF, special adjustments were made; the minimum fan was set to run 6 minutes out of every 10 to conserve internal heat.

The dissertation study was conducted in the summer and temperatures outside were 60 ºF to 70 ºF at 0700. Before noon, temperatures were usually in the upper 80 ºF range. Inside temperatures approximated outside temperatures in the summer and all fans cycled on for maximum ventilation as early as 0800.

In the pilot study, ammonia concentrations ranged between 0.5 to 1.4 ppm. Higher concentrations were noted in the early morning and decreased as the number of running fans increased. However, all farms in the dissertation study had ammonia concentrations below the sensitivity of the ammonia air sampling instrument, (0.1 ppm) except farm P12D. The elevated ammonia concentration in P12D was recorded at 0450, an interesting finding. Again, only one fan was running and the outside temperature was 68ºF with fog. The reading peaked at 8 ppm but decreased to less than 0.1 ppm within 5 minutes. During that time the fog cleared, outside temperature increased, and fans cycled on. No other ammonia reading greater than 0.1 ppm was recorded in P12D during that 4-hour sampling period.

Research Questions

Research Question 1 was "Is there a relationship between number of fans running and concentrations of ammonia and particulate matter in confined swine barns?"

Pearson product moment correlation was used to determine if the concentration of PM was related to the number of activated fans. There was a significant, though small, relationship between PM concentration and number of active fans (-0.144, $p < 0.01$) across all barns (n=1,455 data points). Individual barn analysis indicated no significant relationship between PM levels and number of activated fans for the 1200-series flush pit systems (Barn 1s). However, the 1200-series shallow recharge pit systems (Barn 2s) analysis showed a small but significant inverse relationship between PM and number of running fans (-0.152, $p<0.05$). In the 1900-

series barns a correlation of -0.239, ($p<0.01$) indicated a significant, though small, inverse relationship between number of fans and PM concentrations.

To answer Research Question 2: "Is there a relationship between the work tasks of confined swine farm workers and the concentrations of ammonia and particulate matter to which the workers are exposed?" and Research Questions 3: Does the design of confined swine barns affect the concentrations of ammonia and particulate matter?",

data were collected from 1900- Series and 1200- Series Farms and analyzed by task: feed drop, scraping, sweeping, heat check, and breeding. During these operational task-location activities, measurements of time, number of running fans, and ammonia and particulate matter concentration exposures were recorded.

The ANCOVA analysis showed a significant difference in PM depending on the task that was being performed within a specific building. Table 4 and Table 5 highlight significant differences associated with tasks and buildings.

Table 4

Analysis of Covariance for the Level of Particulate Matter with Number of Active Ventilating Fans as the Covariate

Source	SS	df	MS	F	Sig.
Barn Type	0.671	2	0.335	0.837	.433
Work Task	3.514	3	1.171	2.924	.033
Barn Type x Work Task	7.209	6	1.202	3.000	.006
Error	503.856	1258	0.401		
Total	2936.980	1270			

In the 1200-series Barn 1, the scraping task produced significantly more PM than other tasks performed within these barns. However, in the 1200-series Barn 2, no significant differences were found between tasks. Analysis of the 1900-series barns revealed a significant difference in PM during the feed drop and feeding task compared to other tasks performed within these barns.

Despite the overall concentrations of PM below recommended limits, the aforementioned tasks showed workers have increased exposure when completing particular tasks.

Table 5

Matrix Showing the Task and Barn Combinations That Were Significantly Different in the Concentration of Airborne Particulate Matter

		1	2	3	4	5	6	7	8	9	10	11	12
1	P12-1 Check												
2	P12-1 Feed	2>1								2>9			
3	P12-1 Scrape	3>1	3>2		3>4	3>5	3>6	3>7	3>8	3>9		3>11	3>12
4	P12-1 Sweep	4>1											
5	P12-2 Check	5>1								5>9			
6	P12-2 Feed												
7	P12-2 Scrape	7>1								7>9			
8	P12-2 Sweep	8>1											
9	P19 Check												
10	P19 Feed	10>1			10>4	10>5	10>6	10>7	10>8	10>9		10>11	10>12
11	P19 Scrape	11>1											
12	P19 Sweep												

Summary

Surprisingly, no ammonia was detectable except for the one morning when workers reported to work at 0400 to ship pigs. During the summer months enough fans are running throughout the night to keep the ammonia gas concentrations undetectable within the SCBs. The exact number of fans needed to keep ammonia levels below detectable levels was beyond the scope of this research but is a question for future investigations.

The particulate matter concentrations were much smaller than those detected during the pilot study. Other studies published have not found results this low, but no information on the type of buildings or ventilation systems was included in the published reports. This study indicates that workers are receiving less exposure than other published reports have indicated. Actually the study environment was comfortable and did not elicit respiratory symptoms the researcher had experienced while working in the industry some time ago. This research revealed some areas of concern even with reduced concentrations of particulate matter. Multiple factors influence the concentrations of contaminants inside the SCB. When all factors, ventilation, air exchange, relative humidity, internal temperature and cool cells, are working together, exposures are low.

CHAPTER 5

DISCUSSION

This chapter discusses the findings presented in Chapter 4 and their relationship to the purpose of this study. A brief discussion of participants' demographics is offered followed by discussions of the findings related to each research question. Study strengths and limitations, implications for nursing practice, and implications for agricultural policy and practice are discussed. Future research recommendations specific to task-associated workers' exposures within SCBs are presented.

Demographics

Seven of the eight participants had completed high school and one received a baccalaureate degree in Animal Science. Only one female volunteered to be part of the study and only one participant was over the age of 60; the 60 year old worker denied any health problems. All but one of the workers had worked in SCBs for 10 years or more but denied any changes in respiratory function. Farm managers stated that the turnover rate for employees was only 30% per year. These two observations may demonstrate the "healthy workers" effect; workers stay employed in SCBs because they have few if any health-related effects associated with the environment. This group of participants may have reported no previous respiratory complications or diagnosis of asthma because they were the "survivors". The workers who experienced respiratory problems may have already left the company.

Because of company restrictions, the researcher could not ask workers about the frequency of acute illness they have experienced when working continuously for 12 days in the SCBs or if workers believed symptoms either appeared or were exacerbated as the work week progressed. It would have been interesting to know if symptoms returned on the first day back after 2 days off.

According to Schiffman et al., (2005) smokers experience a synergistic effect when exposed to PM; yet three workers reported they were current smokers and three workers had previously quit but had smoked for more than 8 years, 1 to 2 packs per day. Mastrangelo, Tartari, Fedeli, Fadda, and Saia (2005) also indicated synergistic effects between dust exposure and smoking and further correlated these findings with the development of lung cancer in dairy farmers. The participants in this study did not report how long they had been smoke-free nor if they had noticed an improvement in respiratory function since quitting.

According to the researcher's model presented in Chapter 1, several factors may influence the reactivity of the respiratory system resulting in acute respiratory complications; smoking, extended work week, previous respiratory illness, and tasks performed. However, this sample group denied any respiratory complications during the previous 6 months.

Discussion of Findings

The research questions; "Is there a relationship between the work tasks of confined swine farm workers and the concentrations of ammonia and particulate matter to which workers are exposed?" and "Does the design of SCBs affect the concentrations of ammonia and particulate matter?" were addressed. Findings from this study documented that some tasks completed in particular barns resulted in increased exposures. In the 1200-series barn 1s, the only task that was significantly related to elevated PM exposure was scraping. Contrary to previous findings, the feed drop and feeding task was not significantly different from other tasks within these barns and among other barns in the 1200-series farm. However, feed drop was significantly associated with PM exposure in the 1900-series barns. These results demonstrate that specific tasks routinely performed by swine confinement workers can increase their PM exposure. The interactive association between tasks and building design played a role in determining workers' exposure.

Knowing that specific tasks can increase workers' exposure to PM, agricultural health nurses can collaborate with company officials to initiate administrative changes to reduce net exposure, i.e., rotating workers performing each task. For example, scraping has been identified as a task that increases workers' exposure to PM. The farm manager can rotate workers performing specific tasks, reducing total weekly exposure. If absenteeism requires an individual worker to perform a task several consecutive days, then recommendations for PPEs are warranted. If PPE is needed, specific masks matched to potential exposure should be provided to workers. Using the appropriate mask should better protect workers and be more cost effective for the company.

The research question, "Is there a relationship between the number of fans running and concentrations of ammonia and particulate matter in SCBs?", was answered. The tests of between-subjects effect revealed that only about 6% of the PM concentrations could be attributed to the effects of fans. In addition, Pearson product moment correlation indicated that as the number of fans increased the concentration of PM decreased (-0.239). These findings support the swine confinement occupational exposure model that fans do remove PM from the SCBs resulting in less exposure for workers.

However, the findings also revealed that when the number of fans running in the 1900-series barns exceeded 6 fans, the PM concentration increased. As additional fans activated, more PM was drawn into the work space. It is unclear if larger PM particles are aerosolized or if more small PM particles were responsible for the increase in PM concentration. This question warrants future investigation because respirable particles are believed to increase the risk of lower respiratory inflammation.

During the summer months and in warmer climates gases and PM are removed from workers' environments through air exchange via the ventilation systems. Furthermore, the PM concentrations in this study suggested less need for other administrative, engineering, or worker (PPE) controls in the summer.

Strengths of the Study

The pilot study provided insight into data collection procedures and equipment malfunctions that could occur during the dissertation study. Alleviating operator errors provided consistency in dissertation study data collection.

Consistent data collection techniques were used, taking air samples at or near the same time each day. Identical vests were used to house the sampling instruments during data collection; instruments were placed in the same pockets of the vest each day. This procedure was essential to gathering consistent readings because the air sampling equipment used passive airflow to determine the concentrations of ammonia and PM. This is the first study to air sample continuously near workers' breathing zones during specific work tasks in SCBs.

Another innovation in this study was the presence of the researcher during the entire air sampling period to record observed data: number of fans running, internal temperature, outside temperature, and any signs of workers' respiratory irritancy. Researcher's observations were linked to air sampling at the conclusion of each day. Workers did not have to report or recall events but simply carried the equipment and performed their routine tasks.

Limitations of the Study

Every variable that could affect ammonia and PM concentration was not measured or controlled to determine the most predictive factors in SCBs. In addition, only a small number of workers participated in the study so results cannot be generalized to all workers in all SCBs.

Instruments were placed at workers' waist level rather than near the face to minimize interference with employees' work performance. The researcher could not determine the effect this may have had on exposure concentrations that workers were actually breathing.

Weather conditions outside the SCB varied significantly from day to day and the effects of weather changes could not be controlled. For example, the relative humidity during air sampling should be 50% or less; no instruments were available to record the relative humidity in outdoor or indoor air.

Other researchers have used dosimeters that draw air through a filter via a portable air pump to collect PM. These filters can be weighed before and after data collection using gravimetric instruments. The procedure is believed by industrial hygienists to be more accurate in determining the exact concentration of PM. Although air flow pumps are frequently used to determine PM concentrations, these instruments are expensive and beyond the financial means of this researcher.

Implications for Nursing Practice

Agricultural health nurses (AHN) should ensure that baseline pulmonary function testing, forced expiratory volume in 1 second (FEV1), and forced vital capacity (FVC) are used to assess each worker prior to job placement. Also, students employed during the summer should have pulmonary function tests prior to and after completion of internship to document any adverse effects. The baseline test can be compared to existing standardized pulmonary function graphs, which account for age, gender, height, and weight to determine if potential employees already have respiratory obstructive or restrictive conditions. Consequently, FEV1 and FVC testing can be performed more frequently for workers with existing conditions to prevent exacerbations of respiratory illness that could result in lost work days. For employees with normal baseline FEV1 and FVC, the tests should be performed at least annually.

The AHN should also evaluate conditions inside the barns and make recommendations for respirators appropriate for the season and the contaminants present. Furthermore, the AHN should perform fit-testing for each employee. Finally, the AHN should implement health surveillance programs, conduct walk-through evaluations on farms, and collaborate with management to enforce PPE policies.

Revisiting the model presented in Chapter 1 emphasizes possible implications for nursing. When workers experience acute occupational illnesses, the AHN can ensure early treatment and compliance with treatment recommendations. Identification of workers with frequent bronchitis, sinusitis, or other persistent health problems and subsequent referrals can reduce absenteeism and improve productivity. In addition, measures such as reduction in exposure time, altered work assignments, and limiting the number of days exposed could decrease the risk of workers developing chronic pulmonary disease. Expertise in animal production develops with experience; therefore, employment longevity enhances workers' skills resulting in better conception rates, increased survivability of newborn pigs, reduced medication and veterinary cost, and increased profits.

Concentrated swine operations have not existed long enough for worker exposures to be well documented. Older industries such as coal mining and cotton textile mills have demonstrated how long-term exposure to environmental contaminants can impact worker health.

With 250,000 workers in this industry, some having worked for more than 10 years, health care workers may see an increase in workers needing supplemental oxygen to sustain their quality of life and performance of activities of daily living.

Implications for Agricultural Practice

This study has suggested realistic interventions to reduce PM exposure to SCB workers. Swine production companies should include pulmonary function testing in preplacement examinations for each worker to establish a baseline for later comparison. Implementing no smoking policies inside the facility could also reduce the synergistic effects of exposure to multiple hazards known to impair lung function. Further investigation into the proper type of respirators could reduce cost and provide better protection for workers.

Current policy in the company study barns requires workers to wear respirators when dropping feed and feeding animals. This study indicates that performing other tasks can also increase workers' exposure to PM. For instance, in Barn 1 on 1200-series farms, scraping resulted in increase PM exposure. In addition, the discovery that PM concentrations increased on 1900-series farms when 8 to 10 fans were activated suggest engineering changes may also be needed to reduce PM exposure. Cool cells should be activated after 6 fans are running and temperatures continue to increase. If temperatures cannot be controlled with 6 fans and the cool cells then the final fans should be activated to reduce inside temperature. These recommendations are practical because no additional expense would be incurred by the company to implement these changes. However, additional air sampling should be undertaken to confirm or refute the effect of these changes on worker exposure.

Implications for Future Research

Seasonal variations are well documented in the literature presented in Chapter 2. Therefore, this study should be replicated throughout the year in different parts of the country. Ideally, the study should be conducted in mid winter months because only the minimum ventilation fan is running. During winter months barns are not washed to conserve heat and reduce the risk of animals developing an illness, resulting in dust accumulation on crates, feed lines, and curtains. Late January and early February are usually the coldest times for the region in which this study was conducted. Additionally, mid April and late September or early October would provide data on the effects of spring and fall weather on exposures. Replicating this research study on the same farms in the same locations and at the same time of day would reduce the impact of extraneous variables and identify changes in the SCBs that are primarily attributable to seasonal variations.

Additional studies are also needed to determine the role of fans on PM and ammonia concentrations associated with seasonal variations. For example, would placing fans in the middle of long barns exhaust more PM, especially during minimum exhaust fan operation?

Workers should have FEV1 and FVC tests evaluated prior to working in the facility and after tasks have been completed in the breeding and gestation barns for an entire work cycle (12 days). Workers usually work 12 days and then take 2 days off. The prolonged exposure period may have a greater influence on lung function than is documented in the literature because of continuous inflammation of the respiratory system. Most studies use a 40-hour TWA to predict the decline in lung function. However, a 40-hour TWA is not representative of industry practice. Additionally, FEV1 and FVC from the last day worked should be compared to the first day back to work after 2 days off.

Breeding and gestation workers are only half of the workers on the farm. Workers in the farrowing house need to be informed of areas or tasks that increase their exposures to ammonia and particulate matter. Task-associated air sampling could determine if workers need specific PPE or if administrative and engineering changes could reduce workers' exposure.

Summary

Research publications have documented the effect of seasonal changes in the SCBs environment resulting in reduction of ammonia and PM concentrations (Pickrell, Heber, Murphy, & Henry, 1993; Sigurdarson et al., 2004). Interestingly, there is a current paucity or a total lack of published literature addressing workers' task activities associated with increased PM or ammonia exposure and its relationship to workers' overall health.

This researcher's interest in this area sprang from vast personal experience in the swine industry. How do prolonged exposures in SCBs affect workers' respiratory systems? A need to understand personal experiences resulted in this research endeavor.

Based on this preliminary study, the three research questions have been carefully explored and discussed. New information revealing the interactive association of tasks, building design, and ventilation provide opportunities for agricultural health nurses to intervene and positively impact workers' health. Feasible interventions and recommendations have been identified and presented. Management and workers can collaborate when issues are identified to promote employment longevity, reduced absenteeism, improved productivity, and company profitability.

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APPENDIXES

Appendix A

Institutional Review Board Forms

ETSU

East Tennessee State University
Office for the Protection of Human Research Subjects • Box 70565 • Johnson City, Tennessee 37614-1707 • (423) 439-6053
Fax: (423) 439-6060

IRB APPROVAL – Minor Modification

July 2, 2009

Early Bembry
530 Birch Street
Church Hill, TN 37642

Re: Comparison of ammonia and particulate matter air sample concentrations at task-locations within the swine confinement buildings

IRB#: c08-001s

The following was reviewed as a minor modification:

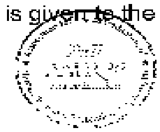
- Modification request – the research site has asked that certain questions be omitted that were on the original study and as a result of these omissions the research title had to be modified to more appropriately identify the research project. Alterations of the narrative reflect the changes that the PI will not be asking workers to identify work task locations that elicit respiratory responses. The research site felt that this may suggest to the workers some unknown environmental hazards and prompt employees to file worker comp claims therefore the PI modified the questionnaire to accommodate the research site's concerns.
- CITI training
- Revised ICD (6/16/09)
- Revised study questionnaire (6/24/2009)
- Permission letter from Prestage Farms, Inc.
- Revised narrative (6/19/09)

On July 2, 2009, a final approval was granted for the above mentioned minor modification. The minor modification approval will be reported to the convened board on August 6, 2009.

The following **enclosed stamped, approved ICD** has been stamped with the approval and expiration date and must be copied and provided to each participant prior to participant enrollment:

- Informed Consent Document **(ver. Date 6/16/2009)**

Federal regulations require that the original copy of the participant's consent be maintained in the principal investigator's files and that a copy is given to the subject at the time of consent.



Accredited Since December 2005

Unanticipated Problems Involving Risks to Subjects or Others must be reported to the IRB (and VA R&D if applicable) within 10 working days.

Proposed changes in approved research can not be initiated without IRB review and approval. The only exception to this rule is that a change can be made prior to IRB approval when necessary to eliminate apparent immediate hazards to the research subjects [21 CFR 56.108 (a)(4)]. In such a case, the IRB must be promptly informed of the change following it's implementation (within 10 working days) on Form 109 (www.etsu.edu/irb). The IRB will review the change to determine that it is consistent with ensuring the subject's continued welfare.

Sincerely,

Chris Ayres, Chair
ETSU Campus Institutional Review Board

BEMBRY TASK ANALYSIS WORKSHEET

TASK PERFORMED	COUGH		SPUTUM OR PHLEGM		SCRATCHY THROAT		RUNNY NOSE		BURNING OR WATERY EYES		HEADACHE		CHEST TIGHTNESS		SHORT OF BREATH		WHEEZING		MUSCLE ACHES AND PAIN	
R= reported O= observed	R	O	R	O	R	O	R	O	R	O	R	O	R	O	R	O	R	O	R	O
DROP FEED/ FEEDING																				
SCRAPPING BEHIND SOWS																				
SWEEPING FEED AISLES																				
BREEDING																				
FILLING OUT BREEDING CARDS																				
HEAT CHECK																				
WALKING BACK AISLES OR PENS																				

PRINCIPAL INVESTIGATOR: Earl Dan Bembry

TITLE OF PROJECT: Comparison of ammonia and particulate matter air sample concentrations at task-locations within the swine confinement buildings

VOLUNTARY PARTICIPATION: Participation in this research experiment is voluntary. You may refuse to participate. You can quit at any time. If you quit or refuse to participate, the benefits to which you are entitled will not be affected. You may quit by calling Earl Dan Bembry, whose phone number is 423-388-0488.

CONTACT FOR QUESTIONS: If you have any questions, problems or research-related medical problems at any time, you may call Earl Dan Bembry at 423-388-0488, or Joy Wachs at 423-727-4202. You may call the Chairman of the Institutional Review Board at 423-439-6054 for any rights you may have about your rights as a research subject.

CONFIDENTIALITY: Codes will be assigned to questionnaires which will provide confidentiality for participants and no identifiers will be established or recorded for the correlation of codes to participants.

____

SIGNATURE OF PARTICIPANT DATE

____

PRINTED NAME OF PARTICIPANT DATE

____

SIGNATURE OF INVESTIGATOR DATE

APPROVED
By The ETSU/VA IRB

By ________
CHAIR/IRB COORDINATOR

ETSU/VA IRB

Ver. 06/16/09 Page 2 of 2 Subjects Initials________

ETSU

East Tennessee State University
Office for the Protection of Human Research Subjects • Box 70565 • Johnson City, Tennessee 37614-1707 • (423) 439-6053
Fax: (423) 439-6060

IRB APPROVAL - Initial Expedited Review

August 7, 2008

Earl Bembry
530 Birch St
Church Hill, TN 37642

Re: Comparison of Swine Confinement Workers' Reports of Location- Task Irritancy from Work Exposures to Ammonia and Particulate Matter and Location Specific Air Sampling

IRB#: c08-001s

ORSPA #: None

The following items were reviewed and approved pending requested:

- FORM 103 with Assurance Statement
- *Narrative (3/24/2008)
- Informed Consent Document (7/16/2008)
- Questionnaire/Survey
- Permission Letter from External Site
- CV
- Conflict of Interest Form (no potential conflict of interest identified)

The item with an asterisk(*) above needed changes requested by the expedited reviewer.

The following documents with the incorporated requested changes have been received by the IRB Office:

- revised Narrative (ver date 8/7/2008)

The revised Narrative (ver date 8/7/2008 incorporating the requested changes was reviewed and approved by an expedited process on August 7, 2008 by Chris Ayres, Chair, ETSU IRB.

On August 7, 2008, a final approval was granted for a period not to exceed 12 months and will **expire on 8/6/2009**. Your Continuing Review is scheduled for 7/4/2009. The expedited approval of the study and requested changes [revised Narrative (ver date 8/7/2008], will be reported to the convened board on September 4, 2008.

Accredited Since December 2005

The following **enclosed stamped, approved ICD** has been stamped with the approval and expiration date and this document must be copied and provided to each participant prior to participant enrollment:

- Informed Consent Document **(7/16/2008)**

Federal regulations require that the original copy of the participant's consent be maintained in the principal investigator's files and that a copy is given to the subject at the time of consent.

Unanticipated Problems Involving Risks to Subjects or Others **must** be reported to the IRB (and VA R&D if applicable) within 10 working days.

Proposed changes in approved research can not be initiated without IRB review and approval. The only exception to this rule is that a change can be made prior to IRB approval when necessary to eliminate apparent immediate hazards to the research subjects [21 CFR 56.108 (a)(4)]. In such a case, the IRB must be promptly informed of the change following it's implementation (within 10 working days) on Form 109 (www.etsu.edu/irb). The IRB will review the change to determine that it is consistent with ensuring the subject's continued welfare.

Sincerely,

Chris Ayres, Chairperson
ETSU Campus Institutional Review Board

Pilot Study Questionnaire

1. Date of birth ___________ Age ___________.
2. Gender ____male ____female
3. Indicate the number of years you have worked in swine confinement buildings

   ______ years
4. Please indicate education level

   ____ Some high school (8-11 years) _____High school graduate (12 years)
   ____ Some college 13-15 years _____ College graduate (16 years)
5. Check the appropriate

   ___ current smoker ___previous smoker but quit ___never smoked

   For those that checked current smoker or previous smoker but quit
   _____ number of years smoked _____ number of packs per day
6. Have you ever been diagnosed with asthma? ___yes ___no
7. During the last 6 months have you been diagnosed with any other respiratory problems? ____yes ___no Please list: _______________

   ____
8. When working in the swine confinement building have you ever had any of the following symptoms (please check all that apply)?

   ___coughing ___sneezing ___sputum or phlegm
   ___chest tightness ___runny nose ___burning or watery eyes
   ___wheezing ___headaches ___difficulty breathing
   ___scratchy throat
9. Describe each location or task within confinement buildings that makes the associated symptoms checked in #8 above worse.
10. Have you discussed you health concerns with any person at your work site.

   ___yes ____no

Study Questionnaire

1. Date of birth ____________ Age _____________.

2. Gender ____male ____female

3. Indicate the number of years you have worked in swine confinement buildings

   ______ years

4. Please indicate education level

   ____ Some high school (8-11 years) _____High school graduate (12 years)
   ____ Some college 13-15 years _____ College graduate (16 years)

5. Check the appropriate

   ___ current smoker ___previous smoker but quit ___never smoked

   For those that checked current smoker or previous smoker but quit
   _____ number of years smoked _____ number of packs per day

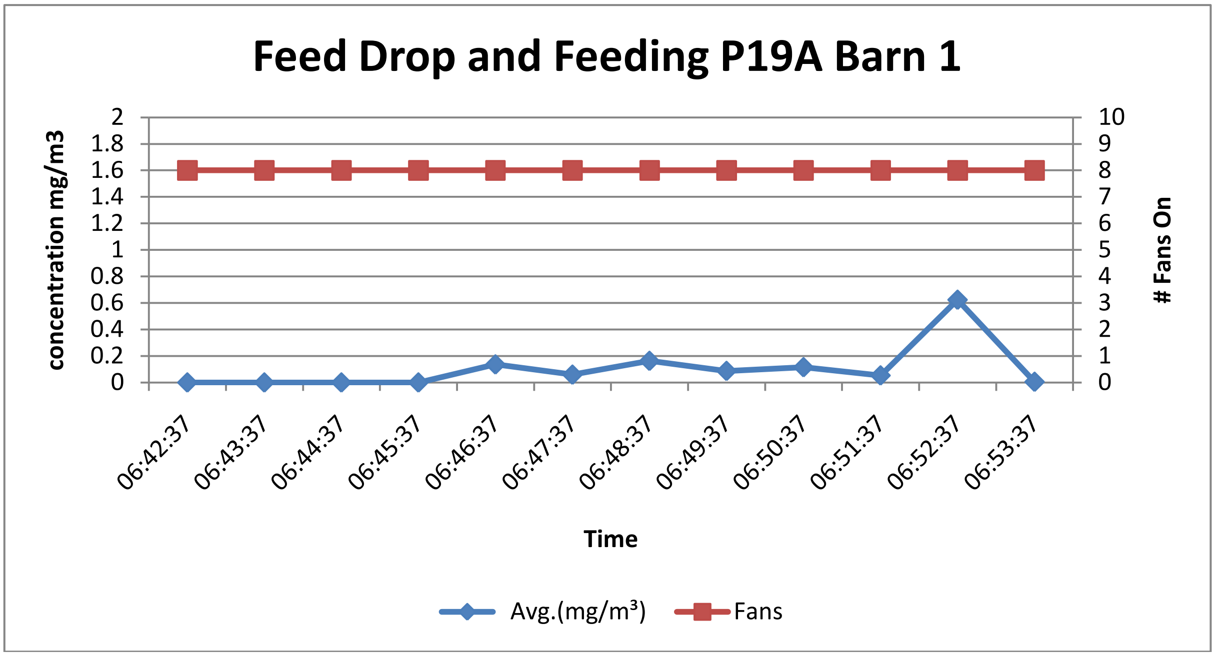
6. Have you ever been diagnosed with asthma? ___yes ___no

7. During the last 6 months have you been diagnosed with any other respiratory problems? ____yes ___no Please list: ____________________
   ____

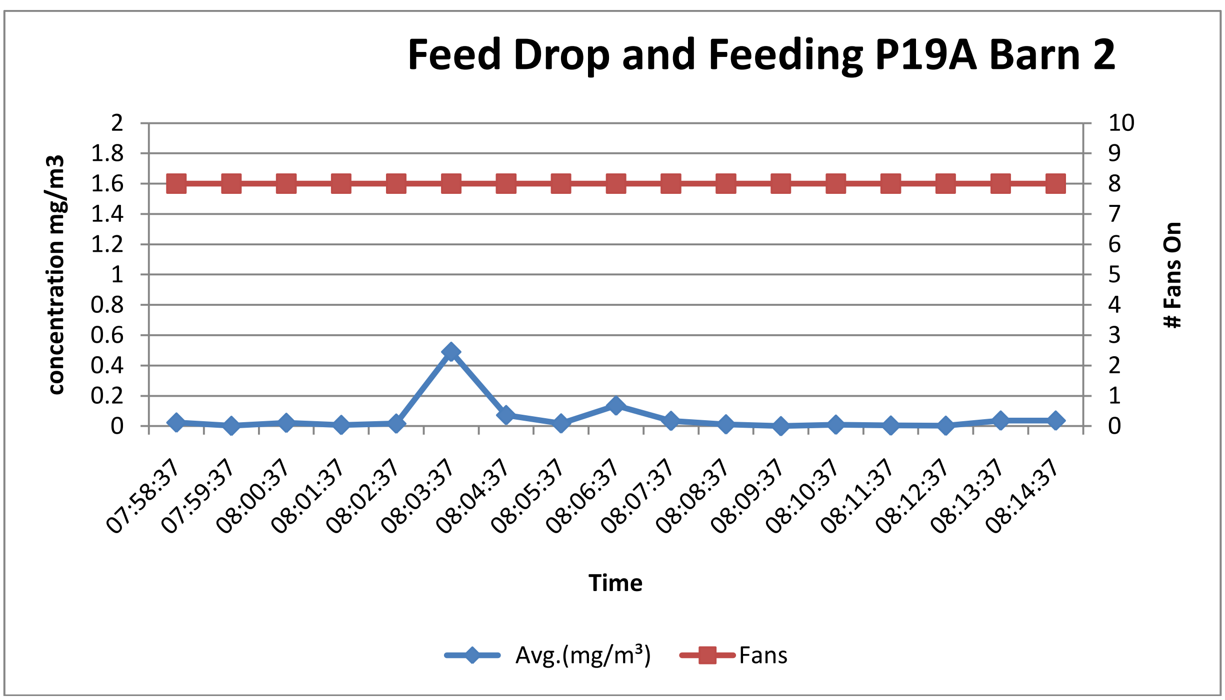
Appendix B

1900-Series Feed Drop Task Graphs

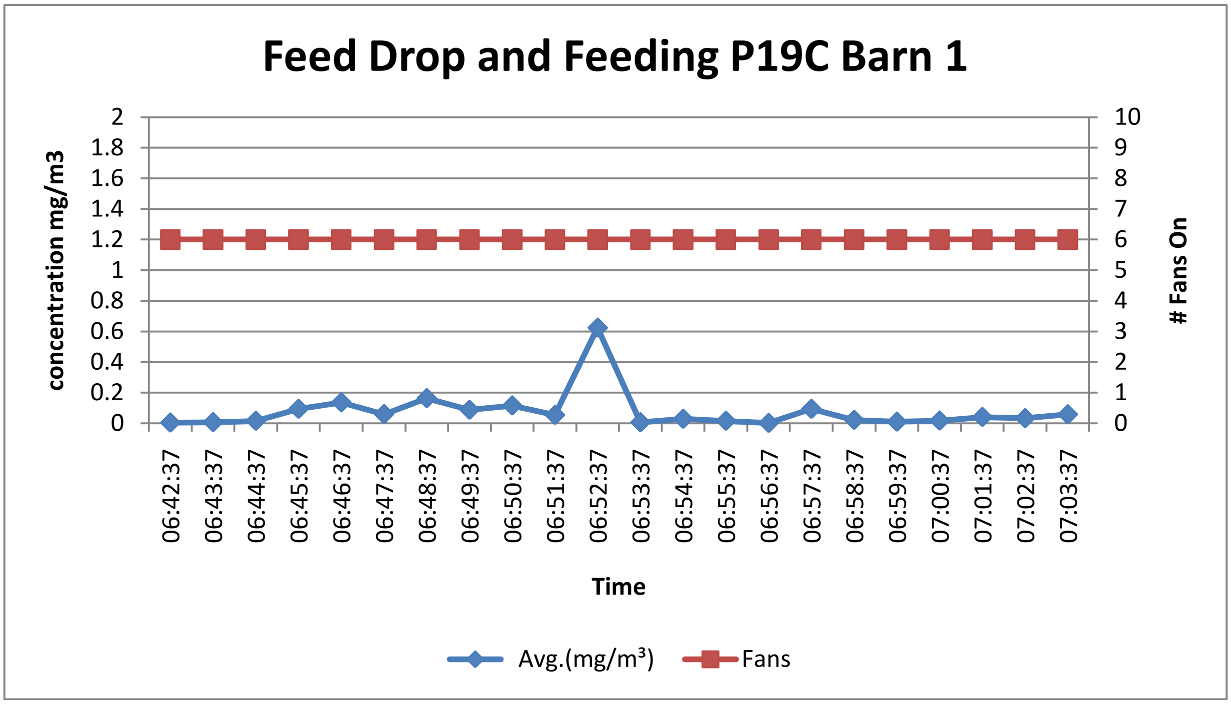
Particulate matter during feed drop and feeding times in P19A Barn 1



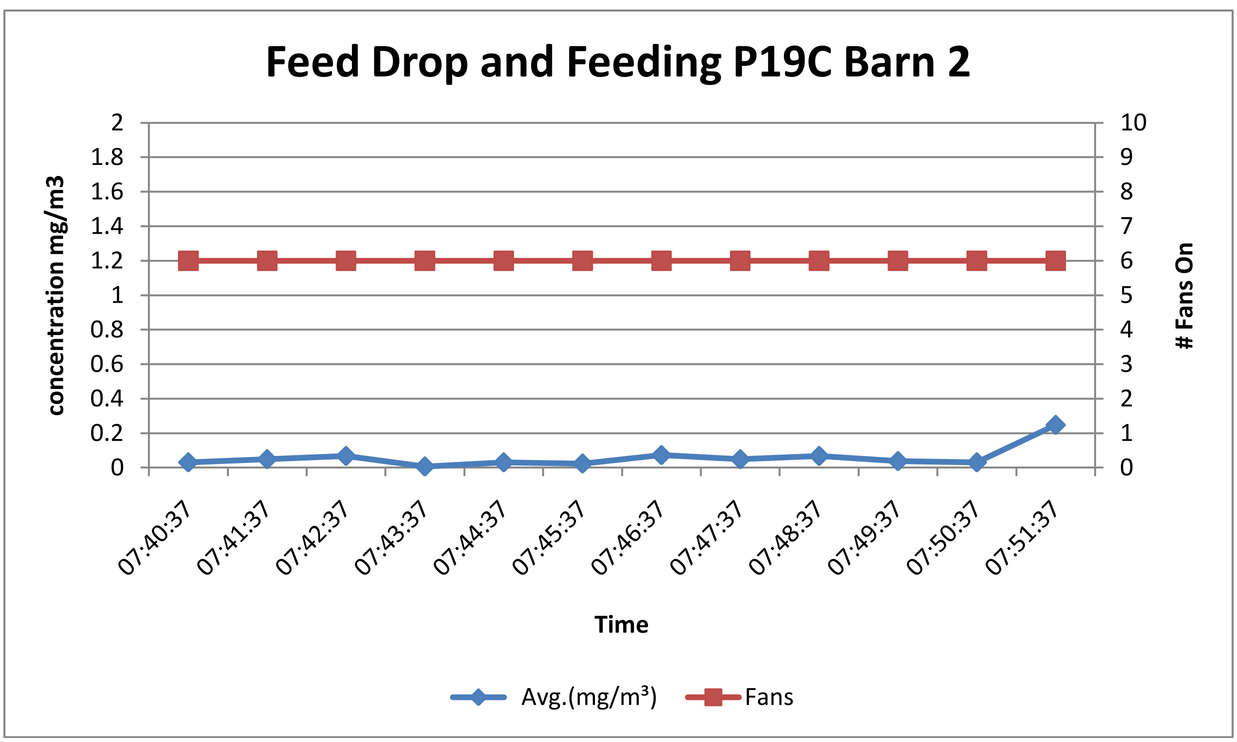
Particulate matter during feed drop and feeding times in P19A Barn 2



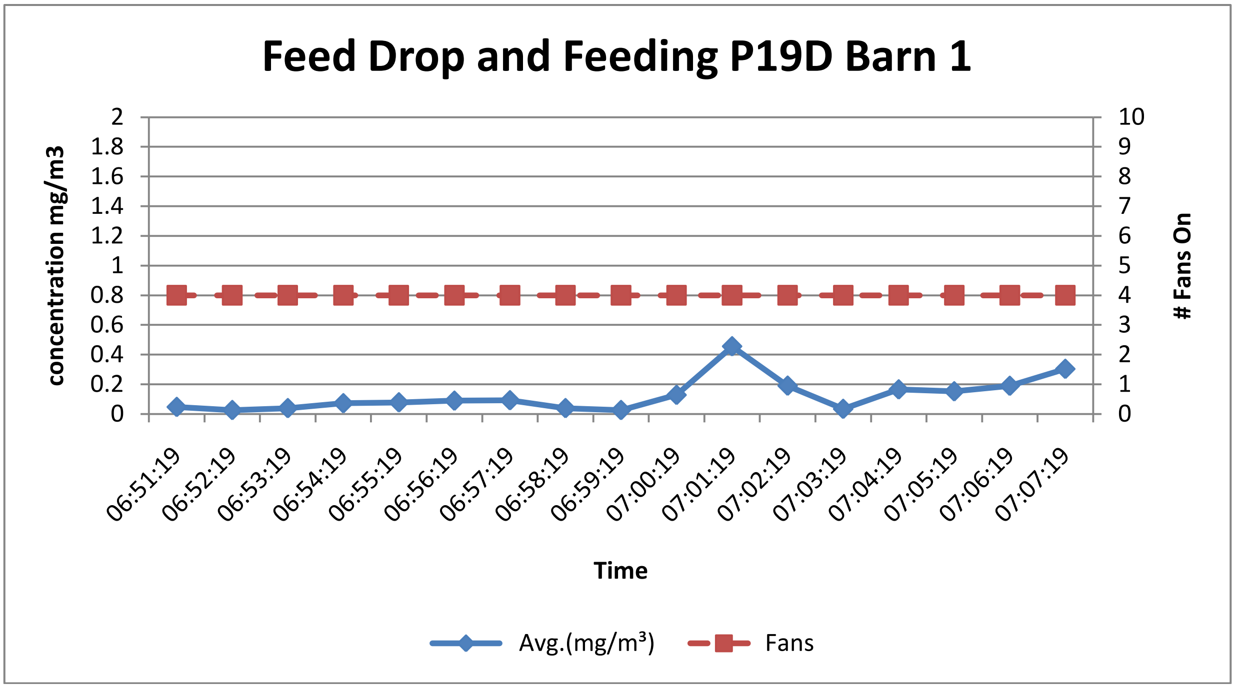
Particulate matter during feed drop and feeding times in P19C Barn 1



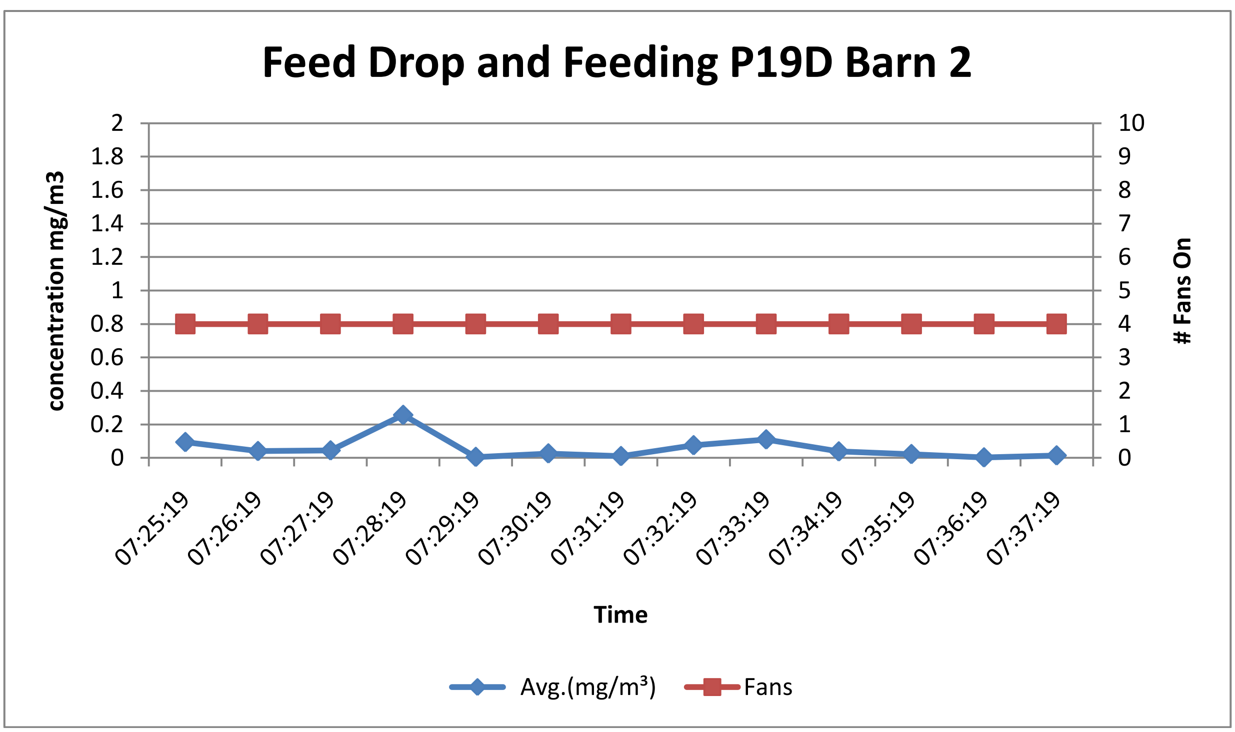
Particulate matter during feed drop and feeding times in P19C Barn 2



Particulate matter during feed drop and feeding times in P19D Barn 1



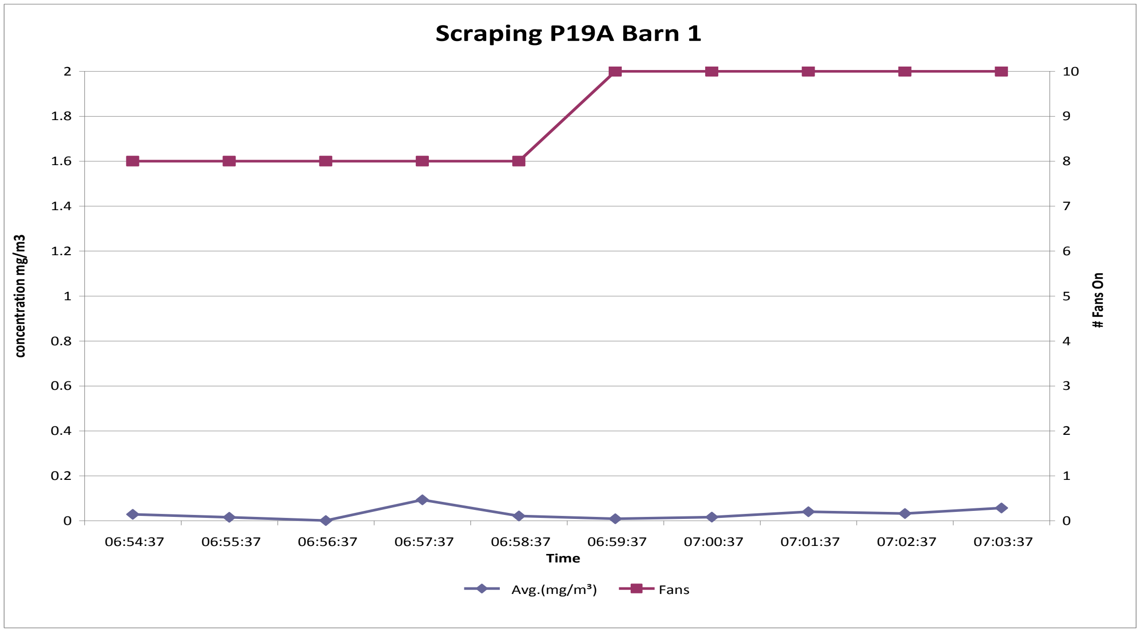
Particulate matter during feed drop and feeding times in P19D Barn 2



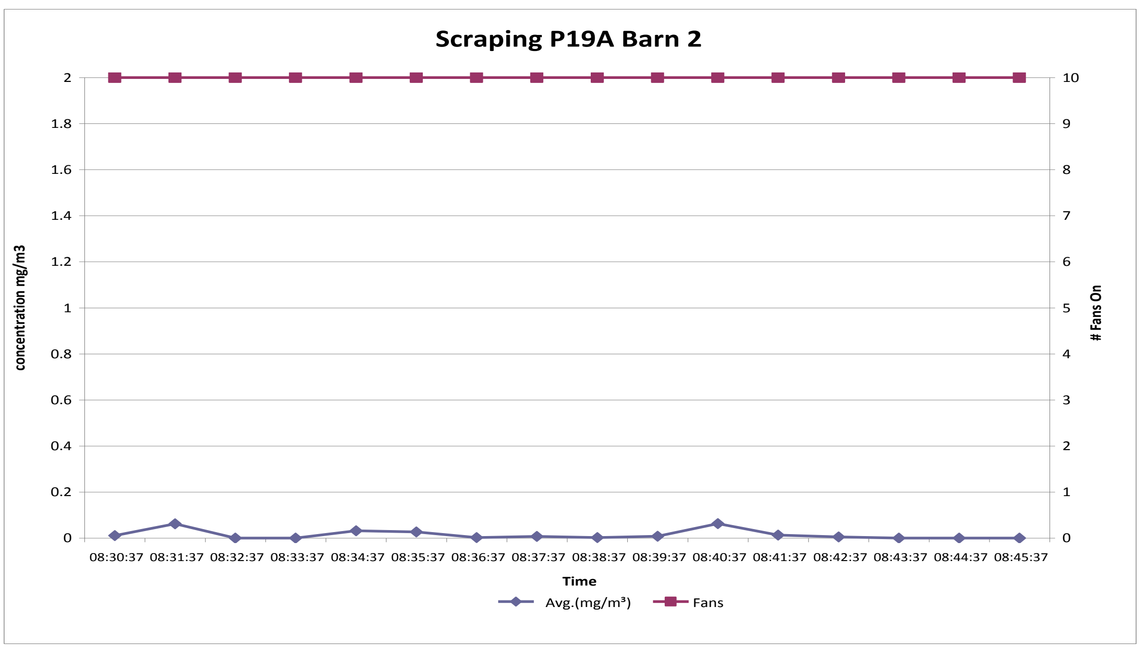
Appendix C

1900-Series Scraping Task Graphs

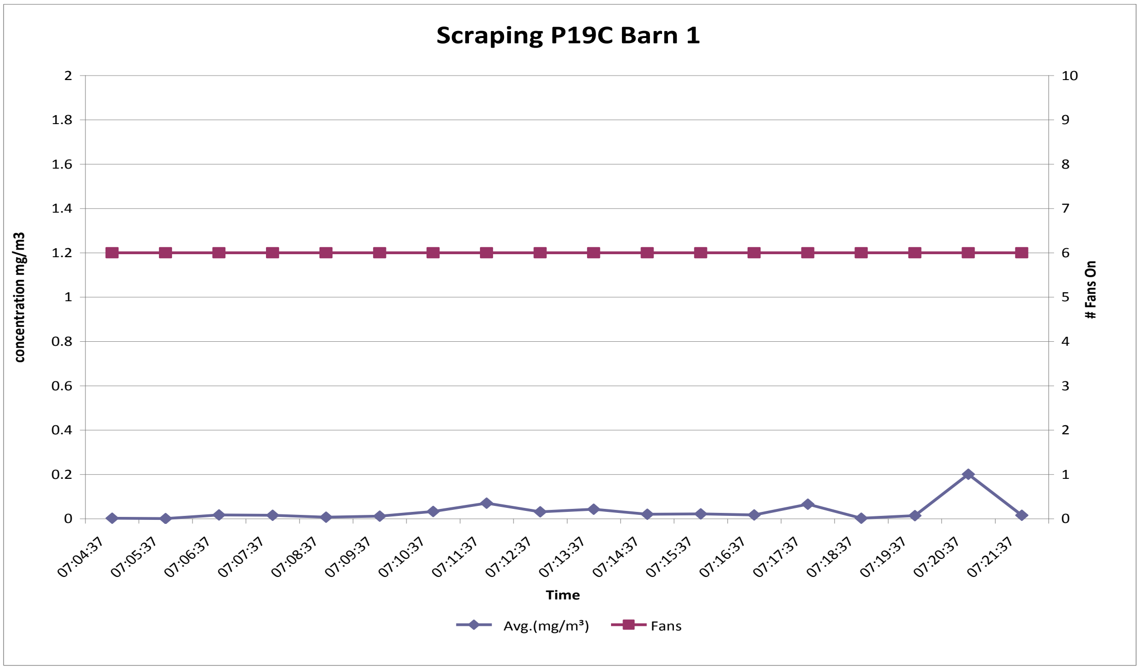
Particulate matter during scraping times in P19A Barn 1



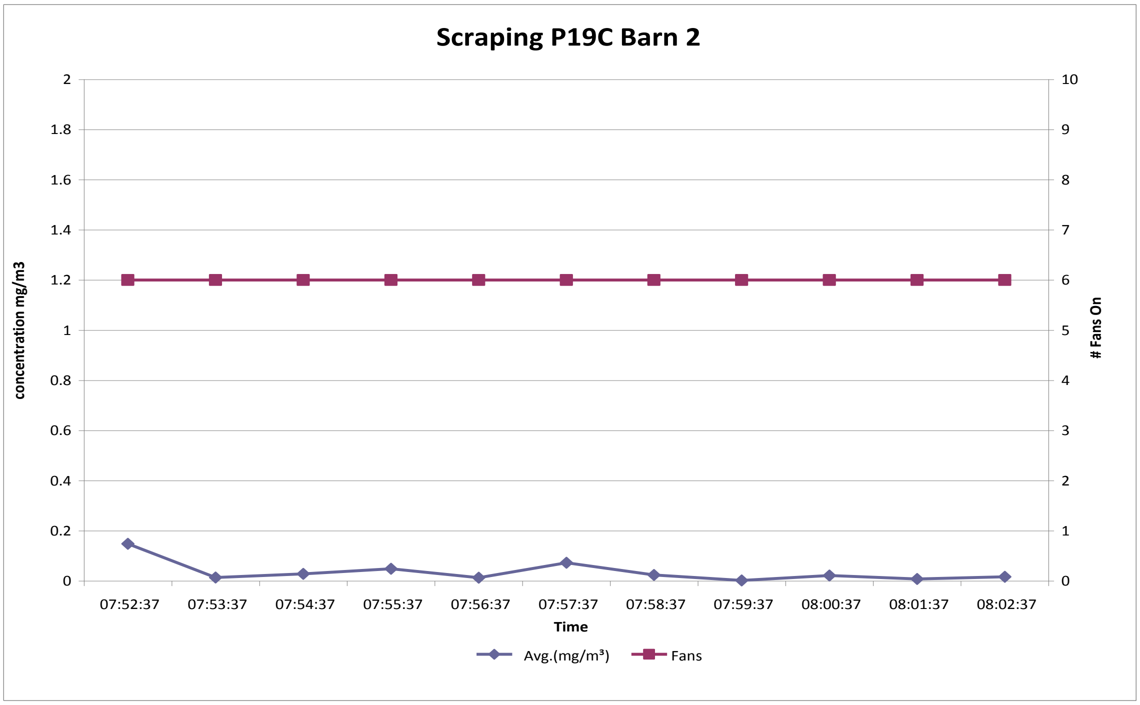
Particulate matter during scraping times in P19A Barn 2



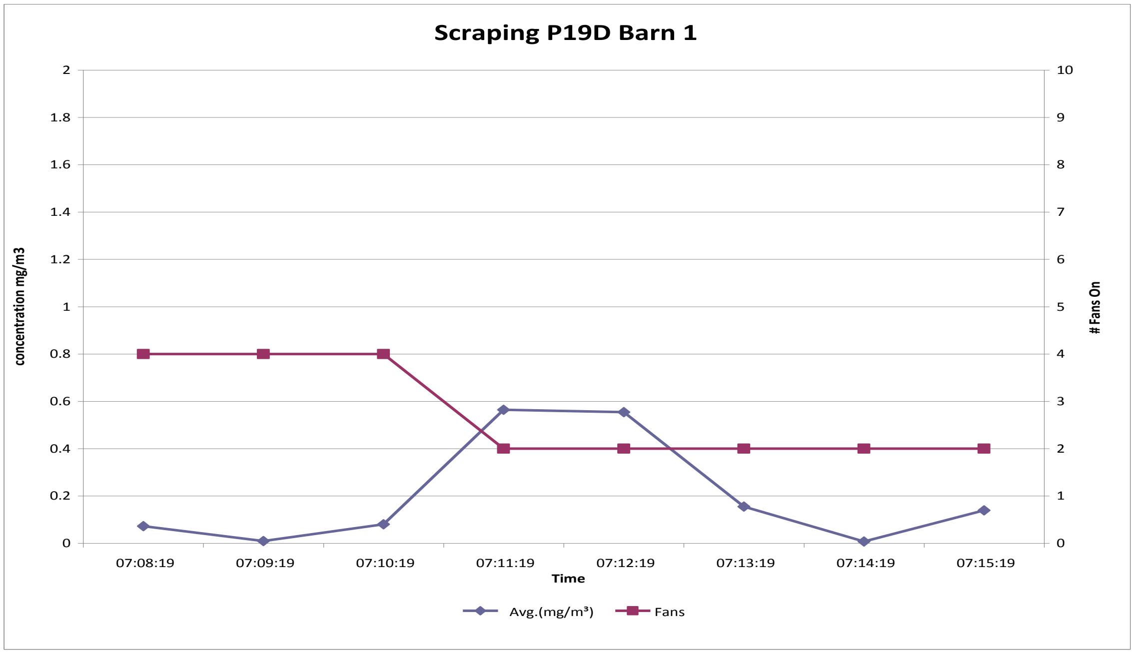
Particulate matter during scraping times in P19C Barn 1



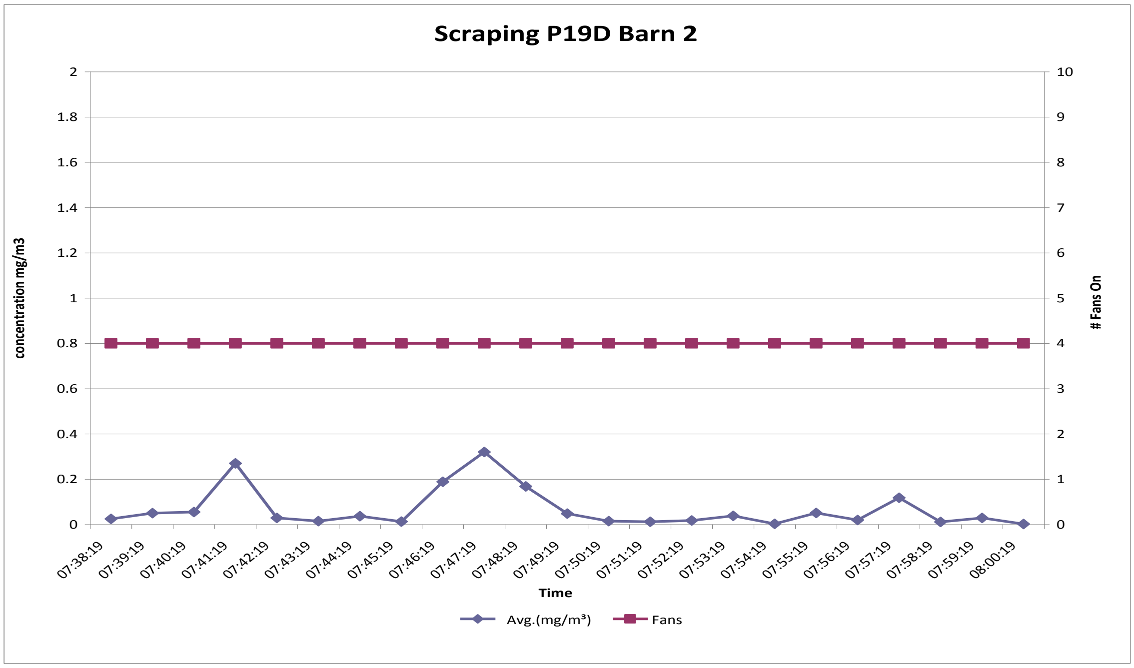
Particulate matter during scraping times in P19C Barn 2



Particulate matter during scraping times in P19D Barn 1



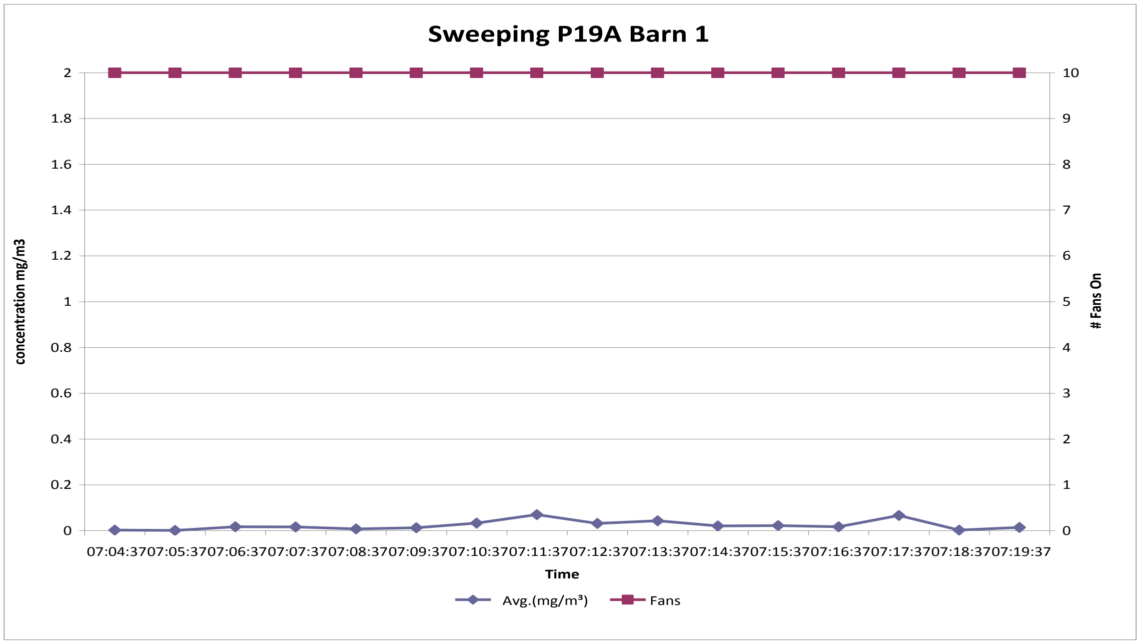
Particulate matter during scraping times in P19D Barn 2



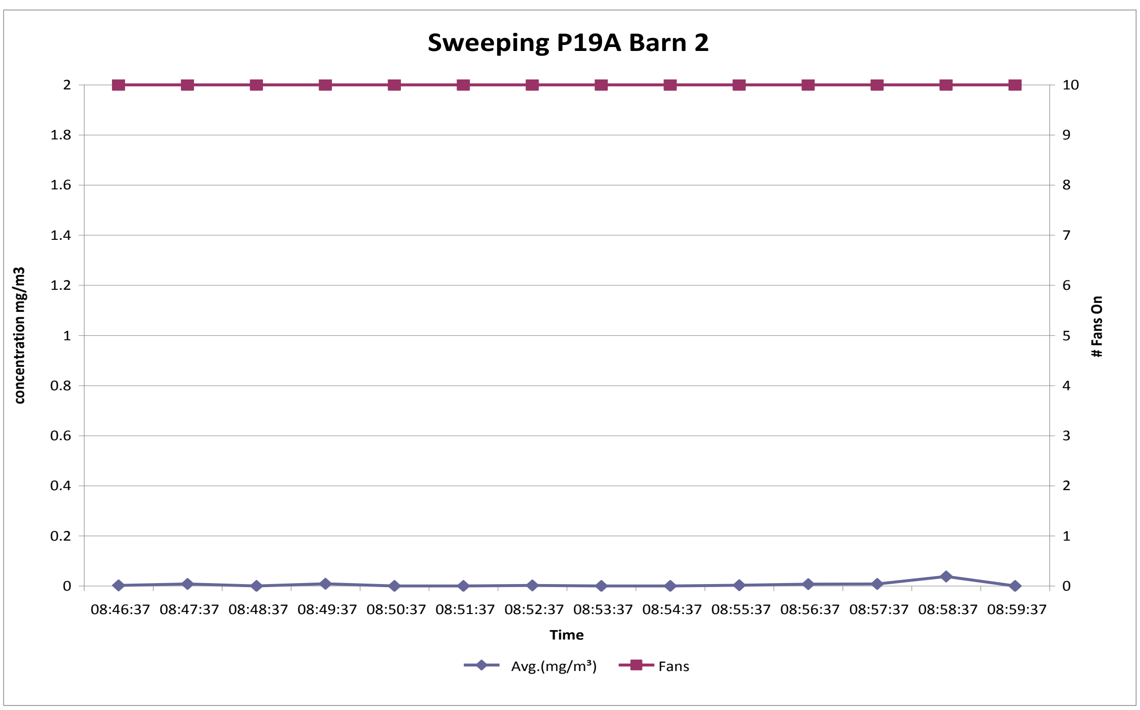
Appendix D

1900-Series Sweeping Task Graphs

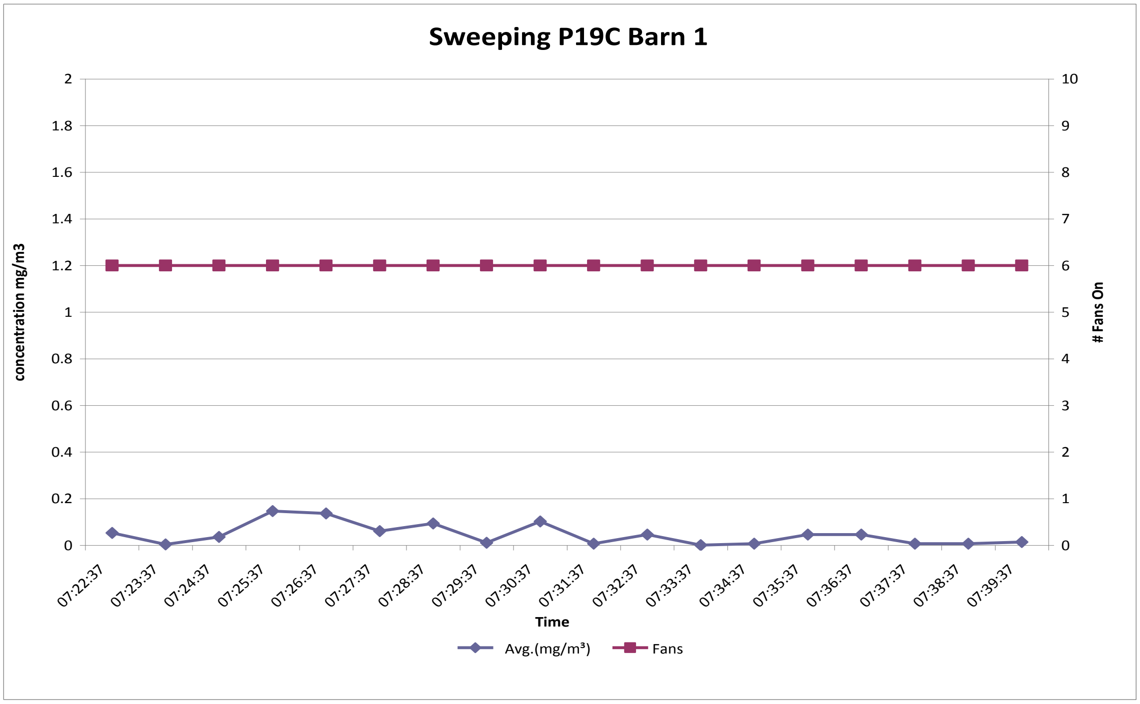
Particulate matter during sweeping times in P19A Barn 1



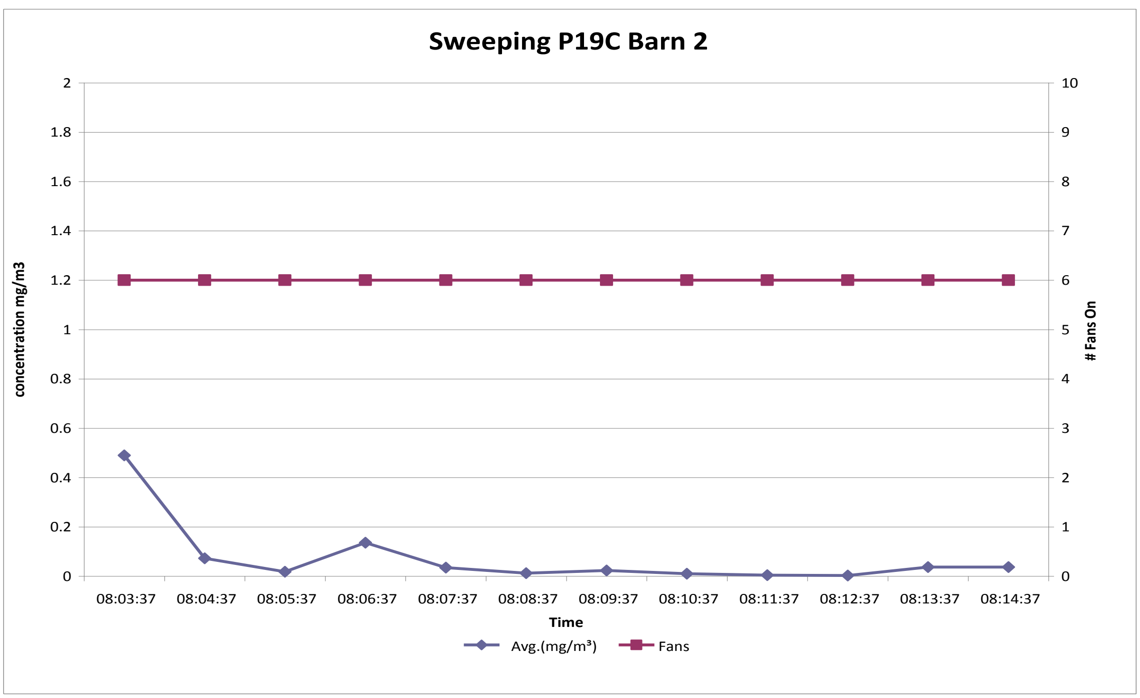
Particulate matter during sweeping times in P19A Barn 2



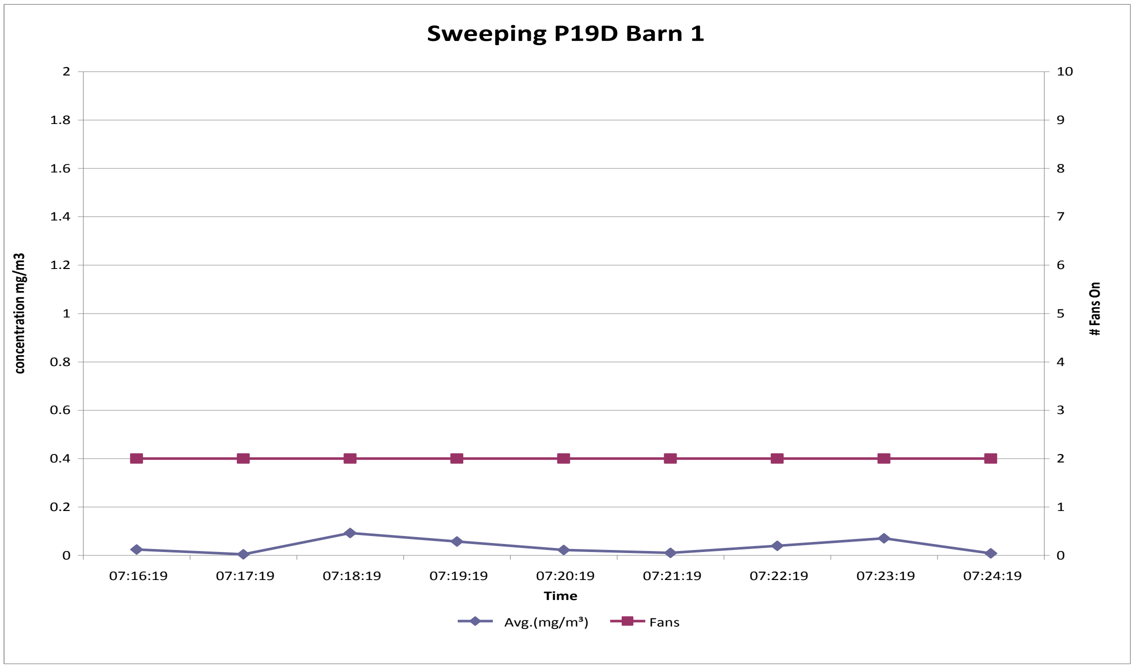
Particulate matter during sweeping times in P19C Barn 1



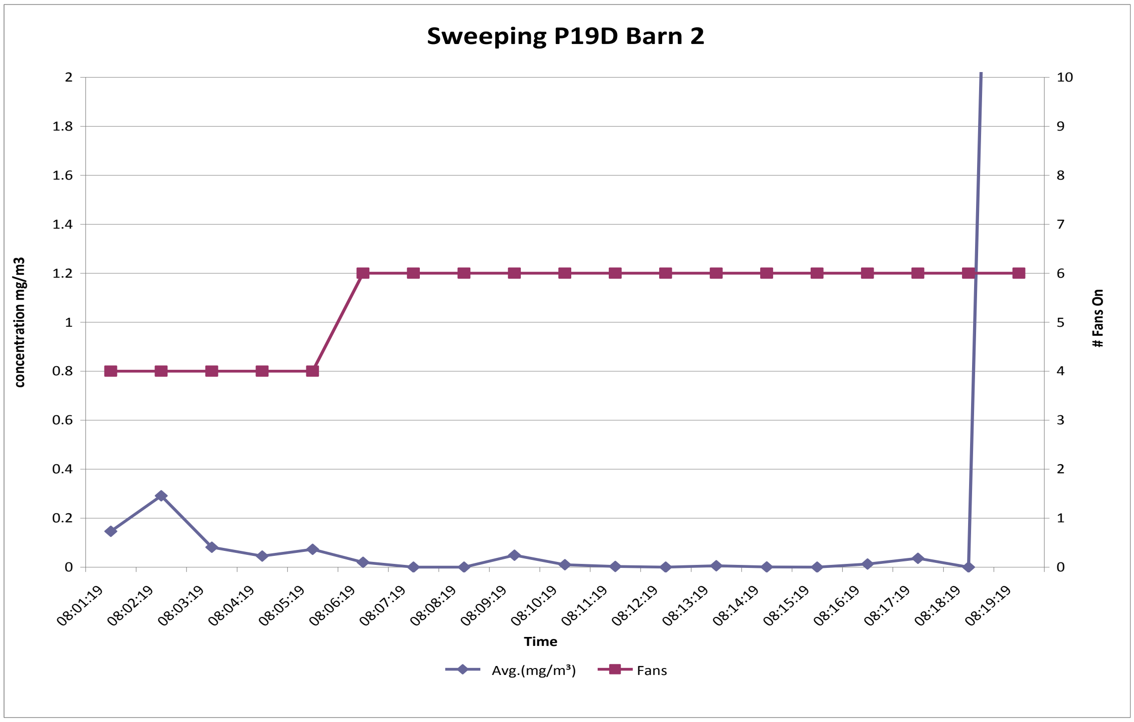
Particulate matter during sweeping times in P19C Barn 2



Particulate matter during sweeping times in P19D Barn 1



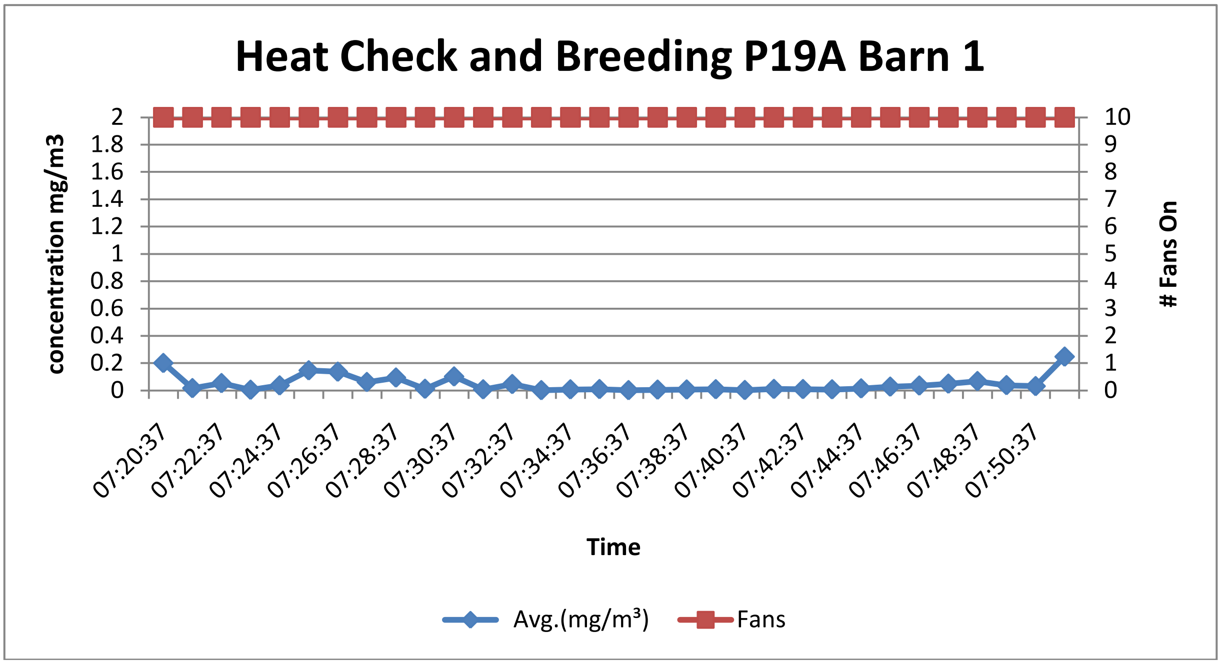
Particulate matter during sweeping times in P19D Barn 2



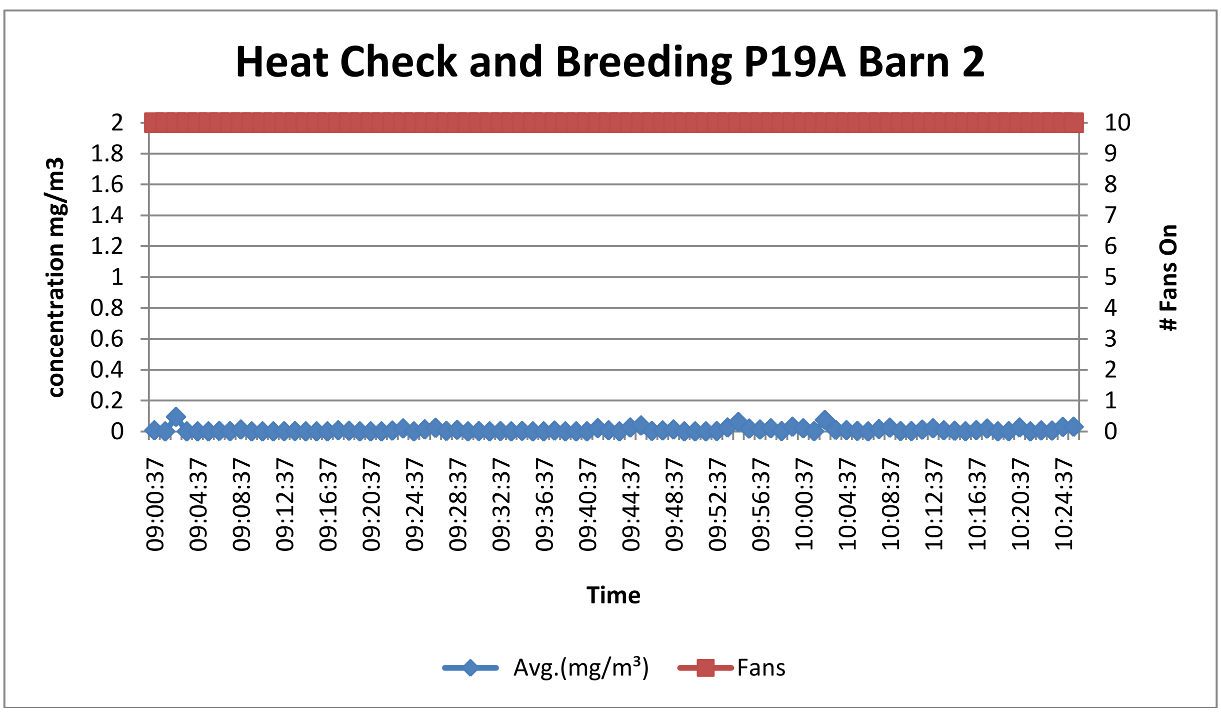
Appendix E

1900-Series Heat Check and Breeding Task Graphs

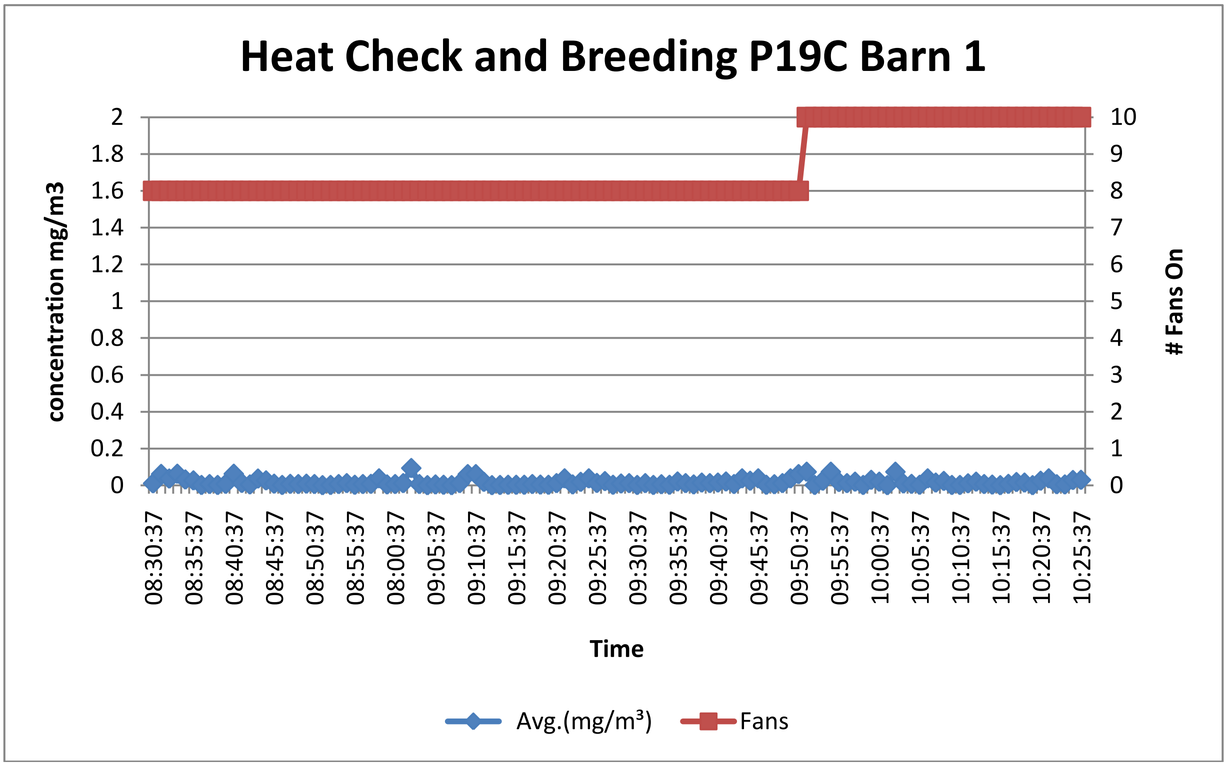
Particulate matter during heat check and breeding times in P19A Barn 1



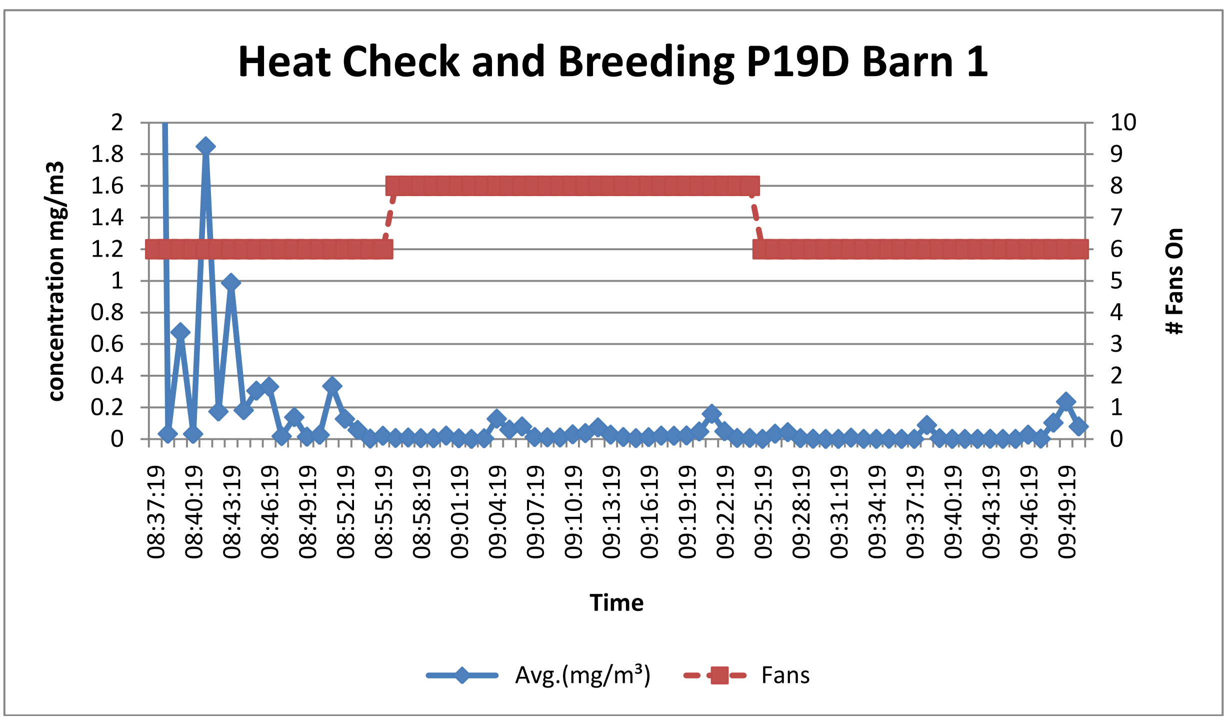
Particulate matter during heat check and breeding times in P19A Barn 2



Particulate matter during heat check and breeding times in P19C Barn 1



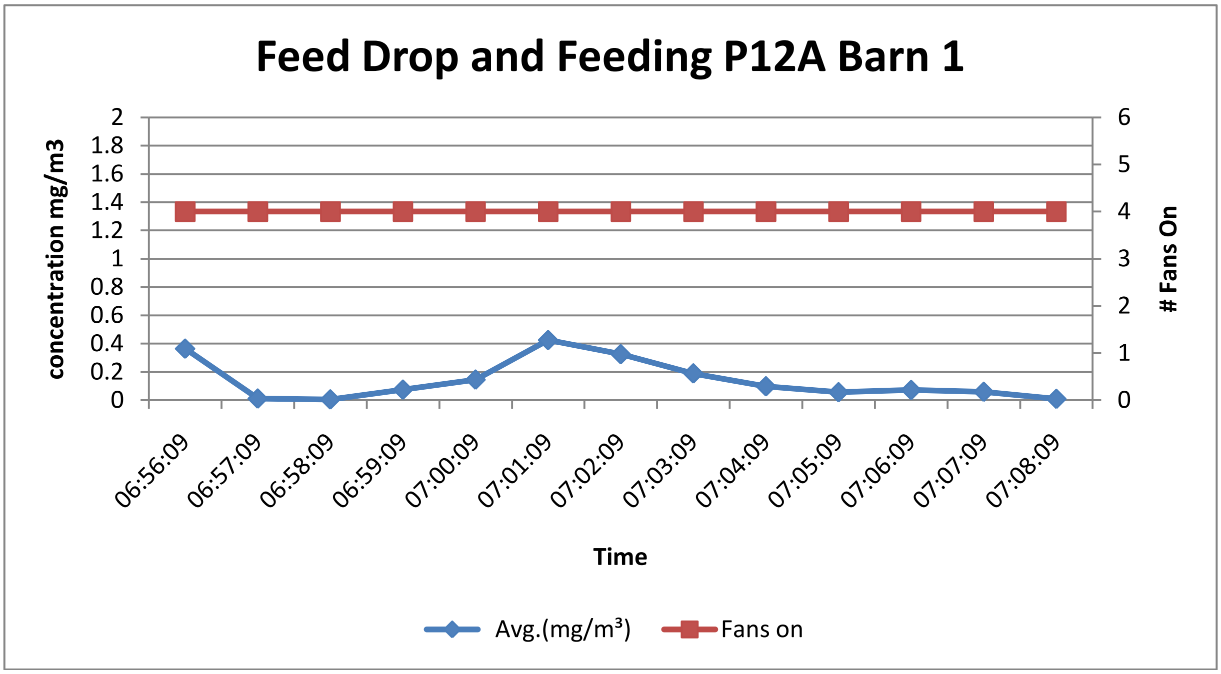
Particulate matter during heat check and breeding times in P19D Barn 1



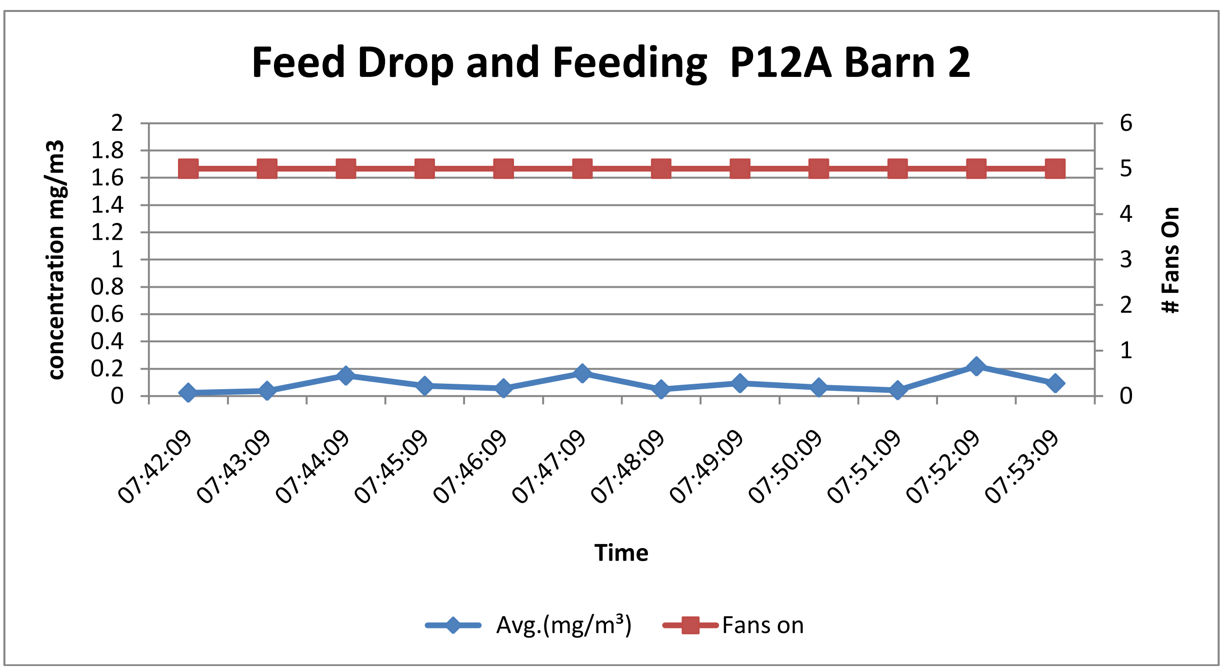
Appendix F

1200-Series Feed Drop Task Graphs

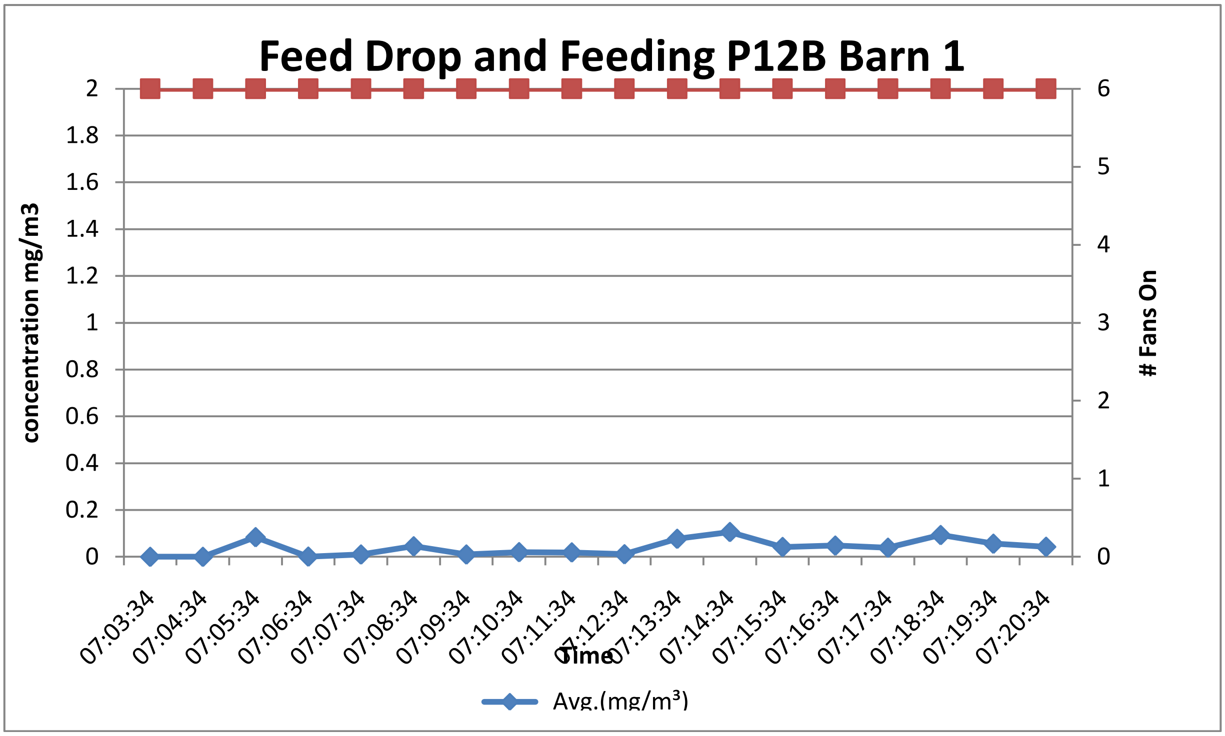
Particulate matter during feed drop and feeding times in P12A Barn 1



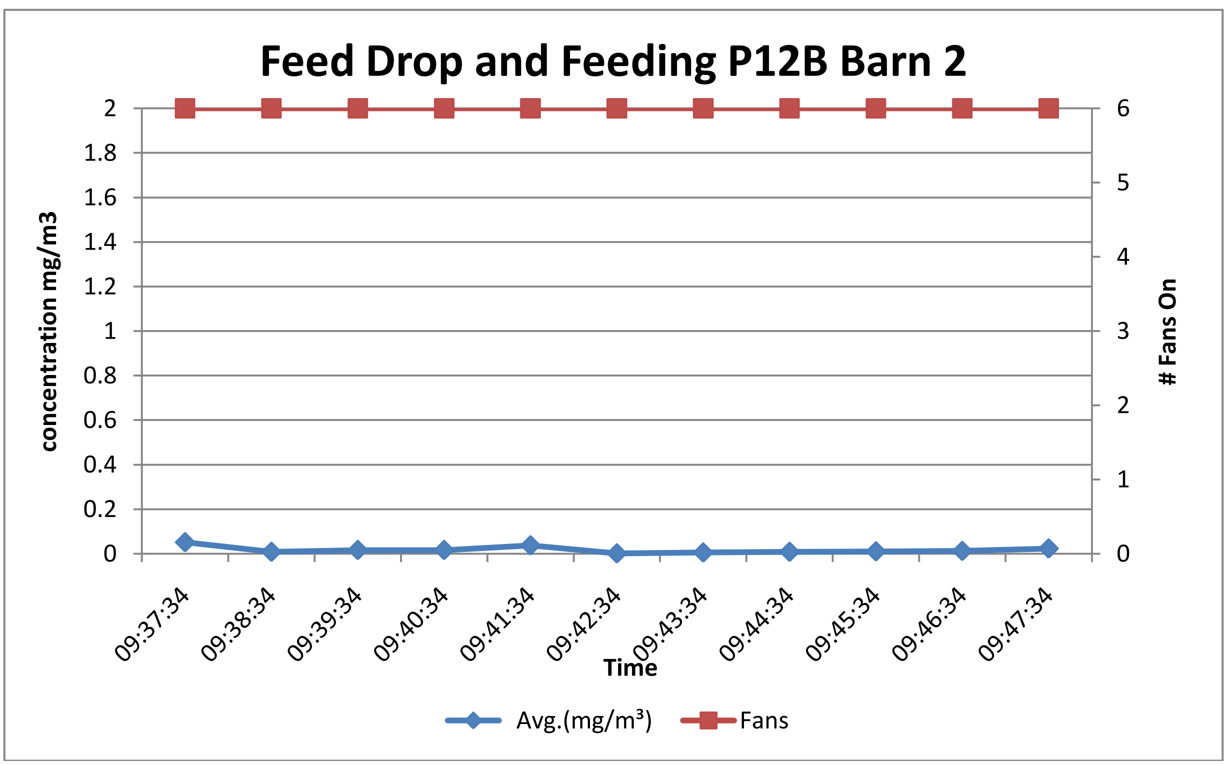
Particulate matter during feed drop and feeding times in P12A Barn 2



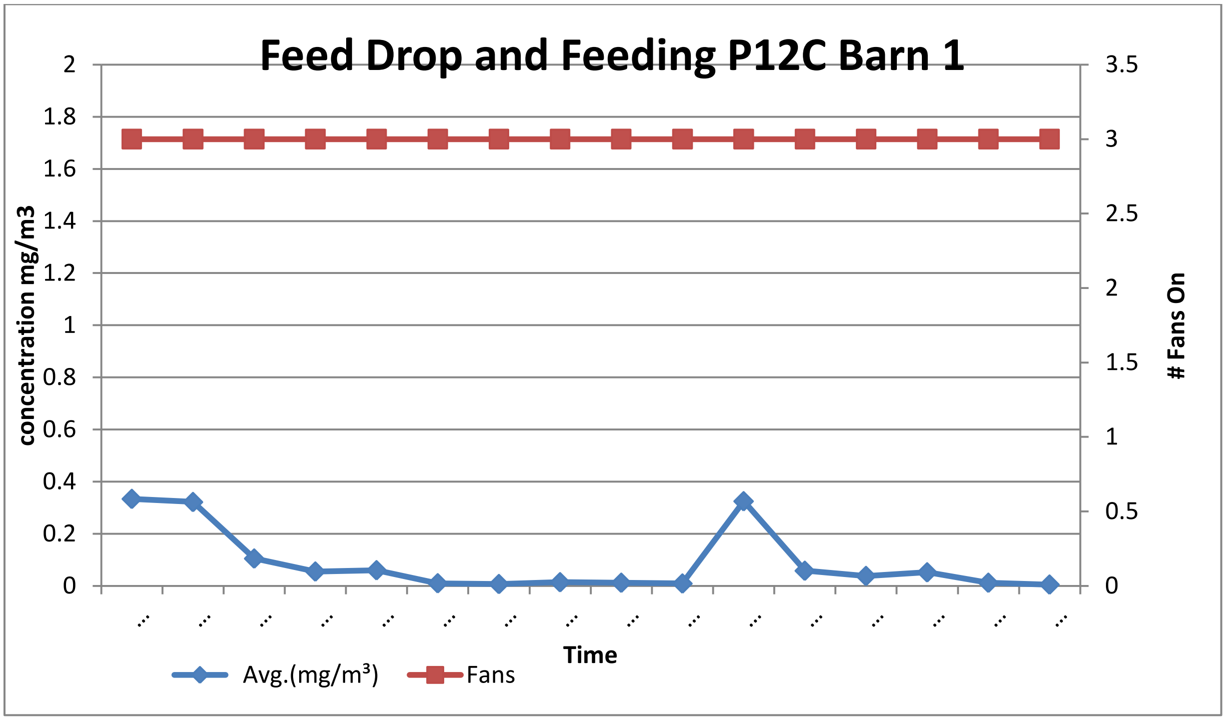
Particulate matter during feed drop and feeding times in P12B Barn 1



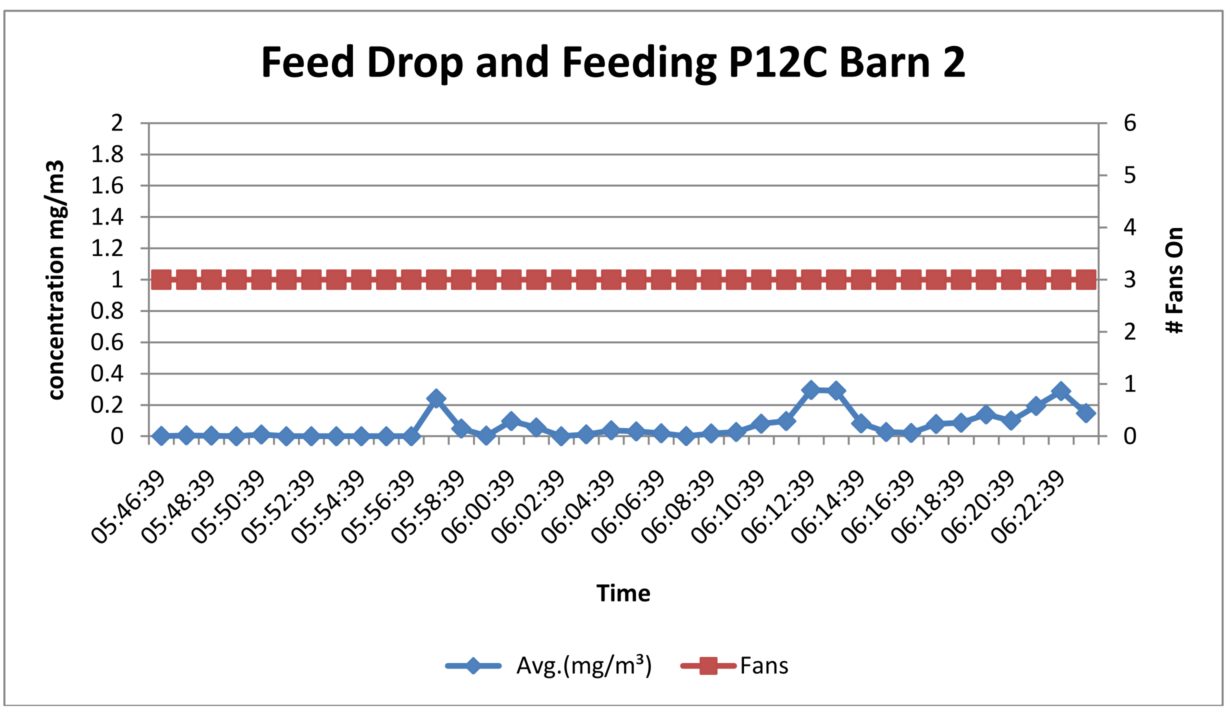
Particulate matter during feed drop and feeding times in P12B Barn 2



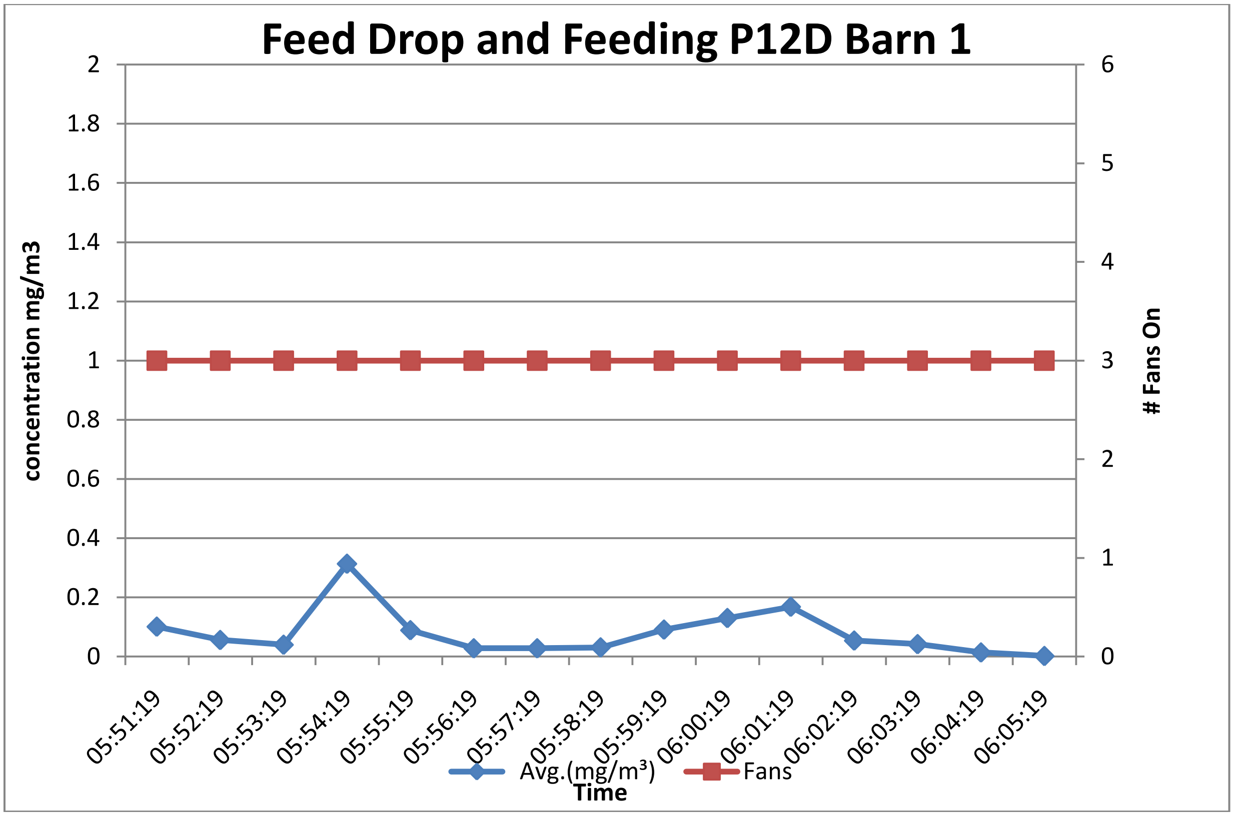
Particulate matter during feed drop and feeding times in P12C Barn 1



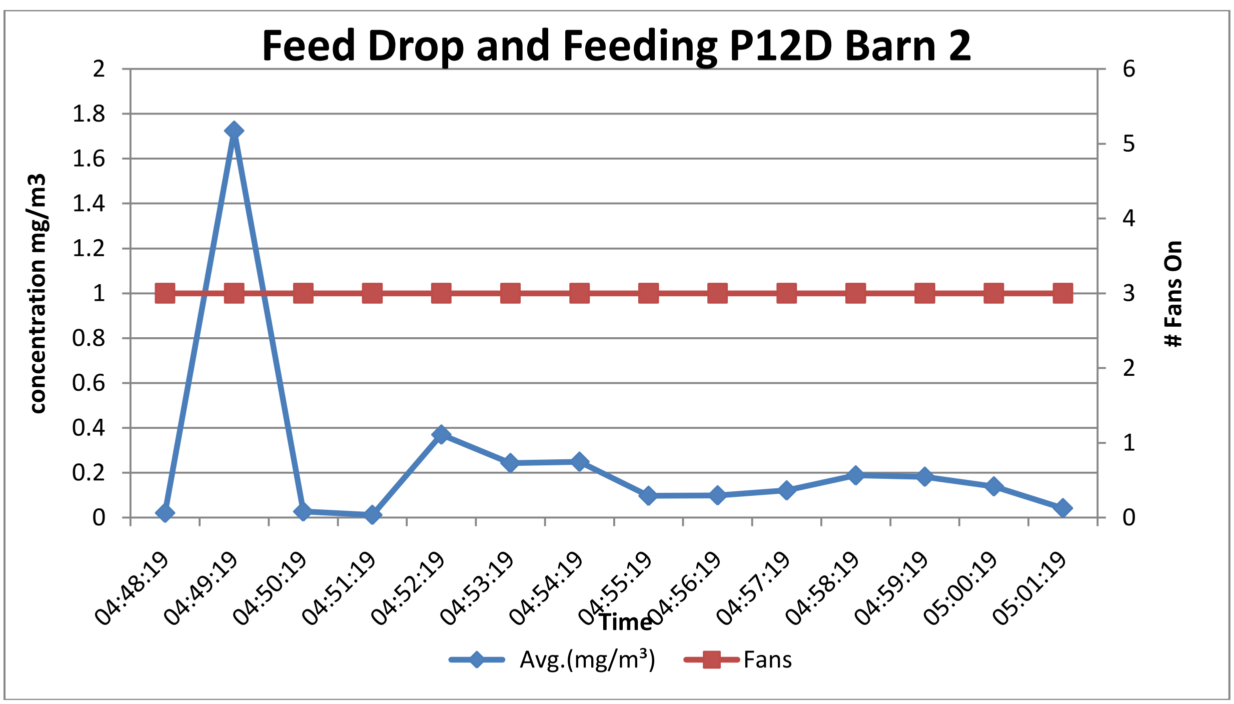
Particulate matter during feed drop and feeding times in P12C Barn 2



Particulate matter during feed drop and feeding times in P12D Barn 1



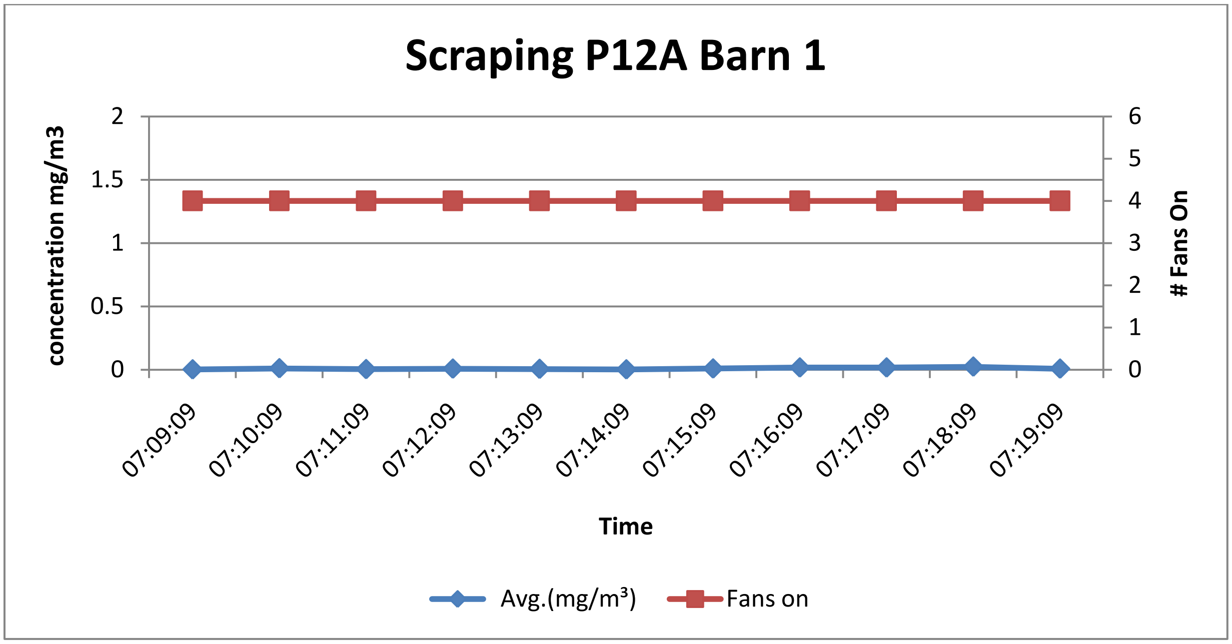
Particulate matter during feed drop and feeding times in P12D Barn 2



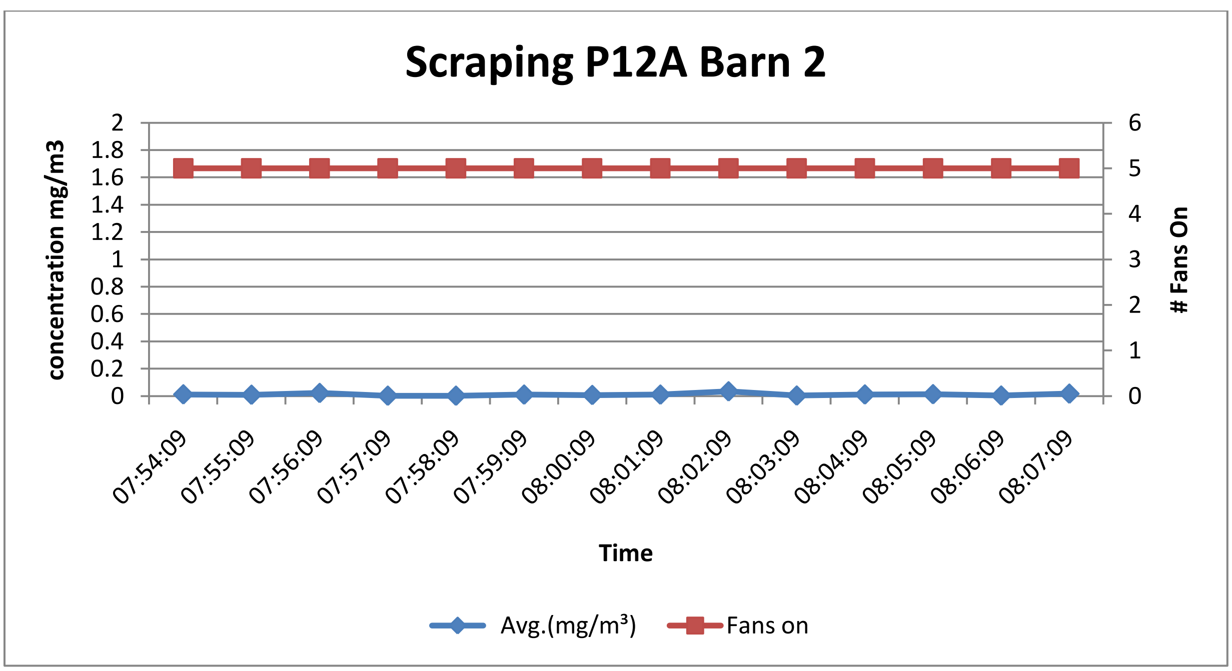
Appendix G

1200-Series Scraping Task Graphs

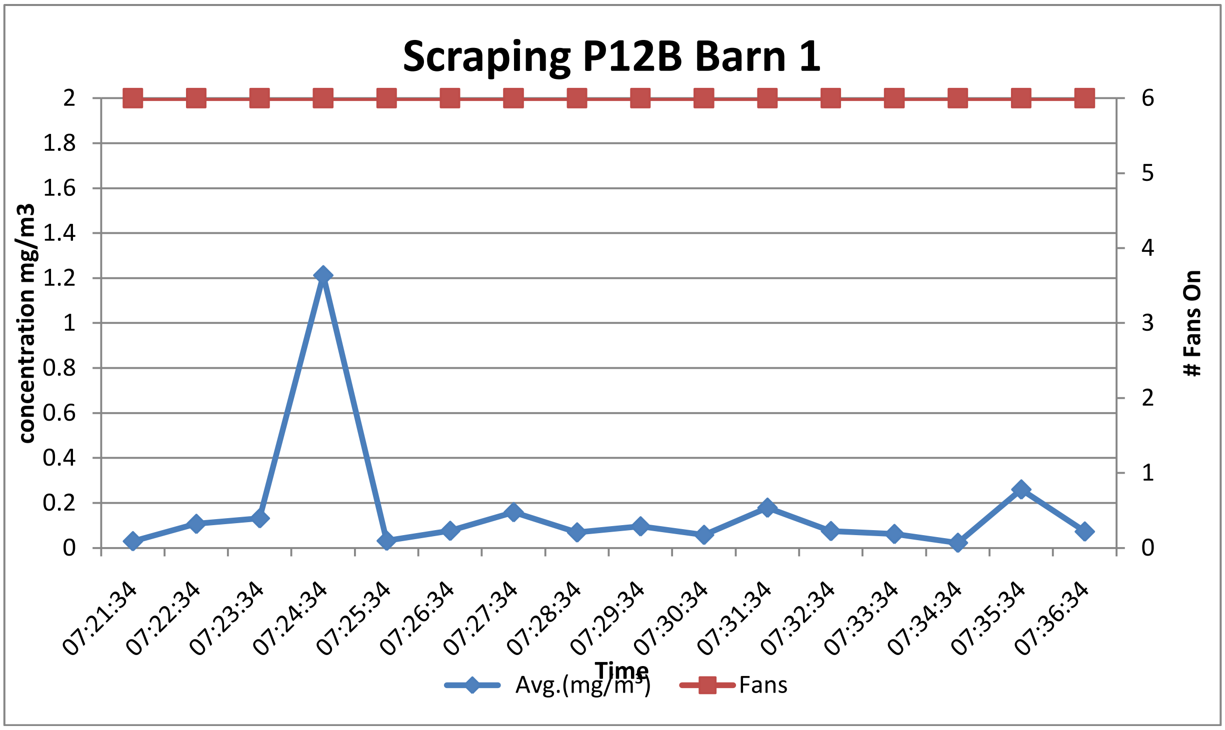
Particulate matter during scraping times in P12A Barn 1



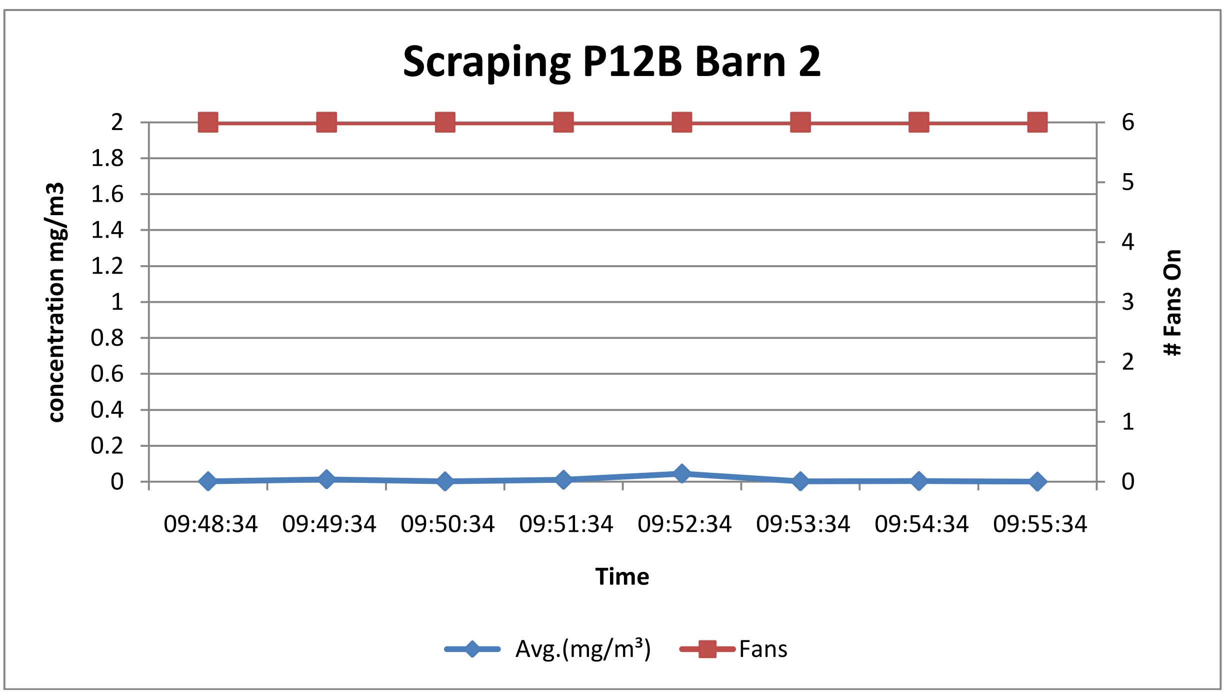
Particulate matter during scraping times in P12A Barn 2



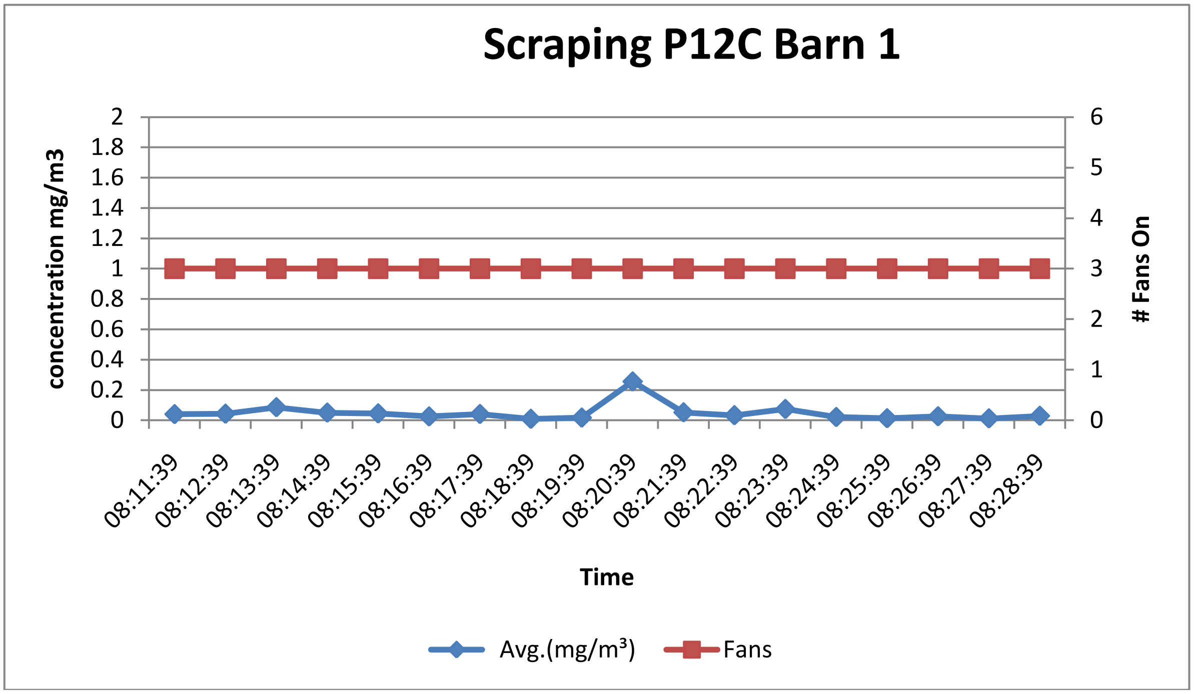
Particulate matter during scraping times in P12B Barn 1



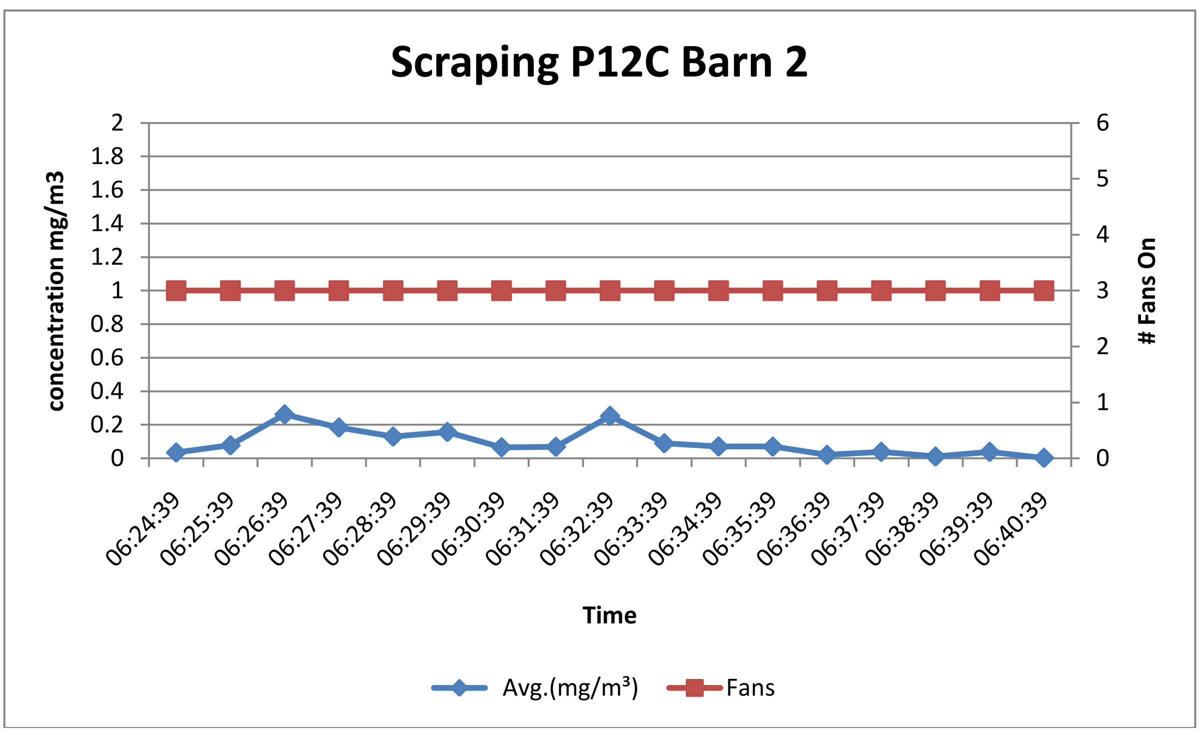
Particulate matter during scraping times in P12B Barn 2



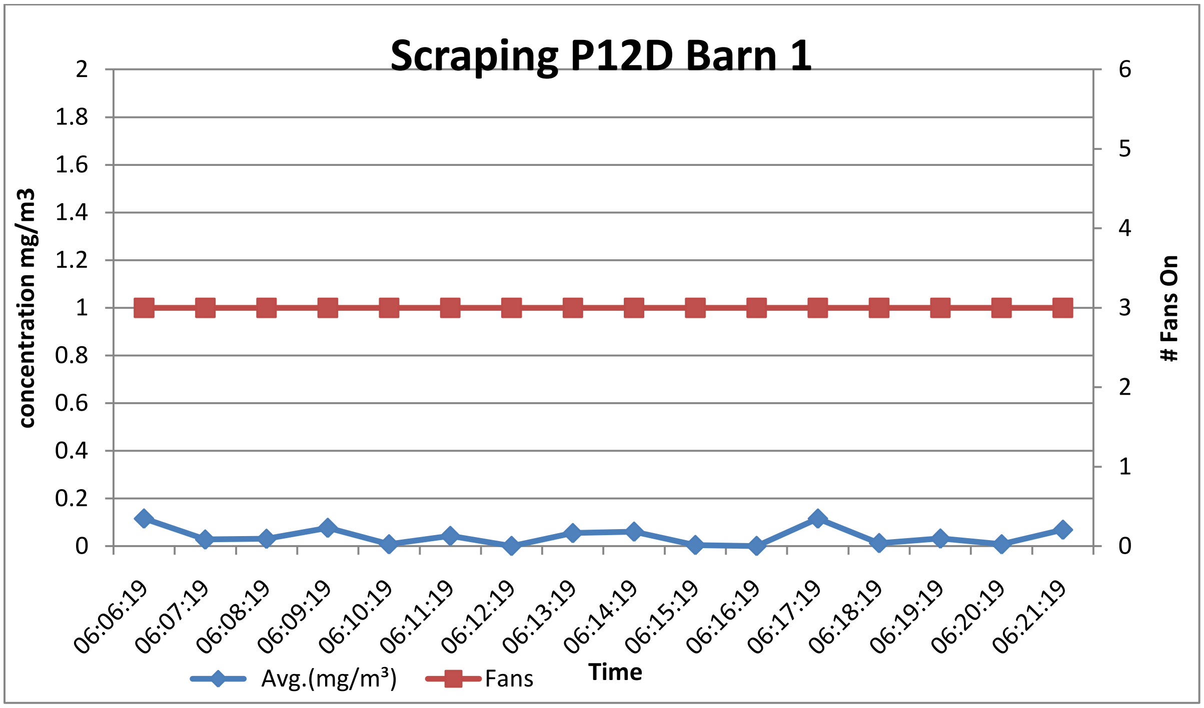
Particulate matter during scraping times in P12C Barn 1



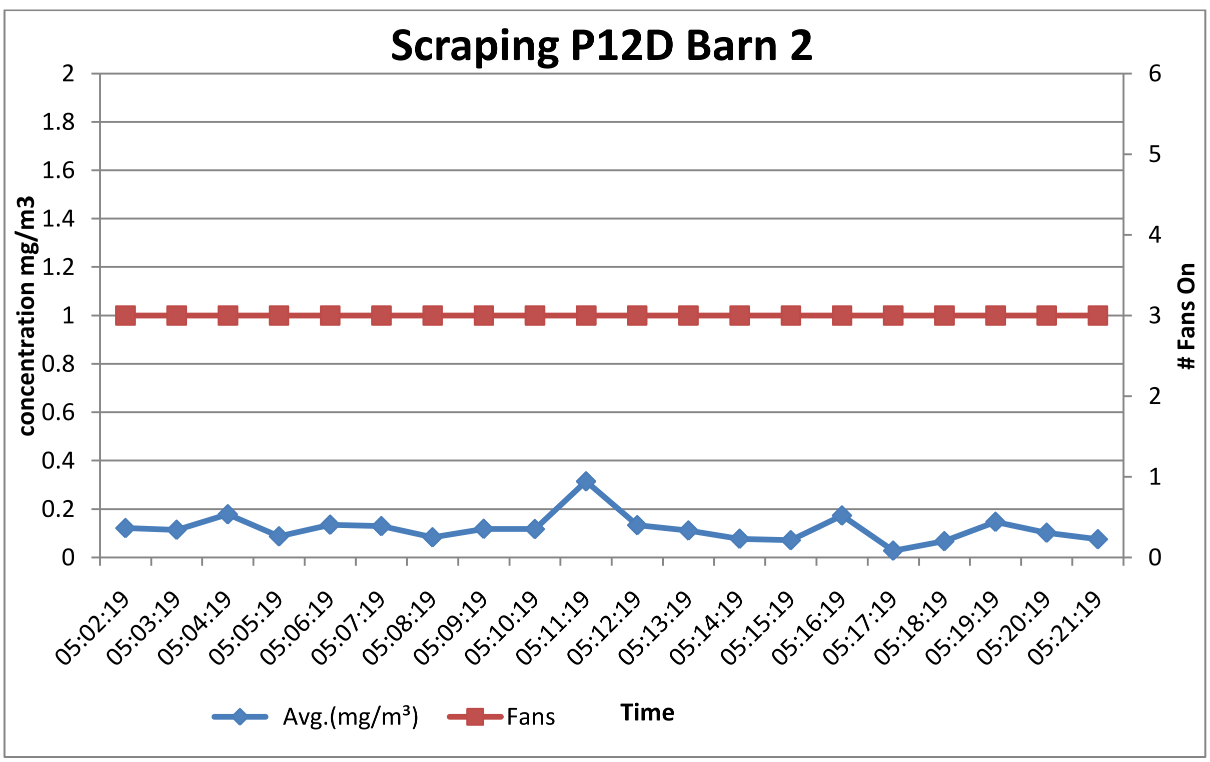
Particulate matter during scraping times in P12C Barn 2



Particulate matter during scraping times in P12D Barn 1



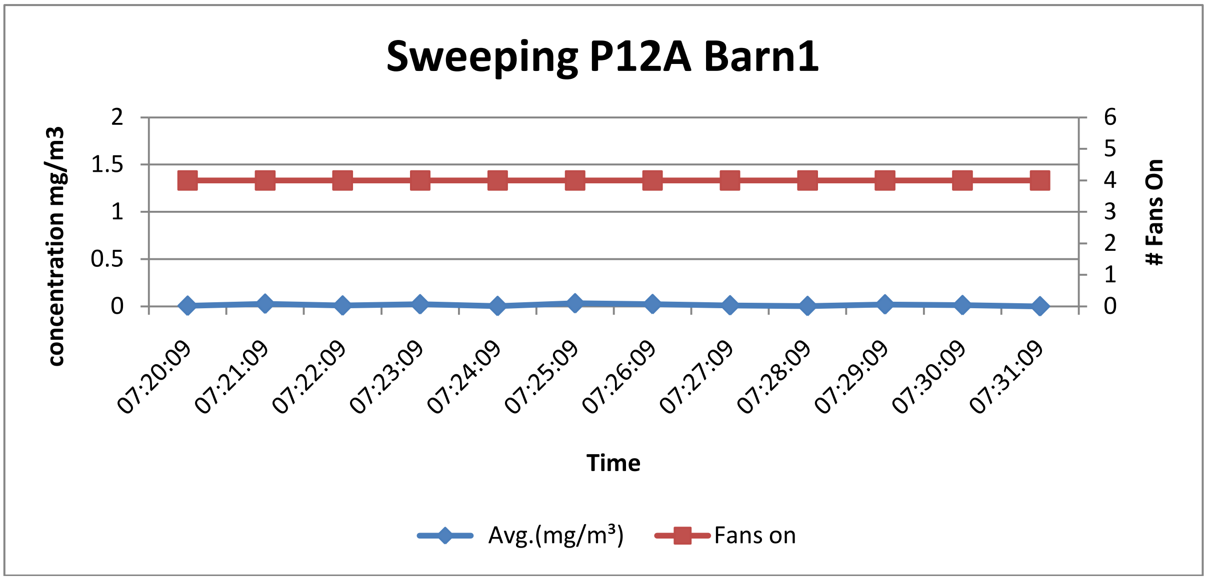
Particulate matter during scraping times in P12D Barn 2



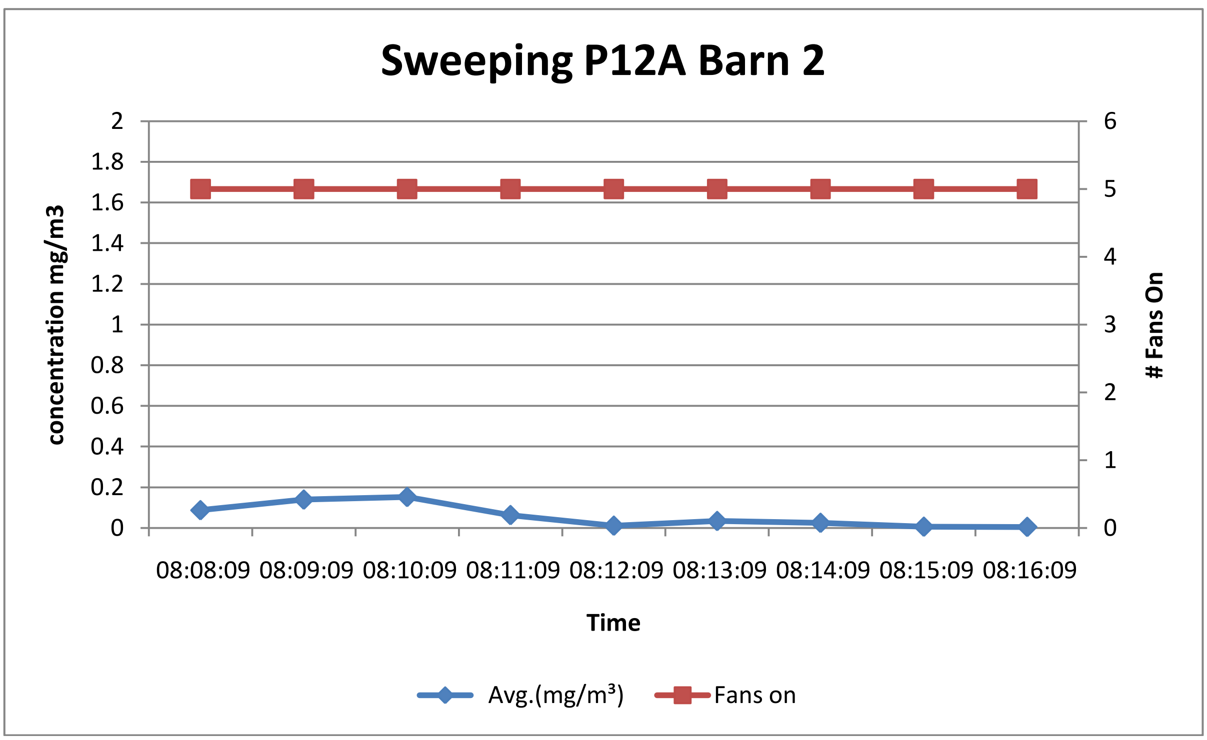
Appendix H

1200-Series Sweeping Task Graphs

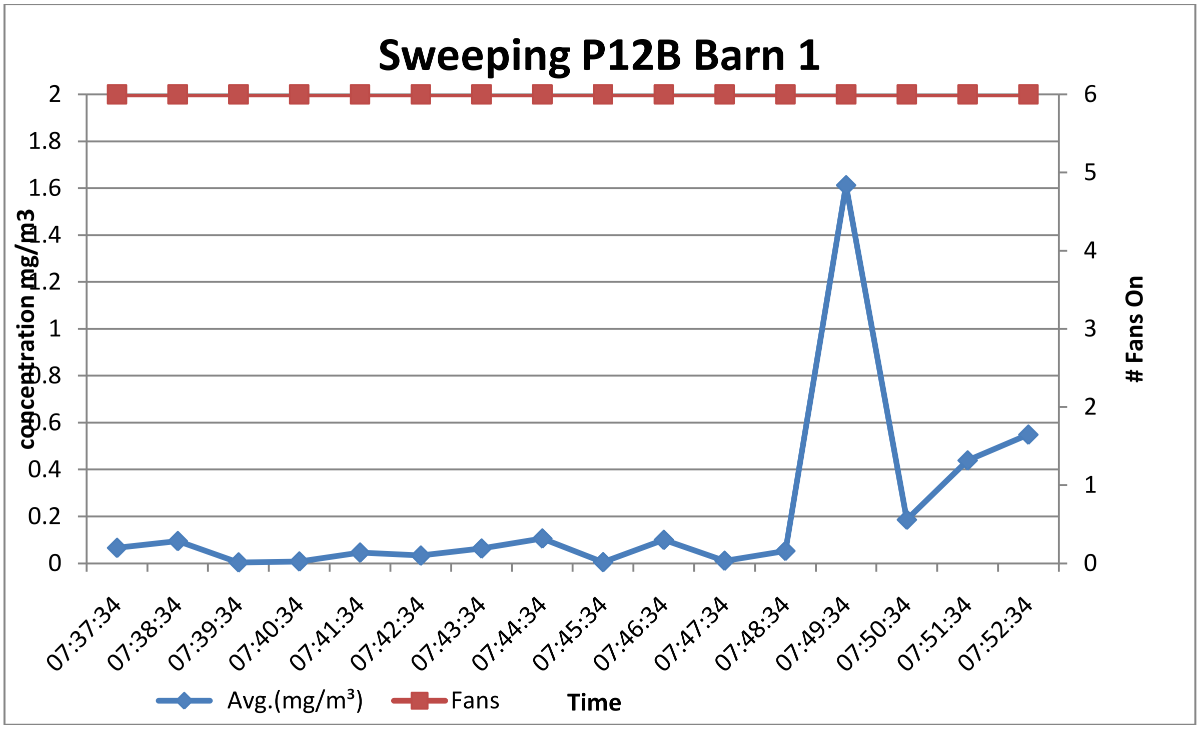
Particulate matter during sweeping times in P12A Barn 1



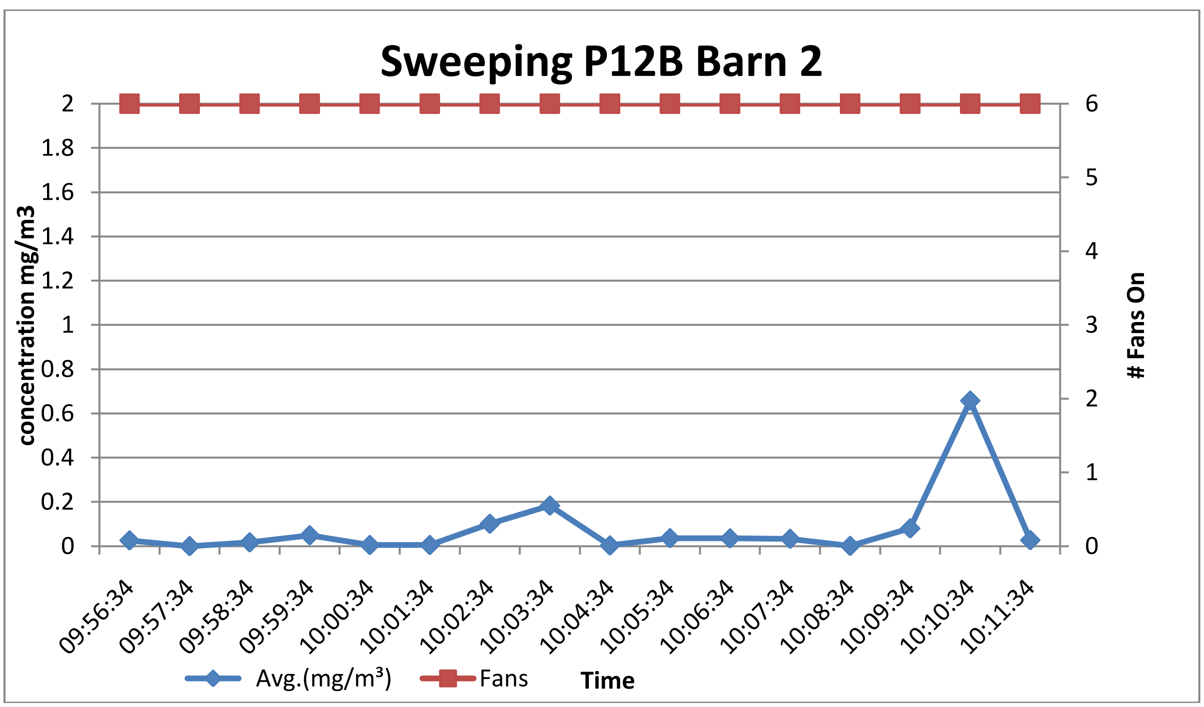
Particulate matter during sweeping times in P12A Barn 2



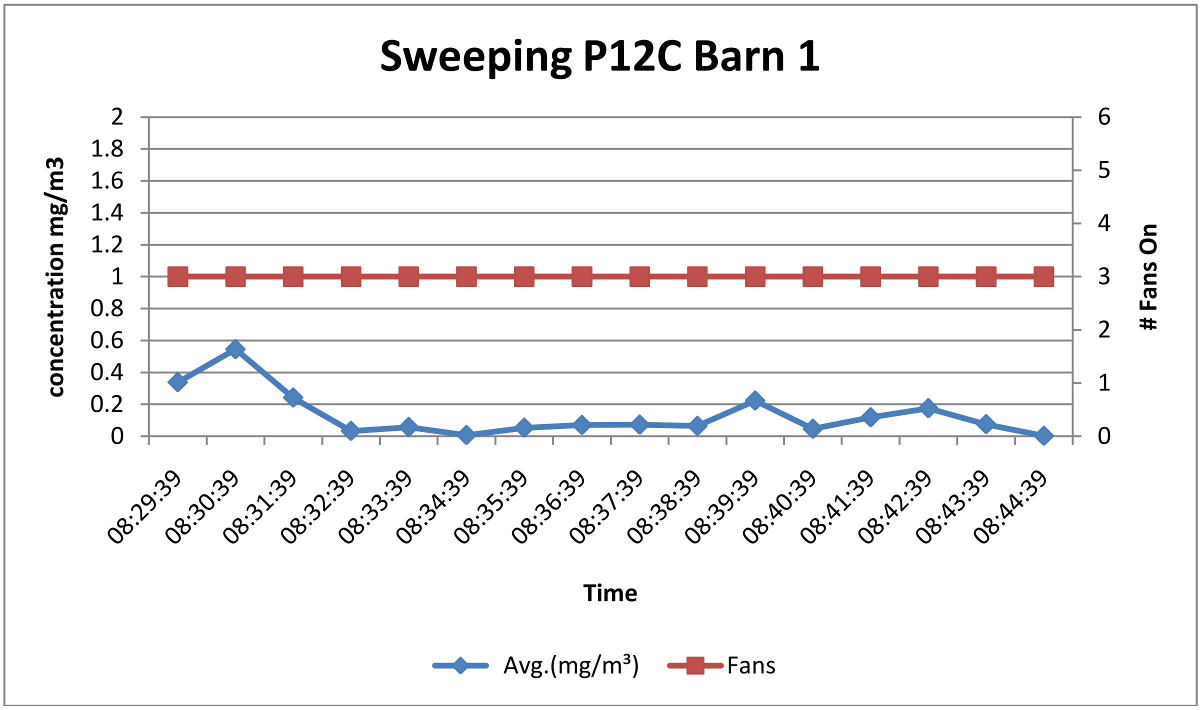
Particulate matter during sweeping times in P12B Barn 1



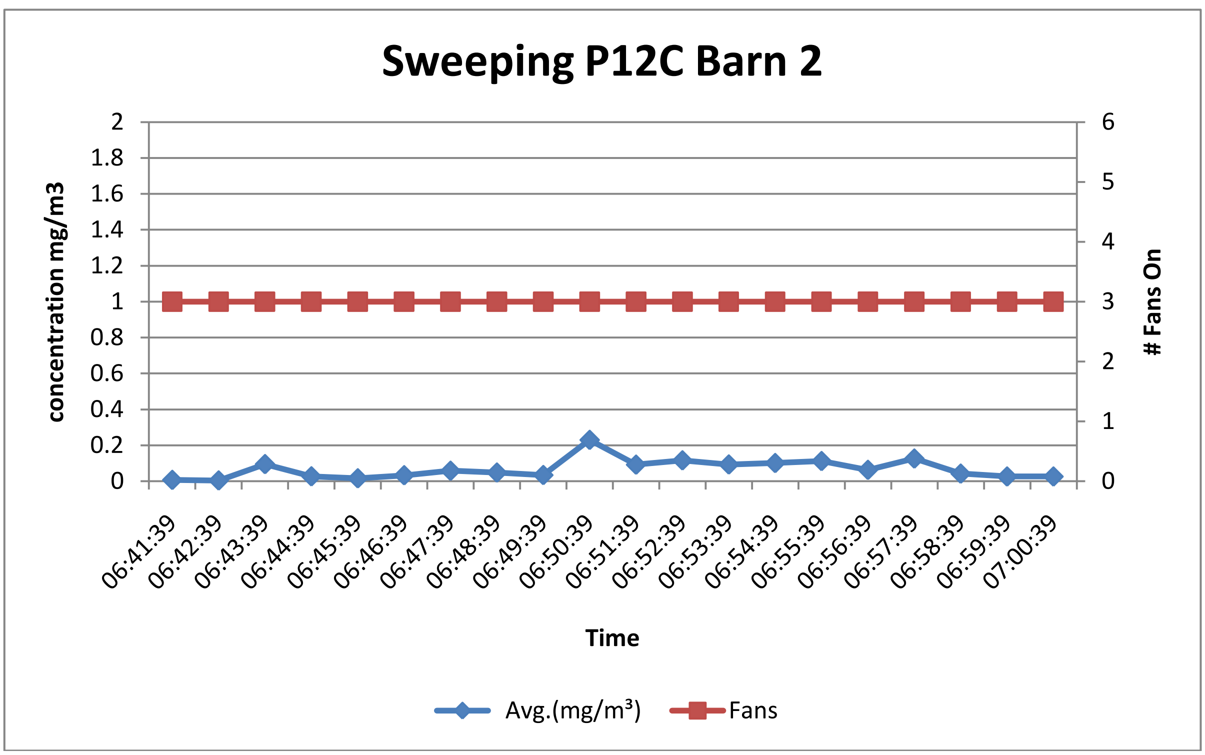
Particulate matter during sweeping times in P12B Barn 2



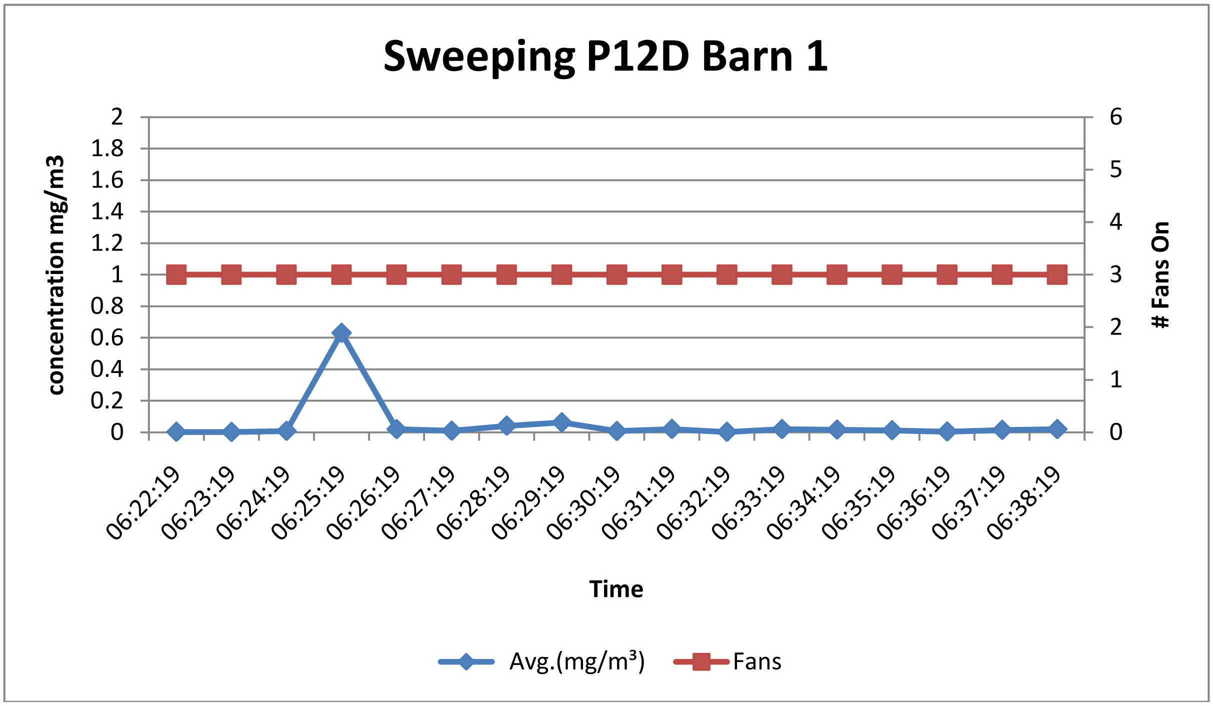
Particulate matter during sweeping times in P12C Barn 1



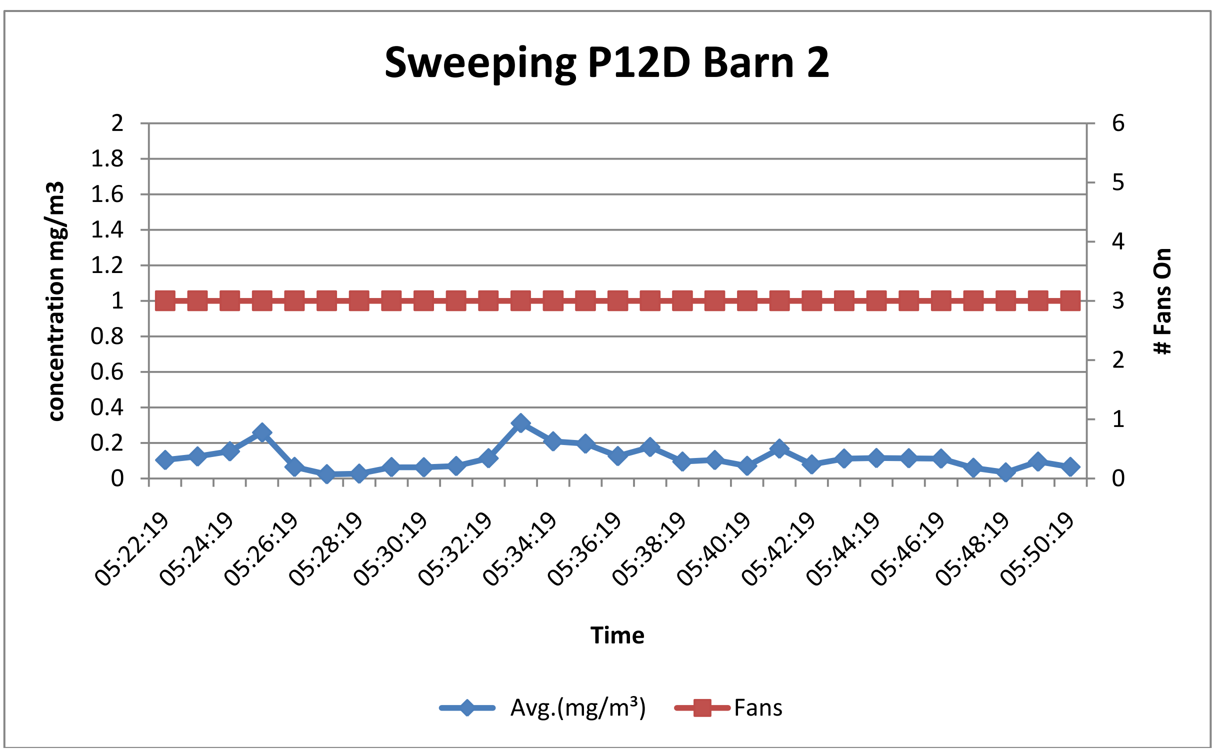
Particulate matter during sweeping times in P12C Barn 2



Particulate matter during sweeping times in P12D Barn 1



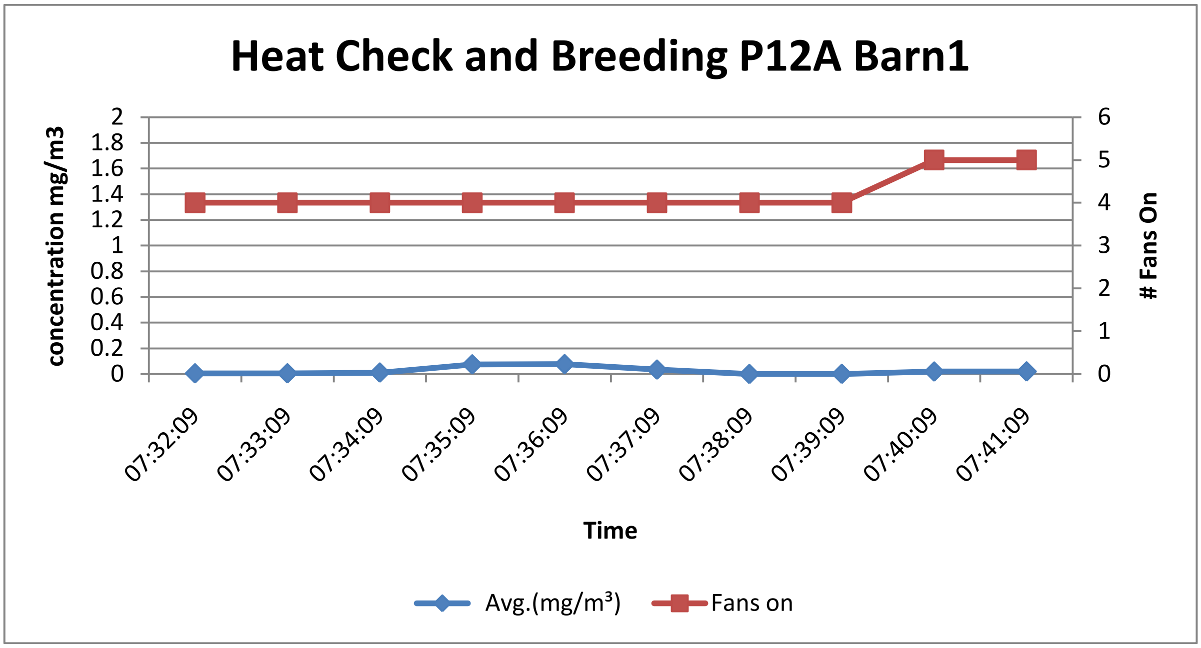
Particulate matter during sweeping times in P12D Barn 2



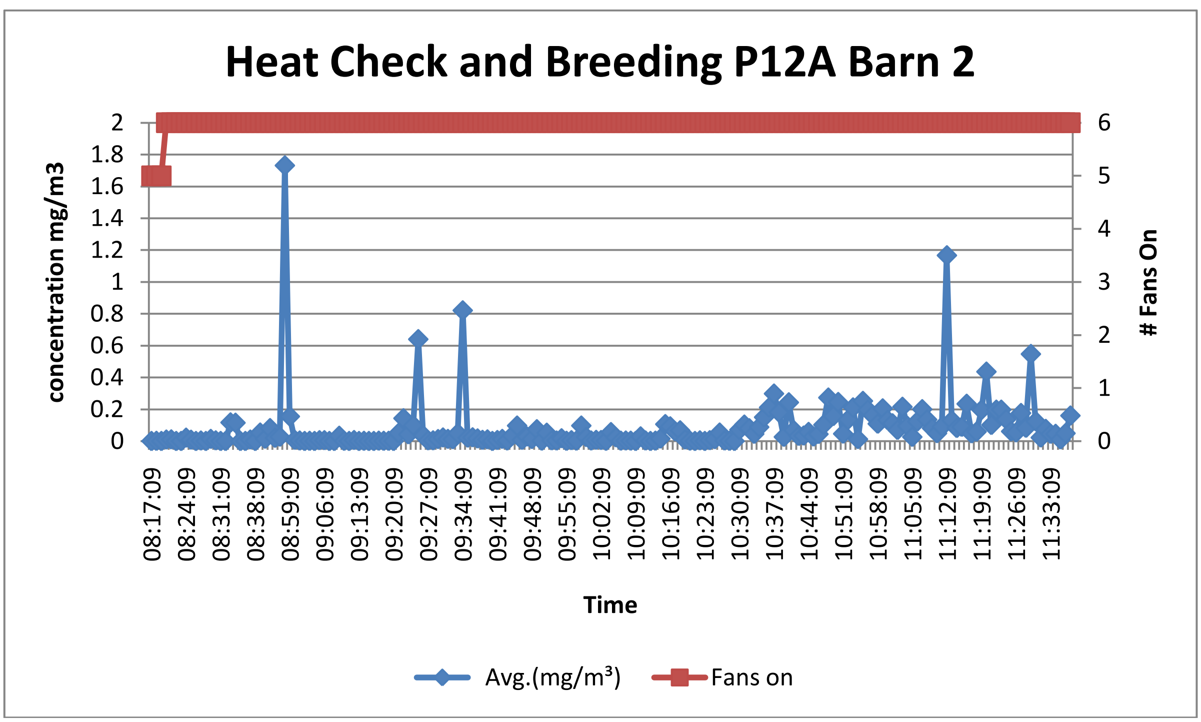
Appendix I

1200-Series Heat Check and Breeding Task Graphs

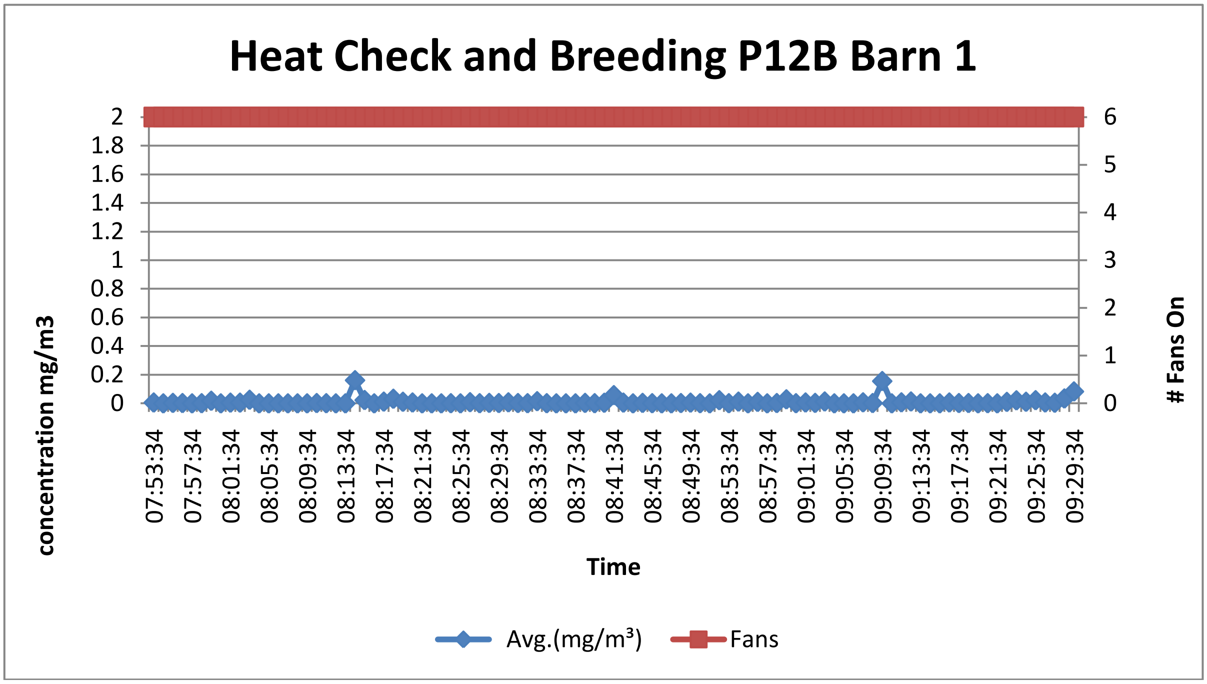
Particulate matter during heat check and breeding P12A Barn 1



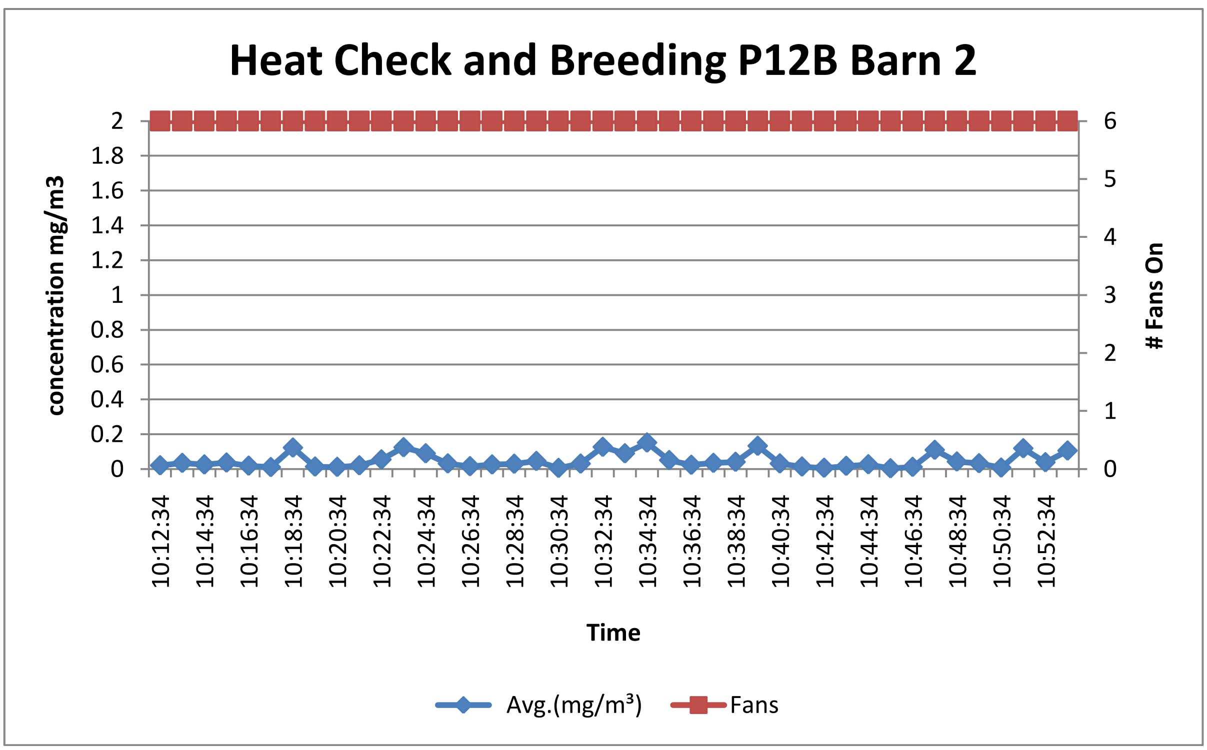
Particulate matter during heat check and breeding P12A Barn 2



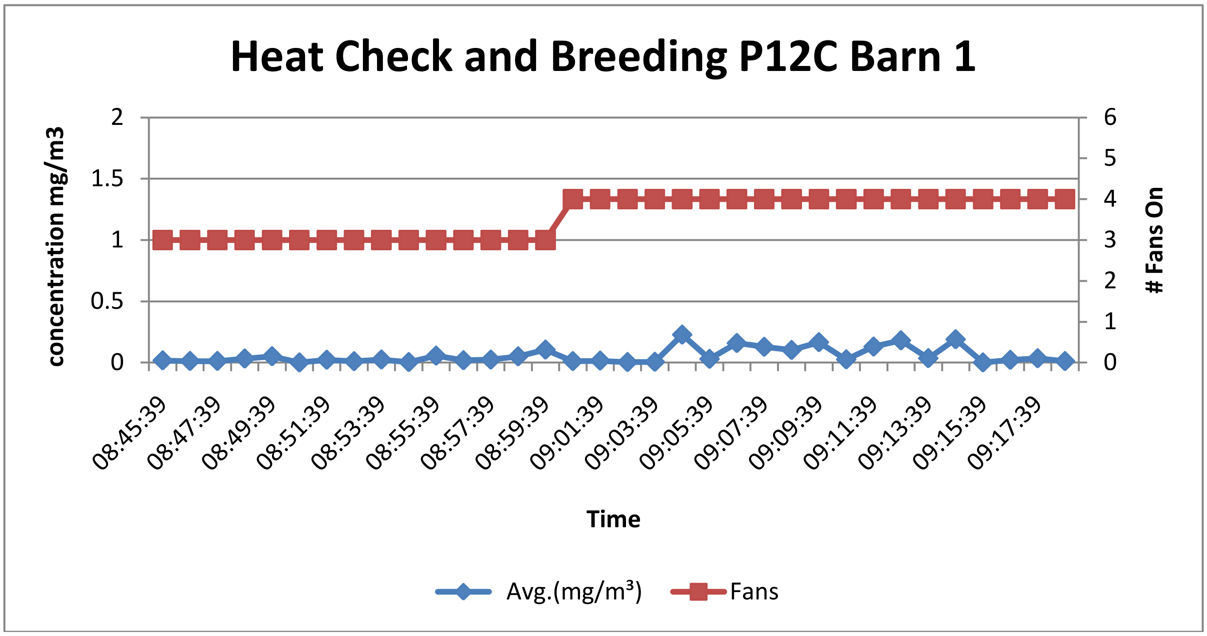
Particulate matter during heat check and breeding P12B Barn 1



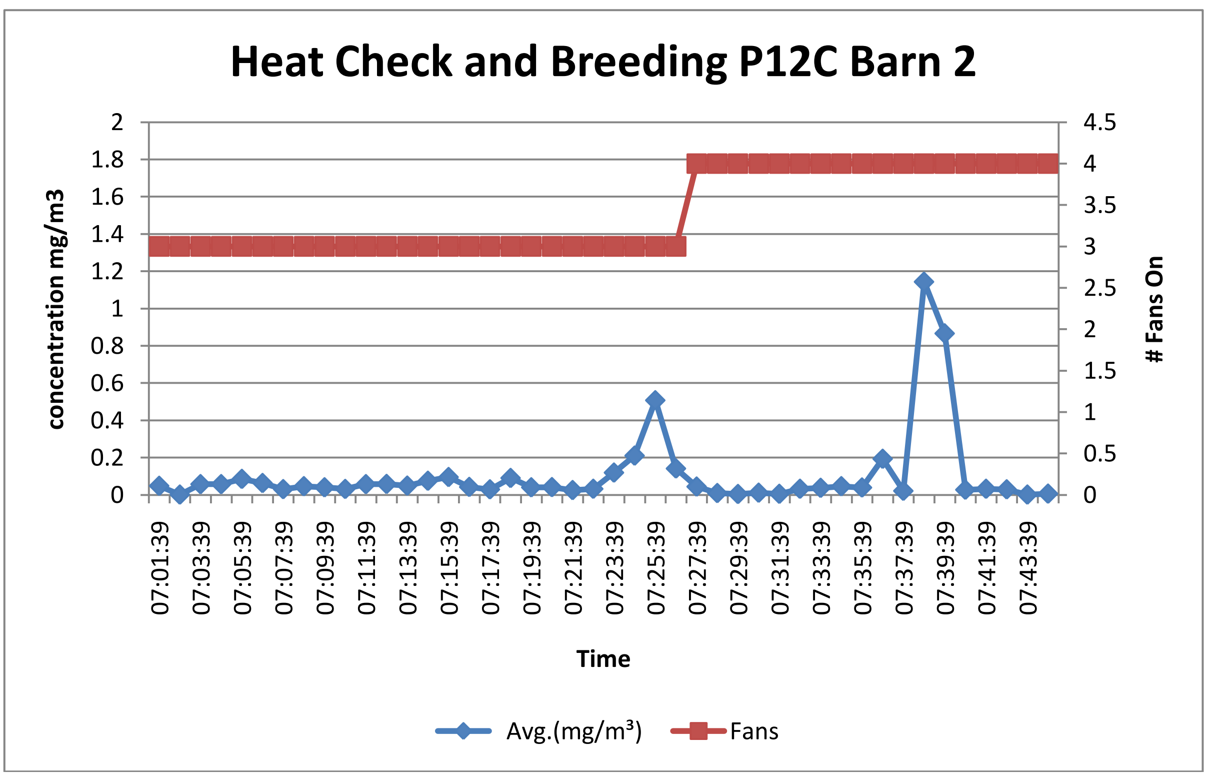
Particulate matter during heat check and breeding P12B Barn 2



Particulate matter during heat check and breeding P12C Barn 1



Particulate matter during heat check and breeding P12C Barn 2



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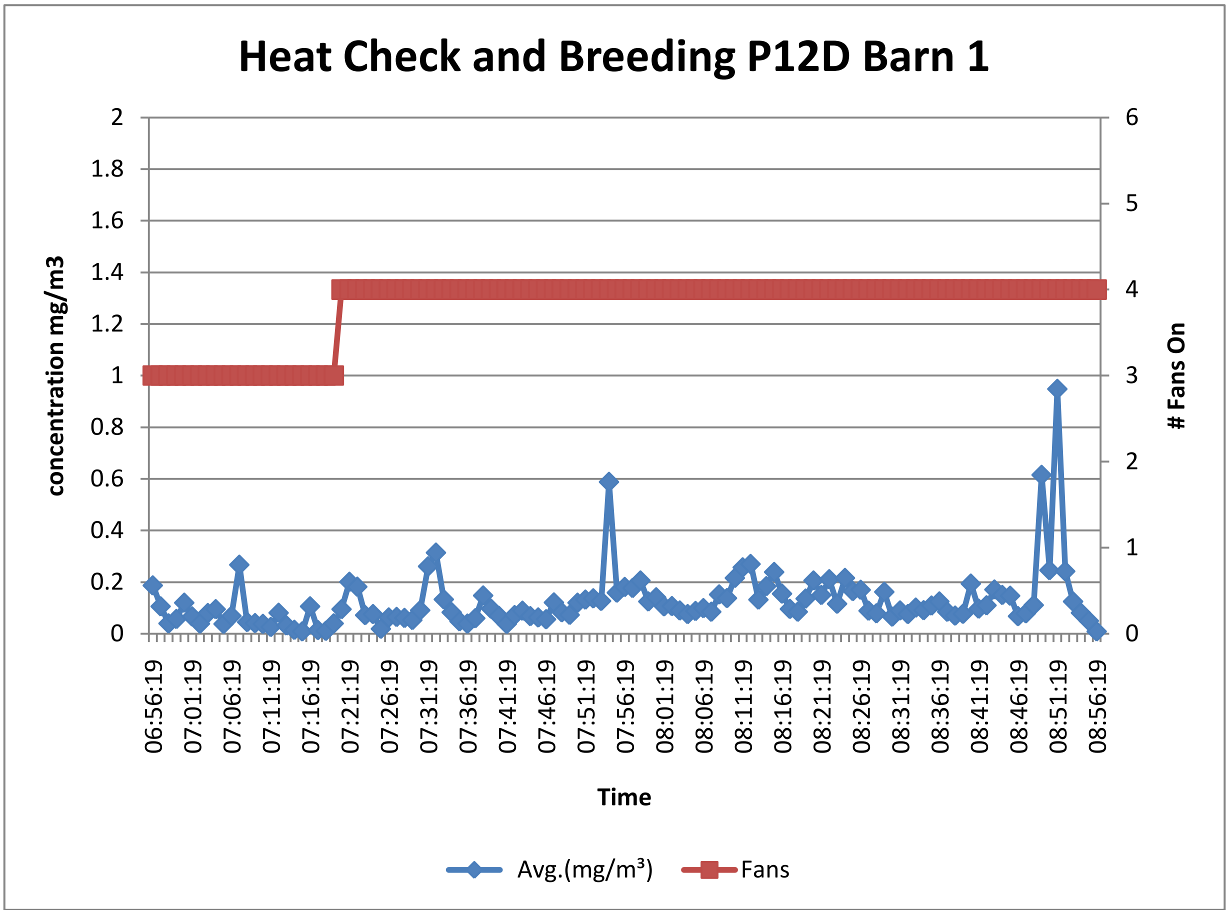
Particulate matter during heat check and breeding P12D Barn 1



VITA

EARL DAN BEMBRY, MSN, APRN, BC

Personal Data:	Date of Birth: April 23, 1953
	Place of Birth: Live Oak, Florida
	Marital Status: Married
Education:	Suwannee High School, Live Oak Florida
	B.S. Animal Science, University of Florida, Gainesville, Florida 1981
	B.S. Nursing, Valdosta State University, Valdosta, Georgia 2000
	M.S. Nursing, East Tennessee State University, Johnson City, Tennessee 2002
	PhD Nursing, East Tennessee State University, Johnson City, Tennessee 2009
Professional Experience:	Adjunct Faculty, Lake City Community College; Lake City, FL Department of Math and Science, 1997 – 2000
	Graduate Assistant and Adjunct Faculty, East Tennessee State University, College of Nursing, 2000-2002
	Adjunct Faculty, Lake City Community College; Lake City, FL, Department of Math and Science, 2002 – 2005
	Graduate Assistant and Adjunct Faculty, East Tennessee State University, College of Nursing, 2005 – 2007

Instructor, Northeast State Technical Community College;

Blountville, Tennessee, 2007-2009

Honors and Awards: Who's Who Among Students in American Universities & Colleges May 2000

USAA All-American Scholar Collegiate May 2000

National Dean's List May 1998 – May 2000

National Collegiate Nursing Award May 2000

Sigma Alpha Chi Valdosta State University Mack Award May 2000

Outstanding Affiliate Student Award VAMC Lake City, FL May 2000

Outstanding Service to the Swine Industry Award June 1990