Appendix L

Final Report on Wisconsin’s Dairy and Livestock Odor and Air Emission Project

FINAL REPORT

ON

WISCONSIN'S DAIRY AND LIVESTOCK ODOR AND AIR EMISSION PROJECT

SUPPORTED BY USDA NRCS

CONSERVATION INNOVATION GRANT

NRCS 68-3A75-5-157 WI DAIRY AND LIVESTOCK AIR EMISSION/ODOR PROJECT

September 2009

Madison, Wisconsin

EXECUTIVE SUMMARY

BACKGROUND

Supported by a U.S. Department of Agriculture Conservation Innovation Grant, this project investigated the air impacts of different manure management practices on typical large animal feeding operations. Over the course of two years, staff from the Wisconsin Department of Agriculture, Trade and Consumer Protection and the Wisconsin Department of Natural Resources measured odors and airborne concentrations of ammonia and hydrogen sulfide, both on and around manure storage lagoons on farms employing these different practices. It should be noted that our sampling was not intended to measure emissions or determine emission factors.

The subject farms for this project were selected through a statewide request for study participation. Interested farms were reviewed by a steering committee consisting of a number of representatives of agriculture, state agency, and environmental groups. Participants in the study were given the incentive of cost sharing for practices they installed on their farms, or a participation stipend in the event that no practices were installed. The steering committee selected six study farms (five dairies and one heifer raising facility), and four control practices to evaluate.

The four practices tested were anaerobic digesters; an impermeable cover; a permeable cover; and a solids separation and aeration system. Two types of digesters were studied, a mesophilic (low temperature) digester and a thermophilic (high temperature) digester. The impermeable cover was a gas-tight HDPE material that is characteristic of those used to line earthen storage lagoons. The permeable cover was a floating geotextile membrane, which acted like an artificial crust to break up the air/liquid interface, yet allowed precipitation and gasses to pass through. The solids separation and aeration was a proprietary system that consisted of two screen roller press filters followed by two waste storage lagoons equipped with floating aerators. The aerators were installed such that they forced air into the upper layer of the stored manure. The theory behind this is to allow the deeper wastes to breakdown anaerobically, but to control the gases being generated by passing them through a top aerobic layer.

A total of 28 sampling trips were conducted on 6 different farms, three of which installed potential control practices during the course of the project, allowing pre- and post- installation sampling. Two of the farms had anaerobic digesters already installed, allowing us to make comparisons to a similar farm without a digester. And the sixth farm was an open feedlot, which provided us with baseline data only. During these trips, a total of over 2,000 air samples for ammonia and hydrogen sulfide were collected, mostly from the perimeters of the manure storage lagoons. Samples were also collected from the lagoon surface. During these trips, 103 odor transects were conducted using a field olfactometer. This report documents the air and odor sampling procedures and compiles the results.

The project focus on lagoons required skilled knowledge of other potential sources of odors on farms, such as barns and sand channels. Where appropriate, these areas were also sampled to facilitate a better understanding of the impact these areas might have on measurement and analysis of data.

KEY FINDINGS

Ambient NH_3 and H_2S Concentrations

Concentrations of ammonia and hydrogen sulfide tended to vary as much or more widely between visits to the same farm as they did between two different farms. This variability, compounded by the relatively few trips made to each individual farm, yielded a situation where we were not able to collect a statistically significant quantity of samples, and our results therefore contain some ambiguity. Samples were collected at the edge of each practice being studied to minimize the interference from other on-farm sources, and to factor out the effect of atmospheric dispersion. For this reason, all results are reported as “near”, however it is logical that concentrations away from these practices would follow the same trends as those nearby.

The following statements appear to be supported by our data:

1) In general, higher ambient concentrations of hydrogen sulfide will be observed around agitated manure storage and treatment system surfaces (either during pumping, or along sand channels, and near outfalls and spillways).
2) Installing an impermeable cover will significantly reduce near lagoon ambient concentrations of ammonia and hydrogen sulfide.

The statements below are less conclusively supported, although they are likely to be true:

3) Installation of a semi-permeable cover is likely to reduce near lagoon ambient concentrations of ammonia and hydrogen sulfide; however, later exposing the covered wastes to air (as is done in a sand separation channel) may lead to significant increases near the uncovered areas, when compared to pre-covered levels.
4) Lagoon aeration may reduce manure surface concentrations of hydrogen sulfide. However, in our test case, surface ammonia concentrations, as well as general nearby ambient concentrations of both compounds increased following aeration.

The following points of interest may have important manure management implications:

5) Digested manure appears to generate lower hydrogen sulfide concentrations near the lagoons than undigested manure, although further study would be necessary to state this conclusively. There appears to be no similar reduction in ammonia concentrations.
6) Hydrogen sulfide concentrations around undigested manure surfaces appear to increase at night relative to daytime concentrations. Whether this is due to overnight inversions allowing the compound to concentrate, or is due to some intrinsic property of the dynamics of exchange across the air/manure interface is unknown.
7) Ammonia concentrations, in contrast, appear to peak during the daylight hours, around both digested and undigested manures.
8) Most near lagoon concentrations of hydrogen sulfide are below air toxics limits for property lines. However, our data shows the presence of highly concentrated and compact plumes near areas of agitation which could potentially travel significant distances before fully dispersing.

Odor Sampling

Downwind odor measurements were taken at 200-foot intervals both before and after the control practices were installed. The general trend in these odor measurements was used to determine the estimated overall odor control performance of each practice. The study focused on odors emitted from manure storage lagoons, since these are typically the single most significant source of odors from concentrated animal feeding operations. Odor levels were measured using a Nasal Ranger™ field olfactometer, produced by St. Croix Sensory of Lake Elmo, Minnesota.

Although a limited number of odor transects were conducted, and conditions varied throughout the study, general trends were observed for each of the control practices tested. The results of that testing are summarized below, and described in greater detail throughout the report. Caution should be exercised when extrapolating these results to other farming operations.

Anaerobic Digesters

The storage lagoon receiving wastes from the low temperature digester produced about 15% less ambient odors than a similar lagoon storing undigested wastes. On the other hand, the storage lagoon receiving wastes from the high temperature digester produced about 15% more ambient odors than did the lagoon storing undigested wastes. Because of the inherently subjective nature of this type of testing, plus or minus 15% should not be considered statistically significant. Factors such as retention time, operational reliability, and addition of substrate material can all influence the performance of an anaerobic digester, and therefore its effectiveness at controlling odors.

Impermeable Cover

Installing an impermeable cover on the manure storage lagoon effectively controlled all ambient odors that had been emitted prior to the installation of the cover (100% reduction). This result can logically be applied to other lagoons, assuming that the covers remain air-tight and that the gasses that form under the cover are collected and burned in a flare or generator set, as was the case with our demonstration farm.

Permeable Cover

Installing a permeable cover on the manure storage lagoon resulted in about an 80% reduction in ambient odors from that source in the first year, and about a 60% reduction in the second year.

Solids Separation and Aeration

Installing this proprietary system resulted in about a 20% reduction in odors in the first year and about a 25% reduction in the second year

CONCLUSIONS

It can be concluded that covers are effective at controlling odors and ambient air concentrations of NH_3 and H_2S from manure storage lagoons. Of these, impermeable covers are very effective (100% reduction), and permeable covers are quite effective (about 70% reduction).

Solids separation and aeration appear to reduce odors somewhat (about 25%) as well as H_2S concentrations, however NH_3 concentrations could be increased.

Anaerobic digesters do not predictably reduce odors or ambient NH_3 concentrations near manure storage lagoons, however they may reduce H_2S concentrations. Advances in H_2S control have been made in Europe that reduce concentrations even further, and these are now being adopted by some U.S. firms.

The odor model used by Livestock Facility Siting rule (ATCP 51) accurately predicts the odors from averaged sized manure storage lagoons (around 4 acres), however it under predicts odors from small lagoons (0.4 acre). The credit given in the odor model for covers, both impermeable and permeable, seems appropriate. Too great a credit may be provided for anaerobic digesters, as well as solids separation and aeration systems. And finally, the odor model may not be applicable for large, lightly stocked earthen feedlots.

This study yielded important insights into controlling odors from manure storage lagoons, and these are detailed in the Lessons Learned and Improving Farm Practices sections of this report. However, it also leaves many questions unanswered, and has raised new questions we did not anticipate beforehand. It will facilitate future investigations by highlighting the challenges in such evaluations, including the dynamic nature of farms. The information gathered by this study should aid in making future decisions regarding the control practices studied, as well as helping to guide future studies into the air impacts of CAFOs.

IMPLICATIONS AND RECOMMENDATIONS

Improving Farm Practices

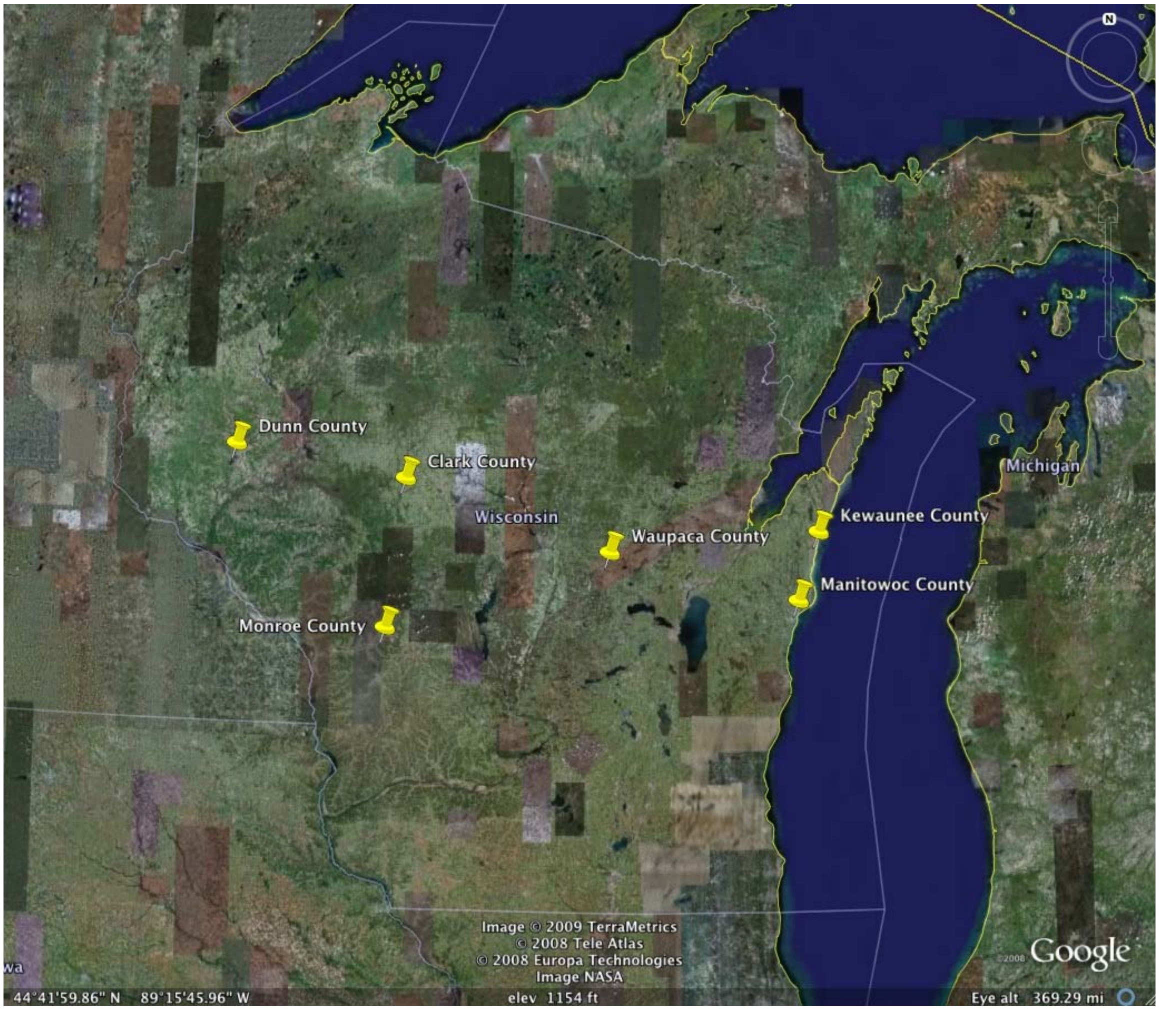
Throughout the course of this study, 28 visits were made to the six study farms over a two year period. This allowed for observations to be made regarding the overall management of the farms, and how that management affected odors and concentrations of ammonia and hydrogen sulfide. Based on those observations, the following suggestions are offered to farmers wishing to reduce odors from their farms:

1. Minimize surface agitation of waste storage lagoons and exposure to the air. This includes using submerged inlets, subsurface versus above surface jets for mixing, and incorporating wastes when land applying. These practices will also minimize the volatilization of ammonia, thus maximizing the amount of nitrogen supplied to your crop. This change alone eliminated neighbor complaints at the low temperature digester farm.
2. If installing a manure digester, maximize the retention time. More thorough digestion of the wastes will reduce odors from the lagoon, and incomplete digestion can actually increase odors. Also install a high quality flare with a reliable igniter and a large wind baffle. This will avoid the unintentional release of unburned digester gas to the air.
3. If installing a new waste storage lagoon, consider incorporating an impermeable cover. A cover greatly reduces odors and other impacts on neighbors. Also, the reduction in greenhouse gasses could qualify you for cost-sharing through a carbon credit program.

The savings in not having to haul precipitation can be significant. And lastly, it is far more economical to add a cover to a new storage lagoon than it is to retrofit one on later.

4. Consider installing a permeable cover on your existing waste storage lagoon. Although not as effective at controlling odors and greenhouse gasses as an impermeable cover, it will provide significant benefits at far less cost. If doing so, be certain to provide a number of well spaced openings for agitation and pumping.
5. Keep stored feed clean and dry. This will reduce odors as well as protect feed quality.
6. Consider the installation of a solids separator to produce your own bedding. Composted manure solids can provide a safe supply of bedding, when moisture levels are properly managed. The cost savings over other types of bedding material, such as sand, can be substantial.
7. Keep animal densities low on open feedlots. High stocking rates can increase odors, as well as runoff and erosion. Ideally, consider going to a rotational grazing set-up. This will bring things into balance with your land base, reducing inputs and impacts on the environment.
8. Separation distance is a simple, yet effective, tool you can use to reduce impacts on your neighbors. When planning for new facilities, and especially manure storage lagoons, site them as far from neighbors as possible, and with consideration for prevailing winds. Odors are far less noticeable at 800 feet than they are at 200 or even 400 feet. If adjacent properties go up for sale, consider buying them as a buffer against future encroachment by development.

STATE MAP WITH COUNTY OF PROJECT SITES IDENTIFIED



ACKNOWLEDGEMENTS

We would like to extend our appreciation to the following individuals and agencies for their support and dedication for funding, involvement and guidance for the DATCP Conservation Innovation Grant project and report you are reading.

USDA for funding this CIG project:
Without their financial support, this project would have never been implemented. The cost of such a project is far beyond what state agencies would normally even consider funding.

DATCP Administration – Rod Nilsestuen, Matt Tompach, Kathy Pielsticker, and Dave Jelinski:
The State of Wisconsin has created state guidelines for siting new and expanding livestock operations. During the process of creating the guidelines, odor and air quality became a major focal point. Their concern of acceptable odor and air quality emitting from livestock operations and the lack of information for such issues being evident, they realized the need for such a study and wholeheartedly endorsed the study concept. They have provided consistent support before, during, and after the life of the project.

DNR Administration – Al Shea, Lloyd Eagan, and Eileen Pierce:
The Wisconsin DNR regulates air quality and odors under SS. 445 and supported the study with dedicated personnel and resources to accomplish this project.

NRCS – Don Baloun and Pat Leavenworth:
NRCS became the conduit of funds from USDA to DATCP, and Don provided support for the administrative process that was involved, and also provided valuable insight on project management.

University of Minnesota – Larry Jacobson and David Schmidt:
Larry and his staff at Minnesota have done a significant amount of work studying air quality and odor emissions from livestock units in the Upper Midwest. They provided invaluable technical assistance that made the project more feasible to accomplish and more relevant to the original focus of the grant.

Environmental Intelligence, Inc. – Douglas B. Johnson:
Doug was brought on board to compile, arrange, and write this report and we appreciate his efforts in accomplishing the task. His patience and skill to produce this report was sorely needed.

TABLE OF CONTENTS

LIST OF FIGURES

Additional Figures (Ambient air sampling NH_3 and H_2S concentrations, and Nasal Ranger™ odor measurement data) for each field visit are presented in the Project Data Supplement.

LIST OF TABLES

INTRODUCTION

PURPOSE

RATIONALE AND PROJECT HISTORY

Agricultural practices in the past 30 years have led to increasingly concentrated animal populations, which in turn have increased the amount of waste generated on each farm. Not only does this complicate waste handling for the farmer, but also it increases the chance that emission of odors and biogenic compounds may cause at least the perception of problems. Whether or not agricultural emissions of such compounds as hydrogen sulfide and ammonia are of legitimate regulatory or health concern is a current research topic.

In 2004, Wisconsin DNR adopted a set of revised rules governing the emission of toxic chemicals of concern (NR 445). Among the chemicals regulated under this rule are several known to be associated with animal manures. At that time, however, there was not enough information available to determine whether or not large animal operations would exceed regulatory limits. As such, a moratorium on the application of the rule to these operations was put in place, until more information could be obtained.

Separately, the Department of Agriculture, Trade and Consumer Protection (DATCP) became interested in examining different manure handling practices in light of whether or not they would have a perceptible impact on odor and emissions. DATCP, in cooperation with DNR, applied for and obtained a Conservation Innovation Grant (CIG) from the United States Department of Agriculture (USDA) in October 2005. The purpose of the study was to implement several different practices on different farms and study the before and after differences observed.

DATCP's role in the study was to choose the farms and oversee the implementation of the test practices, to collect odor samples and data, to collect manure samples, and to collect farm operation information (number of animals, feed information, etc). DNR's role was to provide air sampling support, and to collect and analyze air samples for the chosen parameters. This report covers the air sampling portion of the project.

At the time of the application for project funds, the DATCP-DNR project team proposed that implementing the CIG would improve the understanding of livestock producers and local governments related to ambient air concentrations, odor, and water quality improvements as a result of installing various BMPs. Currently, Wisconsin has very little experience and limited on-the-ground knowledge related to ambient air concentrations and odors from livestock operations. While the state has not aggressively enforced air monitoring and air quality regulations on livestock operations, their location and the air quality surrounding them have been regulated through conditional zoning permits. These generally include setbacks of livestock operations, but do not directly consider the impact of BMPs on ambient air concentrations and odor.

The project team recognized there was a need for a replicable study with potential transferability of results to other agricultural odor related problems in Wisconsin and elsewhere. The team proposed to undertake this project with reasonable expectations that the following benefits would accrue to producers, neighbors and communities, the environment, and animal agriculture industries while providing guidance for policymakers and the regulatory community:

- Documentation of the relative ambient air concentrations resulting from dairy and other livestock operations based on current practices before BMPs are installed would provide a baseline against which to measure potential improvements that might be realized after BMP installation.
- Establishing the costs to implement various best management practices the research shows should reduce ambient air concentrations, odor, and runoff of nutrients to the state's waters would provide a basis for cost-benefit analysis based on implemented cost instead of reliance on cost models that are commonly found in published research.
- Establishing a dialogue between producers, neighboring citizens, and local governments related to ambient air concentrations and water quality would provide a basis to enhance shared understanding of BMPs and their potential to resolve issues.
- A comparison of pre and post installation of BMPs related to the odor estimates and Nasal Ranger odor measurements to further calibrate the odor standards and evaluate the tool established under the state's Livestock Siting Administrative Rule, ATCP 51 would improve the effectiveness of legislative initiatives developed to address issues with livestock siting.
- Documentation of the reduction of ambient air concentrations, odors, and runoff of nutrients as a result of installing BMPs would provide a scientific basis for decision-making by dairy producers and other stakeholders involved with siting and operation of dairies.
- An evaluation of the cost effectiveness of the BMPs based on the degree of reduction would provide producers and others with data to guide and inform decisions on which BMP or technology might yield the most reduction in odors for a given dollar of investment.
- An evaluation of the reductions in ambient air concentrations and odors as a result of implementing a manure digester system would better enable producers and policymakers to make decisions on the policies and practices that impact adoption of manure digesters in Wisconsin and elsewhere.

REGULATORY DRIVERS

Several regulations at the state and local level are driving a need for scientific study and evaluation of ambient air concentrations. Hazardous air pollutant emissions are regulated under ch. NR 445, Wis. Adm. Code. This rule establishes ambient air standards for specific hazardous air pollutants, off the source's property. The acceptable ambient concentration standards for ammonia and hydrogen sulfide are 418 and 335 micrograms per cubic meter, respectively, both on a 24-hour average basis.

NR 445, Wis. Adm. Code was updated in 2008 to extend an exemption period for livestock operations to July 31, 2011. Existing livestock operations are required to achieve compliance by July 31, 2011. After July 31, 2011, new livestock operations are required to comply upon start up. The rule provides several compliance options. A special compliance option for livestock operations is established in the rule, specifically, the implementation of best management practices as approved by the Department of Natural Resources. This study was designed in part to provide information to support department decisions on best management practices for the control of hazardous air pollutant emissions, as proposed under this rule.

There is increasing attention placed on the impact of livestock operations on odor and ambient air concentrations. Wisconsin has promulgated NR 445, Wis. Adm. Code, Control of Hazardous Pollutants. This code establishes best management practices as the method to secure compliance for emission sources involving agricultural waste. Implementation is delayed until July 31, 2011 to allow development of the BMPs to regulate and control emissions from these sources. Wisconsin is experiencing increased conflicts between livestock operations and developing rural communities related to odor and water quality issues.

A number of local governments are regulating the location and expansion of livestock operations through local zoning and issuing of conditional use permits. In 2003, Wisconsin passed the Livestock Facility Siting Law, and in 2006, promulgated ATCP 51, Wis. Adm. Code, to implement the law. The state developed an odor standard to estimate the impact of various farming practices on odor. Since this is the first attempt to set statewide standards related to odors, the effort was relatively controversial. The issue of whether livestock operations are a threat to public health and welfare will continue, especially as the livestock industry transitions to larger size operations.

PARAMETERS OF INTEREST

There are literally hundreds of volatile compounds that have been found associated with manures. Of these, quite a few are listed in NR445. Choosing which parameters to include within this study was a process which balanced the available budget with the existence of testing methods, the perceived likelihood that any particular compound might actually be present in levels approaching those listed in NR445, and the probability that the presence of the compounds is actually associated with the agricultural operation.

Based on these factors, this study focuses on ammonia and hydrogen sulfide as the compounds most likely to be present at almost all farms. Several other compounds that are likely to be present (such as benzene and formaldehyde) were rejected because of their ubiquitous occurrence in the atmosphere, and thus the difficulty of associating their presence with the operation in question. While ammonia and hydrogen sulfide have other sources, both natural and anthropogenic, their concentrations in the vicinity of farms will most likely be driven by the farm itself.

Ammonia is a by-product of the decay of urea, and is present around the urine of all animals. Hydrogen sulfide is a product of the anaerobic decay of organic materials, which in the case of animal feeding operations is the manure.

PROJECT OBJECTIVES

The CIG project will compare the pre and post installation of best management practices and the resulting impact on the measured and estimated odors and the measured ambient air concentrations. The specific project objectives are to:

- Establish and expand cooperative relationships between USDA, Wisconsin DNR, Wisconsin DATCP, UW Extension, the Wisconsin Agricultural Stewardship Initiative

(WASI), Dairy Business Association (DBA), Professional Dairy Producers of Wisconsin (PDPW), WI Farm Bureau Federation, Dairy Gateway project, and the WI Cattleman's Association;[1]

- Estimate odors produced by dairy and other livestock operations utilizing the odor standards in ATCP 51 and other methods to address odor, and to measure odors using a Nasal Ranger;
- Develop a list of best management practices and work with neighborhood citizens, local government, and livestock producers, to reduce odor, ambient air concentrations and improve water quality, within the Dairy Gateway Project and at least one other project area,
- Evaluate the impact of installing livestock related best management practices on participating livestock operations related to ambient concentrations of hydrogen sulfide and ammonia, and odor. The targeted BMPs may include manure storage covers, increased scraping of animal lots, surface-applying manure versus injection and other practices now being used nationwide.
- Evaluate the pre and post installation ambient air concentrations and odors for a manure digester (biogas).
- Prepare nutrient management plans utilizing the new phosphorus based nutrient management standard.
- Communicate the results of the project to DBA, PDPW, WI Farm Bureau, WI Cattleman's Association, and in the Dairy Gateway Project with citizens and local governments, all utilizing the WASI network.

These project objectives will significantly aid producers in furthering the implementation of best management practices to reduce ambient air concentrations, odor, and impacts on the transport of nutrients into the environment. The project will aid in furthering the understanding and adoption of best management practices to reduce the environmental impacts from dairy and other livestock operations.

There had not been a perceived need prior to the livestock siting rules in Wisconsin to address air quality issues related to agricultural operations. As livestock operations transition into larger operations where adjoining land uses are sensitive to the odors, ambient air concentrations, agricultural runoff, and other impacts on the environment; the livestock operations must utilize best management practices to offset these impacts. The project brings additional focus to the problem of manure-related odors and provides producers, regulators, neighbors and others with an evaluation of the solutions by communication of the results to the livestock producers and the public.

[1] The following links are provided for reader's convenience: www.usda.gov; www.dnr.state.wi.us/; www.datcp.state.wi.us/; www.uwex.edu/; www.uwplatt.edu/pioneerfarm/wasi/index.html; www.widba.com/; www.pdpw.org/; www.wfbf.com/; www.dnr.state.wi.us/org/caer/cea/assistance/agriculture/dairy.htm; www.wisconsinbeef.com/

WORK PERFORMED

The Project Team:

- Developed and implemented a plan to evaluate the odor standards in ATCP 51, Wis. Adm. Code, through odor measurements and the relationship with measured ambient air concentrations on six to eight dairy/livestock farms.
- Oversaw the installation of best management practices meant to control ambient air concentrations, odors and runoff.
- Evaluated installation of a manure digester to produce methane for production of electricity.
- Evaluated post implementation impacts on ambient air concentrations, odors, and water quality.
- Communicated the results through WASI.

PROJECT DURATION

The project commenced in August 2005. Initially scheduled for completion in August 2008, the project was extended through June 2009.

Project Action Plan and Timeline

1. Initiation

   Upon signing of the CIG funding contract with USDA in summer 2005, the Project Team began selection of participating livestock producers and development of air sampling protocols. In Dairy Gateway, at the Kewaunee County participating farm, the Project Team surveyed and presented information to neighboring citizens, local governments and producers regarding BMPs and project objectives.

2. Baseline air emissions monitoring

   Beginning in October 2006 and continuing through October 2007, the Project Team conducted air emission monitoring to establish “before” levels of ambient air concentrations of key parameters of interest to the study.

3. Installation of Best Management Practices

   With the exception of the digesters, Best Management Practices described in more detail later in this report, were installed beginning in June 2007 through September 2008.

4. Post-BMP air emissions monitoring

   Beginning in May 2008 and continuing through fall of 2008 the Project Team conducted air emissions monitoring to document “after” levels of ambient air concentrations, including completion of odor score sheets and Nasal Ranger™ testing of livestock operations. Additional sampling took place the spring of 2009.

5. Project Extension (Waiver)

   In September 2008, the Project Team requested an extension to allow data collection with a project site that experienced a delay in adoption of a BMP.

6. Data Analysis and Final Report Development

   Data analysis and final report development commenced in Spring of 2008. The extension of the project also allowed for an extended internal analysis and discussion of the data and key project outcomes.

7. Outreach

   A post BMP survey was conducted in late summer 2008, and post-project BMP installation follow-up meetings with neighboring citizens, local governments and producers in the designated project areas commenced in Fall of 2008. These activities continued through early Summer of 2009.

PROJECT MANAGEMENT

PROJECT CO-DIRECTORS

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PROJECT COLLABORATORS

Timm Johnson, Executive Director, Wisconsin Agricultural Stewardship Initiative (WASI)
Paul Zimmerman, Wisconsin Farm Bureau Federation (WFB)
Laurie Fischer, Executive Director, Wisconsin Dairy Business Association (DBA)
Shelly Mayer, Executive Director, Wisconsin Professional Dairy Producers of Wisconsin (PDPW)
Eileen Pierce, South Central Region Air & Waste Leader, Wisconsin Department of Natural Resources (DNR)

Three organizations collaborated to sponsor the project.

- The Wisconsin Department of Agriculture, Trade and Consumer Protection had overall responsibility for managing the project with technical responsibility for developing the Odor scores assigned to DATCP’s Conservation Engineering Section.
- The technical responsibility for conducting the air emission monitoring is within the purview of the Wisconsin Department of Natural Resources’ Bureau of Air Management.
- The Wisconsin Agricultural Stewardship Initiative had lead responsibility for working with the producers, neighboring citizens, and the local governments who agreed to collaborate on the project, and served as the liaison between the groups and the other project sponsors.

The final report represents a team effort between DATCP, DNR, and WASI. Also, WASI representatives made arrangements for printing outreach and educational outputs, evaluating the success of the project and making sure that the results are transferred to producers and the public.

PROJECT TEAM BIOS

Initiated by (Co-Director) Ed Odgers, Chief of the Conservation Engineering Section of the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP), Steve Struss (Co-Director) provided direct management of the project.

Steve Struss obtained a B.S. in Civil (Environmental) Engineering from the University of Illinois in 1975. He spent the next eight years as an Environmental Researcher in air and water pollution control with the Army Corps of Engineers, and as a Project Engineer for an engineering consulting firm designing wastewater treatment plants. He moved to Wisconsin in 1983 where he became a registered professional engineer and worked as a Design Engineer and Project Manager for a mechanical contractor, a Staff Engineer for an accident reconstruction firm, and a Sole Proprietor of his own wastewater treatment business. In 1991 he began working as an Agricultural Engineer for the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP). For 16 years he worked in the areas of erosion control and animal waste management. He has served on a number of statewide technical committees, and was instrumental in developing the odor standard and the livestock facility siting rule (ATCP 51). He is currently the state's Livestock Facility Siting Engineer.

Eileen Pierce is the DNR South Central Region Air & Waste Leader in Fitchburg, Wisconsin. At the inception of the project, she served as the Air Monitoring Section Chief in Madison, Wisconsin. Ms. Pierce has a Bachelor's Degree in Chemical Engineering from the University of Notre Dame. She has worked for the DNR for over 20 years.

David Grande was the DNR lead worker on the project. Mr. Grande has a Bachelor's Degree in Chemistry from the University of Nebraska at Lincoln. He has worked in the air monitoring field for most of the past 24 years, including more than 14 years in his current position as a Toxic Air Monitoring Chemist. Notable projects include ammonia monitoring around a wastewater solids composting facility in western Wisconsin, and PCB monitoring during sediment remediation on the Fox River.

Timm Johnson, is the Executive Director of the Wisconsin Agriculture Stewardship Initiative (WASI). Mr. Johnson has a Bachelor's Degree in Dairy Science from UW Madison. He owned and operated his own dairy farm and was a partner in a dairy farm with a total of 25+ years experience prior to becoming the executive director of WASI in 2002. Mr. Johnson also serves as the Dairy Ombudsman for DATCP Secretary Rod Nilsestuen.

PROJECT STEERING COMMITTEE

Department of Agriculture, Trade and Consumer Protection Secretary Rod Nilsestuen appointed a CIG project steering team in October 2005. The steering committee met six times and provided recommendations related to the types of control technologies and livestock operations to evaluate and helped the project sponsors to evaluate the applications received to participate in the project. In addition, a technical team was assembled to provide guidance on technical issues related to the project.

The members of the Steering Committee and Technical Team are listed below.

Project Steering Committee

Kathy Pielsticker	Administrator, Ag. Resource Mgmt. Division, DATCP
Paul Zimmerman	WI Farm Bureau Federation
Laurie Fischer	Dairy Business Association
Al Koepke	Professional Dairy Producers of Wisconsin
Al Shea	Administrator, Air and Waste Division, DNR
Eileen Pierce	DNR South Central Region Air & Waste Leader, DNR
Timm Johnson	Wisconsin Ag. Stewardship Initiative
Duane Ford	Dean, Business, Industry, Life Sciences & Ag., UW Platteville
Tom Hunt	UW Platteville Pioneer Farm
Rick Klemme	Associate Dean, UW Extension, UW Madison
Dennis Frame	UW Discovery Farm
Jordan Lamb	Wisconsin Pork Producers and WI Cattlemen's Association
Andrew Hanson	Midwest Environmental Advocates
Ed Odgers	Chief, Conservation Engineering Section, DATCP
Keith Foye	Chief, Land Management Section, DATCP
Tom Krapf	NRCS - Madison

Project Technical Advisory Team *

Ed Odgers	Chief, Conservation Engineering Section, DATCP
Bob Wilson	Agricultural Engineer, DATCP, Appleton
Eileen Pierce	DNR South Central Region Air & Waste Leader, DNR
Steve Struss	Livestock Siting Engineer, DATCP
Vid Grande	Air Monitoring Chemist, DNR
Timm Johnson	WASI
Tom Hunt	UW Platteville Pioneer Farm
Fred Madison	UW Discovery Farm
Brian Holmes	UW Biosystems Engineering and UW Extension
Mark Powell	USDA – Agricultural Research Service and UW Soils
Pat Murphy	USDA Natural Resource Conservation Service

KEY PROJECT COSTS

TOTAL PROJECT COST AND TOTAL PROJECT FUNDS REQUESTED

The project was projected to cost a total of $1,386,545. The project sponsors requested $646,945 from the Conservation Innovation Grant Program.

COSTS – COOPERATOR BMP SOLUTIONS

Potential project participants were offered an incentive payment to offset some of the capital and operational costs related to adoption and evaluation of technologies. Six farms agreed to participate in the study. Two of these farms were chosen to provide "background," or control data, which, in theory, would provide a control reference for farms that elected to install one of the technologies under evaluation. Where appropriate, project participants were also offered an incentive to invest in a Nutrient Management Plan or a Comprehensive Nutrient Management Plan. Table A below provides a summary of the cost to the project for planning, control and incentive payments to producer participants in the project.

Case Study ID	Type of Project	County Location	Incentive Payment ($)	Control Technology Cost ($)	NM Plan or CNMP Cost ($)	Total Cost ($)*
1	**Manure Digester**	Waupaca	5,000	NA	4,350	9,350
2	**Manure Digester Impermeable Manure Storage Cover**	Dunn	NA	294,287	11,438	305,725
3	**Permeable Manure Storage Cover**	Kewaunee	NA	196,195	4,400	200,595
4	**Manure Solids Separation and Storage Aeration**	Monroe	NA	140,668	704	141,372
5	**Background for Animal Lot**	Clark	5,000	NA	NA	5,000
6	**Background for Manure Storage**	Manitowoc	5,000	NA	7,500	12,500

* The participating farms were paid 75% of the total cost of the control technologies and the nutrient management plan or comprehensive nutrient management plan.

Table A

Summary – Planning, Control and Incentive Payments to Producers Participating in the Conservation Innovation Grant (CIG) Wisconsin's Dairy Air Emission Odor Project

DATA GATHERING, ANALYSIS, ADMIN AND REPORTING COSTS

CONSERVATION INNOVATION GRANT (CIG)
BMP INSTALLATION, DATA GATHERING, ANALYSIS, ADMINISTRATIVE AND REPORTING COSTS*

CIG Activity	CIG Funds Requested	Funds from CIG Partners	Source of the Partner Funds	Total Project Funds
Installation and Operation of BMPs	$ 8,263 (W) 137,696 (K) 5,000 (C) 10,625 (Ma) 229,294 (D) 100,528 (Mo) $ 491,406 Total	$ 1,087 (W) 62,899 (K) 0 (C) 1,875 (Ma) 76,431 (D) 40,844 (Mo) $ 183,136 Total Grand Total = $821,765	Producers Cash For Digester Operation $ 629,129 Producers Cash For Other BMPs $ 183,136 Producers In-kind For Digester Operations $ 9,500 Producer In-kind For Other Practices $ 0 Total Cash From Producers $ 812,265 Total In-kind From Producers $ 9,500 Total Producer Funds $ 821,765	$1,313,171
Air Sampling/Odor Evaluation and Sampling/ Technical Assistance Cost of Sampling- Equipment Š staff	$20,123	$213,300	Total WI Cash $ 56,601 Total WI In-kind $ 156,699 Total WI Funds $ 213,300	$233,423
Outreach Materials & Printing Š WASI	$10,000	$0		10,000
WASI - Staff Costs	$15,000	$0		$15,000
Subtotal	$536,529	$1,035,065		$1,571,594
DATCP Indirect Costs	$91,200	$0		$91,200
Total	$627,729	$1,035,065		$1,662,794

* Original NRCS Grant Agreement amount was $646,945.
(C) = Clark County site (D) = Dunn County site (K) = Kewaunee County site
(MA) = Manitowoc County site (Mo) = Monroe County site (W) = Waupaca County site

Table B
Project Cost Overview

METHODS

STUDY DESIGN AND LIMITATIONS

The determination of emissions from a pollution source requires collection of both contaminant concentrations, and the air flow of the exhaust they are associated with. At a traditional industrial source, the contaminants are most often associated with discrete vents from which both of these parameters may readily be measured. In addition, industrial operations typically operate at near steady state, so that measurements made at any time during typical conditions are widely applicable.

Agricultural operations present formidable difficulties in determining actual emissions associated with them. Most of the emissions from these operations are from multiple large complex area sources (barns, lagoons, feed stocks, etc). Emissions are highly influenced by local conditions (manure surface crust, wind speed and direction, humidity, solar radiation, and temperature, to name a few). As they are not constrained to discrete vents or stacks, and do not have specific air flows associated with them, measuring them is a difficult and time-consuming prospect.

There are several studies underway on a national level, which are attempting to measure emissions from large farming operations. One of these, conducted under the auspices of the EPA, is attempting to measure emissions from barns, using a variety of real time instrumentation over the course of a 2-year study period. Concentrations for a number of parameters as well as air flow measurements made at representative fans are to be used to estimate the emissions. It is anticipated that this study will help refine emission factors used to estimate emissions.

A second study, sponsored by the USDA, is attempting to measure whole farm emissions by using laser technology across transects downwind of the farm and extrapolating emissions from a combination of observed concentrations and meteorological information. In addition to requiring the use of specialized and delicate equipment, this type of test of extremely sensitive to ambient conditions, such that a sampling event covering 10 days may result in 4 or 5 days worth of usable data.

Rather than attempting to emulate these better supported studies and trying to determine actual emissions associated with the farms in this study, the DNR has adopted a simpler and more limited approach. Our goal is to measure concentrations around the waste handling facilities in an effort to determine whether there are observable differences between the different farms that can be attributed to the waste management practices.

To meet this goal, a relatively large number of samplers are deployed around the lagoons at each farm, and two sets of samples collected (one during the day, and one overnight). While up to a hundred samples may be collected during each sampling event, this does not necessarily represent a statistically significant sample set, as each sampler measures concentrations in a limited area, and the samplers are deployed around lagoons, which are frequently several acres in extent.

In addition to the ambient sampling, a limited number of samples are collected directly above the manure surface using a flux chamber flushed with a stream of clean air. These samples are being collected to more directly compare the emission potential of different manures. It should be noted that the flux chamber being used is approximately 1 foot in diameter, and thus is not representative of the entire surface of a several acre waste lagoon.

Another limitation of our study design is that we are constrained to relatively few visits to each farm (3 – 6 over the course of a year and a half). Given the wide variability that can be expected to occur naturally at each farm during the course of a year, these trips do not guarantee representative measurements. For ambient measurements, EPA typically requires a sampling frequency of once every six or twelve days to ensure representativeness (60 or 30 sampling events per year).

In addition to the design limitations discussed above, several other factors affect the utility of our data. Scheduling conflicts preclude the ability to readily re-schedule sampling trips to avoid less than ideal sampling days. Because of this, several of our trips have been affected by rain, which not only changes the ambient concentrations of the chemicals of interest, but which also reduces our ability to obtain valid usable samples.

Finally, the length of each sampling period (6 – 14 hours) stretches our equipment to the limit, and leads to the potential for sampling losses related to power failures. While we have made significant progress in overcoming both of these difficulties, by providing weather shelters for the samplers and equipping them with timers, we have still not achieved 100% sampling success on any of our trips. As such, our already design limited sampling protocol has suffered from the loss of additional samples.

Because of these limitations, our data should not be used to represent typical ambient conditions, nor should our results be used to extrapolate annual average concentrations for the purposes of comparison to NR445. Our data does not yield emission factors, or overall emissions from the lagoons at the farms studied.

As a final note, except in a very few specialized situations, barn associated measurements are not being made. The primary reason for this is that the management practices being compared relate to the handling of the waste after it leaves the barn, so our measurements concentrate on the waste handling end. As such, our data do not attempt to measure the total air impact of these large agricultural operations.

In spite of these difficulties, our data set is unique in its size and scope. It does provide a means to compare pre- and post- installation concentrations of ammonia and hydrogen sulfide on and around manure storage lagoons. As long as care is taken with applying the data, some comparisons are possible between the different operations sampled.

FARM SELECTION PROCESS

DATCP appointed a steering committee to work with staff to develop criteria for selecting livestock operations for participating in the study. The original application of the funding included specific mention of studying the impact on air emissions and odor from at least one anaerobic manure digester, various methods of manure application or injection, and other appropriate control technologies. The steering committee recommended, and the department agreed, to give priority to evaluating the following types of control technologies: anaerobic digestion, covered manure storage, reduced solids in manure storage, animal lot design and management, and freestall alley scraping. The evaluation of various types of manure applications was not included in the recommended project because the final version of ATCP 51, Wis. Adm. Code, the livestock siting rule did not include evaluation of manure spreading relative to odors and siting of livestock operations.

The department published an application for the CIG project funds on March 9, 2006, with applications due back by March 29, 2006. WASI received 15 applications, including one from a "community project" in Richland County from several landowners. The CIG Technical Committee reviewed the applications and actually visited the sites. An application was returned representing each of the categories included in the request for proposals. The technical committee gave a passing score and recommended 7 projects to the CIG Steering Committee. The CIG Steering Committee provided a ranked order recommendation to further review nine of the applications. The review would include a better estimate of the cost of the project and ability to complete the project in the allowed timeframe.

The department ultimately selected six projects for the study, including evaluations of existing manure digesters in Dunn and Waupaca Counties, solids separation and aeration of a manure storage pond in Monroe County, animal lot improvements in Clark County, a manure storage cover in Kewaunee County, and to collect background information to compare with the farms with digesters in Manitowoc County. As the project unfolded, a decision was made by the producer in Clark County not to implement animal lot improvements, and the Dunn County producer with the existing digester decided to place an impermeable cover on the operations manure storage pond. The cover was included in the original application.

The department completed contracts with all six livestock operations for the project.

PRE- AND POST-PROJECT SURVEY METHODS

As part of the study, we tried to gauge neighbor's perceptions dealing with air quality and odors from a dairy operation in the study group. A survey form was created using basic questions that would show actual impact on outdoor activities as well as perceived nuisances that may be a result of bias towards larger dairy operations. Neighbors were identified within approximately 1.5 miles of the operation in all directions, and each residence received the questionnaire. The survey form used is included in the attachments, with the results from both the pre installation of the lagoon covers and after the installation of the covers. There is a time lag between the two surveys of nine (9) months, and the post installation survey results reflect the experience of neighbors in warmer seasons with outdoor family activities.

LABORATORY SELECTION

Discrete air samples collected for chemical analysis were submitted to the Wisconsin Occupational Health division of the State Laboratory of Hygiene located in Madison, Wisconsin. This lab is fully accredited by the American Industrial Hygiene Association for all aspects of industrial hygiene analysis, and has a long term working relationship with the DNR. In addition to providing sampling materials and analytical services, they provided the pumps used for air sampling. Air samples taken for laboratory odor analysis were submitted to the University of Minnesota, Department of Bioproducts and Biosystems Engineering, St. Paul, Minnesota. Manure samples were analyzed by AgSource Soil & Forage Laboratory, a state certified lab with headquarters in Bonduel, Wisconsin.

TECHNOLOGY SELECTION CRITERIA AND RATIONALE

There are not specifically defined methods required for the sampling performed in the course of this study, and as such there is considerable latitude in the choices of equipment. In general, sampling equipment employed has been chosen because of its ready availability (previously owned equipment or borrowed from other institutions) and applicability to the sampling employed.

FIELD EQUIPMENT

Flux Chamber

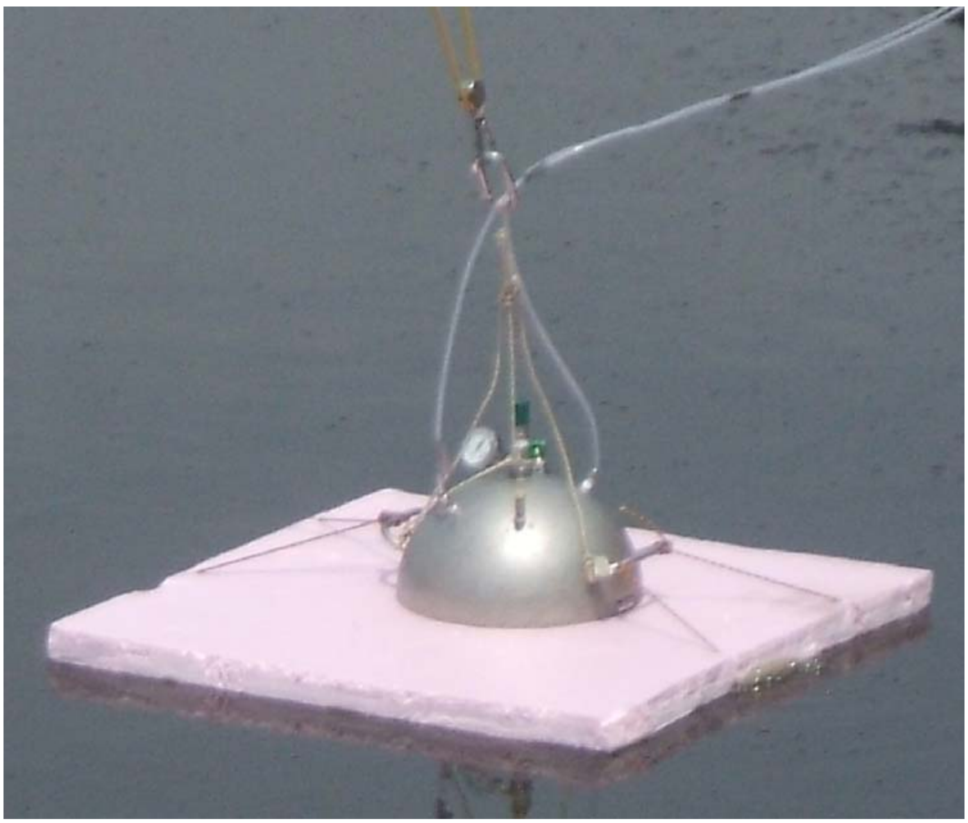

Figure A
Flux Chamber

The flux chamber is a device intended to obtain samples of gases generated by a surface. The particular chamber employed by the DNR is a stainless steel dome about a foot in diameter, with fittings to attach sweep air and a sampling line. Clean air is introduced to the chamber through the sweep air port, and samples collected off the sampling line. The equipment was designed for use with solid surfaces loose enough to dig the rim into. A draw back of this system with a liquid surface is that not all of the air introduced through the sweep air line is returned through the sampling line; there are significant losses through leaking out the bottom of the chamber and possibly aerating the surface of the manure.

Jerome Hydrogen Sulfide Meter

Figure B
Jerome Hydrogen Sulfide Meter

Real time measurements of hydrogen sulfide are made using a Jerome Hydrogen Sulfide meter. This portable instrument provides near instantaneous measurements of the gas, and is used in surveys around the property that are intended to help locate high concentration locations for samplers and to provide some information which can be used to help validate the time weighted average samples. The principle of operation involves measuring electrical potential across a gold foil, which changes as the quantity of hydrogen sulfide that it encounters changes. Display indicates hydrogen sulfide concentration in ppm, with a range from 0.001 – 50 ppm.

Nasal Ranger™

Figure C
Using a Nasal Ranger™ and GPS Unit to Take an Odor Measurement in the Field

The Nasal Ranger™ is a field olfactometer developed by St. Croix Sensory of Lake Elmo, Minnesota. An olfactometer is a device used to quantify ambient odors using the human olfactory (nose and sinuses) as the detector. Figure C shows a Nasal Ranger™ in use in the field. It functions by filtering ambient air through activated carbon filters to provide a "zero-odor" baseline and clearing the operator's sinuses. Once initialized, the operator then introduces incremental amounts of unfiltered air by rotating a dial with calibrated openings. As the opening sizes increase, a greater percentage of unfiltered air is blended with the filtered air stream. The point at which the odor is first detected is then a direct function of the odor's intensity. The openings are sized to provide dilution ratios of 60:1, 30:1, 15:1, 7:1, 4:1, and 2:1. The units of measurement are expressed as "Dilution-to-Threshold" (D/T). Logically, a strong odor is detectable even in very dilute form and will register a high D/T. Likewise, a weak odor will not be detectable until it is in a more concentrated form and will register a low D/T. The Nasal Ranger™ is also equipped with an electronic flow meter to assure that all operators are "sniffing" in a consistent manner.

The science of measuring odors is complex. For example, odors from agricultural operations result from a combination of over 200 individual compounds. Everything from ammonia and hydrogen sulfide to butyric acid and methyl mercaptan contribute to the overall tone and intensity of "country air". To empirically classify any given odor would require an accurate measurement of all 200 plus compounds simultaneously – a monumental task. Fortunately (or at times unfortunately) the human olfactory can detect upwards of 10,000 different compounds, and all their synergistic interactions. By taking advantage of this amazing detector, and calibrating it, the Nasal Ranger^{TM} provides as accurate a means of quantifying odors in the field as is currently practicable. According to product literature, when used by trained staff the Nasal Ranger^{TM} provides results with +/- 10% accuracy and +/- 2% repeatability.

For the above reasons, the Nasal Ranger^{TM} was chosen to take field odor measurements for this study. Because our primary interest was in collecting before-and-after data sets, we needed a device that could provide us with valid comparative results. To further assure this validity we used the same operator for the before and after sampling on any given farm. All the operators were trained and certified in the proper use of the Nasal Ranger^{TM}. Each operator was also tested for odor sensitivity periodically throughout the study. A sample odor sensitivity test data sheet is provided in Appendix B.

Solar Powered Meteorological Station

Meteorological information is collected using a portable solar powered met station on loan from the University of Minnesota. The met sensors are mounted on a 6 – 8 foot tripod, which is set up at a prominent point around the lagoons upon arrival at the site. Parameters include wind speed and direction, ambient temperature, relative humidity and solar radiation. Data is recorded on a fifteen-minute average basis.

Figure D
Solar Powered Meteorological Station

Weather Shelters, Timers and other

The sampling pumps employed in this study are intended for industrial hygiene sampling, the majority of which occurs indoors and is attended throughout. As such, they came without provisions for protection from weather or power outages. During the first few sampling trips for this study, it became apparent that protection from weather and a means for measuring how long samplers ran before the batteries expired would be needed. For the majority of the project, samplers had been equipped with run-time meters and housed in plastic weather shelters constructed for this purpose. Most often a single shelter contained a pump with a splitter, allowing the collection of both a hydrogen sulfide and an ammonia sample.

Figure E
Sampling Equipment Weather Shelter

SAMPLING METHODS & TESTING PROTOCOLS

FIELD METHODS

Hydrogen sulfide and ammonia samples are collected using modified Occupational Safety and Health Organization (OSHA) methods. The basic methods involve sampling air by drawing it at a measured rate through adsorbent tubes, which are then submitted to the Wisconsin Occupational Health Laboratory in Madison for analysis. Most samples are collected at a flow rate of about 0.5 liters per minute, for between 6 and 14 hours. As such, they represent time weighted average concentrations at each of the sampler locations.

Hydrogen sulfide is collected on charcoal tubes, desorbed using peroxide, which oxidizes the sulfide to sulfate, and then measured using ion chromatography. The adsorption onto the charcoal is a physical process, and can be reversed under adverse conditions. These conditions can potentially include high humidity and heat.

Ammonia is collected onto carbon beads, which have been treated with sulfuric acid. The ammonia reacts with the sulfuric acid to form a chemical bond on the tube, which is then reversed in the lab. The resulting solution is then measured using ion chromatography. The chemical nature of the absorption makes these samples more stable to external conditions than the hydrogen sulfide samples.

LABORATORY METHODS

Manure samples were collected and shipped for analysis by AgSource Cooperative Services.[2]

SAMPLE CHAIN OF CUSTODY

Sample records are maintained on a chain of custody form, which documents all pertinent field data necessary, to determine sample validity and calculate air volume sampled. Following sample collection, all samples are sealed with end caps, placed in a sealed plastic bag with all other samples of the same type, and stored in a cooler until submission to the laboratory. Samples are usually submitted within 24 hours of collection.

ODOR STUDY METHODS

The approach taken to evaluate odors downwind of each of the practices studied was to stand adjacent to the practice and set a waypoint on a hand-held GPS unit. Then using that point as a reference, the tester walked downwind from the practice a distance of 1,000 feet. Another waypoint was set and the tester took the first of six Nasal Ranger™ odor readings, after first "zeroing" his olfactory by breathing 100% filtered air for two minutes. The tester then proceeded back toward the practice setting additional waypoints and taking additional readings every 200 feet, the last of which was back at the downwind edge of the practice. If the wind shifted during a sample run, the tester would move laterally until he was back within the odor plume. Weather permitting, four separate runs were made on each visit to a farm, representing early AM, AM, PM, and late PM time frames. This was done in an attempt to learn how changes in weather conditions throughout the day affect odor transport and dissipation.

The Nasal Ranger™ odor readings ranged from a low of 2 to a high of 60 in the following sequence: 2, 4, 7, 15, 30, and 60. Each reading represents an approximate doubling in odor intensity from the reading before it, creating a logarithmic scale. If no odors were detected, a reading of <2 was recorded. And at times the odors may have been so intense that they would have exceeded 60, however that was the highest reading available on the Nasal Ranger™ units being used in this study. A notation was made if odors other than manure were detected, such as feed, freestall, cut hay, etc. No attempt was made to characterize the manure odors, as this would have increased the subjectivity of the data. If lagoon odors were detected they were simply noted as such, along with the Nasal Ranger™ reading at that location.

To aid in the analysis of the odor data, as well as to better display the data for this report, aerial photos of the farms were used with the GPS odor sampling waypoints and the associated odor

[2] Upon Request, AgSource will provide a copy of their laboratory methods reference document, Recommended methods of manure analysis A3769.pdf. Contact AgSource at: http://agsource.crinet.com/

readings superimposed on them using ArcMap software. The four odor runs were depicted using four different colors, and the size of each color dot was scaled relative to the odor reading at that location (see the Project Data Supplement for Nasal Ranger™ data display graphics). This provided us with a "snapshot" of the odor conditions on each farm during each visit. By comparing the before and after figures for each practice, a fairly clear picture emerged of the overall effect that the practice had on odor.

In addition to the visual representation of the odor readings, some numerical analyses were conducted as well. For this, the odor readings for each distance from a practice were averaged across all runs, both prior to a practice being installed, and after. By comparing these averaged values, an estimate of the percent change in odor levels was determined. These numerical results were then depicted on graphs to help illustrate the changes in odor levels each practice provided. It must be cautioned that the data collected for this study was very limited, and as such should be used with caution. The results may not be typical when extrapolated to other farms.

In an effort to characterize odor emission rates, as well as to verify our Nasal Ranger™ findings, a flux chamber was used to sample the gasses being released by a one square foot area of the lagoon surface (see the Field Equipment section of this report for details on the flux chamber). The samples thus collected were sealed in Tedlar bags and shipped overnight to a lab at the University of Minnesota. The next morning a panel of trained experts would rate the odor intensity of each sample using a laboratory olfactometer per CEN Standard 13725.2003. This provided a more controlled procedure than what was possible using a field olfactometer. The findings from these flux chamber samples are described in each of the case studies below.

The final piece of odor-related information, which was gathered during each trip, was to collect manure samples from each farm. These were taken from the lagoons being studied, and occasionally from manure reception pits as well. These samples were packed on ice and shipped overnight to a lab for testing. The lab ran a standardized set of manure analysis on each sample, including solids content, pH, nutrient levels, COD, and volatile fatty acids. These data were collected in an attempt to identify which characteristics of manure contribute most to its rate of odor generation, as well as to see how the installed practices may affect the manure make-up. The result of this testing is described in the case studies below, whenever relevant.

DATA ANALYTICAL METHODS

DATA PRESENTATION

Meaningful representation of the data collected during this project proved to be challenging. Not only are the numeric concentration results important, but the spatial distribution of the samples and the wind conditions as well. Intercomparison between the different sampling episodes is essential. All of these elements are combined into a visual form using ArcMap to plot the sample points, with the results presented both as bar graphs associated with the points and as numeric values in a table.

Incorporating the wind rose directly into the figure enhances further data interpretation. A wind rose indicates the wind speed and direction during the sampling period. The color of the wind rose bars indicates the speed of the wind, while the direction the bars point towards indicate the direction from where the wind was blowing. The length of the bar is measured against circular lines labeled with percentage values, which indicate what percentage of the time winds were blowing from that direction.

Note that sample location numbers are compiled from all sampling runs. Prevailing winds at the time of setup and number of functioning pumps, as well as other factors may affect the placement of sampling locations, so that not all locations are used in any single run. Many of them are used only in a single run.

Almost all bar graphs are scaled to the same values, so that sampling runs can be directly compared with each other visually. The single exception to this are the results obtained around the Manitowoc County Sand Channel (Case Study 6.1), which were significantly higher than those observed elsewhere.

DATA COMPARISONS

Direct quantitative comparisons between the different farms are not really possible with our data. This is in part because of the relatively few trips made to each farm throughout the project (we do not know whether or not we sampled during "typical" conditions at any particular facility). In addition, our data generally shows variations between trips to the same farm that are as great as the variations we observe between farms, thereby raising the question of whether the differences we see are actually the result of different management practices, or part of the natural variability associated with large area pollutant sources. We did not collect a statistically significant quantity of data from any single farm, much less from the whole spectrum of farms included in the project.

There is a natural tendency to want to compare results from the different farms, however. A couple of methods have been employed to attempt comparison. The first of these is through the manure surface sampling. Under ideal circumstances, this sampling is theoretically representative of concentrations at the manure/air interface. It should be noted, however, that there are significant physical challenges to obtaining valid samples using these techniques. For example, sweep air could frequently be seen bubbling out of from underneath the flux chamber, raising the question of whether or not the air being sampled was truly representative of the air at the surface.

In spite of these difficulties, the assumption that our manure surface samples are generally comparable has been made with the idea that the various challenges for collecting the samples would be comparable between the different sites. As such, charts and tables comparing the surface sample results from the different farms have been included in the Discussion and Lessons Learned section following the case studies.

Comparisons between the ambient samples collected around the manure lagoons and sand channels are somewhat more difficult to accomplish. Given the approach to sampling we adopted, a percentage of samples at any site are going to contain non-detectable quantities of ammonia and hydrogen sulfide. How many of the samples deployed yield non-detects is going to vary not only on the emissions of the facility being tested, but on the basis of wind direction and speed as well as a host of other factors not well understood.

Likewise, the magnitude of any detected quantities of these compounds is going to be dependent on a variety of factors beyond the variables we are attempting to test for (i.e., the management practices). The relative paucity of data we collected essentially ensures that we will observe as great or greater variability between visits to a single farm than we do between farms, thus greatly complicating interpretation and comparison of our data.

However, comparison of data between sampling visits and farms is desirable, even with these caveats, and as such an approach has been adopted wherein concentrations observed on the downwind side of the lagoons are compiled for comparison between runs. In general, the highest three concentrations observed are used for the comparison purposes.

These values are reported in tables and figures, with the maximum, minimum and average values shown for each individual run, for the overall data set, and for all daytime and all nighttime samples. Intra-farm comparisons between runs and before and after installation of practices are included with the case studies, while inter-farm comparisons are included with the Discussion and Lessons Learned section following the case studies.

DISCRETE SAMPLE DATA MANAGEMENT AND BASIC CALCULATIONS

All field samples collected for ammonia and hydrogen sulfide require a number of parameters to be recorded. These include a unique identifying sample number, start and stop times, start and stop flow rates, and location for field data, and the amount of analyte collected and whether or not this amount represents a detect for the lab data.

All data collected for these samples is maintained in an Access database, set up with a number of built in calculations to facilitate data analysis. The basic concentration observed is calculated using the following equations:

Elapsed Time (in minutes) = (Stop Time) – (Start Time) OR
(Elapsed Timer End) – (Elapsed Timer Start)

Note: Clock start and stop times are preferred. Elapsed timer values are used in cases where the batteries died during the run and no observed stop time was recorded.

Average Sampling Rate (in Liters/Minute) = ((Start Rate) + (Stop Rate)) / 2

Sample Volume (in m^3) = ((Elapsed time) X (Average Sampling Rate)) / 1,000

Note: The factor of 1,000 is to convert liters to cubic meters (m^3).

Concentration ($\mu g/m^3$) = (Lab Result) / (Sample Volume)

Note: Lab Result is the reported lab value in µg/sample.

The resulting concentration values are used in further evaluation by incorporating them into site maps showing bar graphs representing the results obtained at each location. These representations generate a visual aid to interpreting the results.

TREATMENT OF LOD AND LOQ SAMPLES

A common misperception about analytical results such as are reported here is that a number reported as a result represents reality in the way that one can count ten apples in a basket and say there are ten apples. Trace analysis doesn't really work this way. Results reported represent the most probable value obtained at a particular time and place, given the constraints of the methods used to collect the values. Each phase of the sampling and analysis provide potential sources of error to the overall determination.

Many samples, however, can be treated in the short hand as if the chemical of interest was counted like the apples. This is because limits of error associated with the analysis are established and within the acceptable parameters defined by the standard methods in use, and because it is simpler to consider the results at face value.

There are two important statistically determined values called the Limit of Detection (LOD) and the Limit of Quantitation (LOQ). The LOD is the lowest amount of the compound of interest that can be clearly distinguished from the analytical background. A non-detect means the observed concentration was less than the statistically determined LOD, not that there was none of the compound of interest present.

The LOQ is the lowest amount of analyte that can be definitely quantified, and is conventionally set at three times the LOD. Results between the LOD and LOQ are technically considered estimates, with less assurance that the values are “correct” as reported than for results above the LOQ. In a sense, any result obtained in this range could actually be any concentration within the range, with approximately equal probability.

Ideally, all results obtained from a test of this nature would be above the LOQ, thereby removing any difficulty arising from evaluating values with less confidence. However, samples with either non-detectable or barely detectable results are obtained, and evaluation of these results is necessary.

The problem of incorporating non-detects into a numerical data set is one with several answers. One approach is to simply disregard non-detected values entirely. This approach has the advantage of averaging only clearly determined values. The problem with this method is that the information provided by the presence of non-detect samples is lost, and resulting averages generated may be artificially high.

Pretending that the non-detects represent samples where there was none of the analyte present, and setting the value of such samples at zero is another option, but this approach doesn’t necessarily reflect reality very well either. The most that can be said about non-detects is that ambient concentrations are less than the detection limit. This particular study has generated a relatively large number of non-detects, in part because samplers have been deployed on both the upwind and downwind sides of the lagoons, both in an effort to determine how much of each compound has been added to the atmosphere by passing over the lagoon, and to compensate for potential changes in wind direction during the sampling period.

Because we are not interested in averaging all samples together to determine an overall average concentration, but rather are interested in the amount added by passage across the lagoons, non-detects are incorporated into the dataset as if they were zero, to provide a maximum added value when evaluating the data. The rate of detection (number of detects / number of samples) provides an additional, qualitative method with which to compare the different operations.

Similarly, there are different approaches to rationally incorporating results obtained between the LOD and LOQ. For simplicity’s sake, these values are treated in the same way as values above the LOQ, in other words, as if they represent the most probable concentration during the sampling period. The variable rate of samples exceeding the LOQ at the different sites provides an additional tool for comparing results.

DATA QUALITY ANALYSIS, BLANK SAMPLES

The collection of blank and duplicate samples for quality control purposes was an integral portion of the project. Blanks are samples prepared as though they were ambient samples, except that they are packaged without sampling. They provide a measure of potential contamination encountered by the sampling media during the setup process, and thus are an indicator of potential problems. If material is detected in the blank, the laboratory will usually use the field blank value to correct the ambient samples associated with it.

The table below summarizes all blanks submitted during this project. In general, two blanks for each parameter were submitted for each sampling trip. The preferred result for a blank is a non-detect. This table shows the number of blanks collected (approximately 5% of all samples), how many of the blanks had detectable quantities of material on them and what percentage of the total that represents. The maximum detected value in micrograms is shown, and for hydrogen sulfide, the average of all detected quantities, the number of results greater than 10 µg, and the average excluding the maximum value.

Note that the maximum value returned for hydrogen sulfide was associated with an alternate sampling media supplier, which was used for only a few samples, and is therefore not indicative of general sampling. That a significant percentage of the H_2S blanks returned detectable results is not particularly surprising, because the charcoal used as an absorbent contains a small amount of sulfur naturally. When the maximum value is excluded, the average blank value is less than two times the detectable limit (4.0 µg), which is reasonable for this method.

The ammonia sampling tubes were generally clean, with the single detect only slightly above the detection limit of 7 µg.

	Total Blanks	Detects	% Detect	Max (µg)	Avg (det)	>10	Avg (det, - max)
H2S	54	20	37.0%	69	9.6	1	6.5
NH3	54	1	1.9%	8.3			

Table C
Blank Sample Results

DATA QUALITY ANALYSIS, DUPLICATE SAMPLES

Duplicate sampling is collecting two samples for the same parameter side by side for the purpose of comparing the results to determine an overall sampling precision. Not all duplicate collection efforts are successful; one or both of the pumps for the samples may fail during sampling, or some other mishap may affect the process. Because of this, not all sampling runs have a successful duplicate sampling pair associated with them.

The pertinent quality parameter is the relative percent difference (RPD), which is the difference between the samples divided by the average of the results expressed as a percent. Ideally, this type of sampling should generate RPDs of less than 30%.

RPD can only be calculated if both samples have detectable results. In cases where one or both samples return non-detects, the duplicates are considered to either qualitative agree or disagree. Duplicate samples showing qualitative agreement are considered to have passed, but they are not included in the RPD calculation.

Results for successfully sampled duplicates are shown in the table below. The table shows the number of duplicate pairs analyzed, how many are in Qualitative Agreement (QA) or Disagreement (QD); how many pass or fail the numeric criteria (RPD < 30%), and then what the average, maximum and minimum RPDs are far each parameter. In addition, the percentage of duplicate pairs that are in each category (QA, QD, Pass or Fail) is shown.

This analysis shows that when our duplicate sampling efforts were successful in the field (both samples submitted to the laboratory), the sample pairs passed quality assurance criteria 82% of the time for H_2S (QA plus Pass) and 75% of the time for NH_3. The overall RPDs of 25.0% and 28.2%, respectively, are within sampling criteria as well.

While a zero fail rate for these efforts would be preferable, these results are not entirely unexpected given the difficult nature of the sampling conditions. Specific tests wherein individual duplicate sampling pairs were outside of quality limits are noted during discussion of their results.

	Pairs	QA	QD	Pass	Fail	RPD	Max RPD	Min RPD
H2S	48	18	2	21	8	25.1%	144.3%	0.0%
		39%	4%	43%	15%			
NH3	54	3	4	37	10	28.2%	180.5%	2.0%
		6%	6%	69%	19%			

Table D
Duplicate Sample Results

METEOROLOGICAL DATA MANAGEMENT

All meteorological parameters are collected on a data logger and downloaded to the central project database. The wind data is used to help decipher sampling results by enabling a determination of whether a particular sampling location was upwind or downwind of the different potential sources. Rather than averaging all wind data to generate a vector mean average wind speed and direction, each individual 15 minute average set of values is used to generate a wind rose using a freeware program developed by Lakes Environmental, known as WRPlot.

Each individual sample run has a unique wind rose containing all 15-minute data points from the inception of sampling to the collection of the final sampler. The wind roses generated from this data are included on the site map results representations to improve the effectiveness of the display.

RESULTS

The Project Team proved successful at enlisting the participation of six farms in the study. While each of the case study farms is unique, and each of the six cases is focused on odors emanating from a manure lagoon, two of these farms also used sand channels as part of their manure management system. Field data measurement and analysis indicated that the presence of sand channels impacted data collection and results sufficiently to justify an extended analysis and a separate, additional write up to discuss sand channels and their potential role as sources of odors from dairies.

CASE STUDIES: SIX PARTICIPATING FARMS

OVERVIEW

The six farms used in this study were selected based on their size and animal type, which made them representative of Wisconsin farms, and their layouts, which made them good candidates for air monitoring. These farms ranged in size from 400 to over 2,500 head of cattle. Five of the farms were freestall dairies and one was an open feedlot heifer raising operation. Odor control practices were installed on four of the farms and two were used for baseline data collection.

This study centered around four odor control practices. These were:

1. Anaerobic digestion
2. Impermeable cover on waste storage
3. Permeable cover on waste storage
4. Solids separation and aeration

Due to the time required to construct an anaerobic digester, it was not possible to conduct a before-and-after study on one farm within the length of the project. Therefore, two similar farms were selected, one with a digester already installed, and the other without. The Manitowoc County farm was the baseline “before” farm, and the Waupaca County farm was the “after” farm. Three sampling trips were made to each of these farms throughout the study.

The impermeable high-density polyethylene cover was installed on the Dunn County farm. Three trips were made prior to cover installation, and two trips were made once the cover was installed.

The permeable geotextile cover was installed on the Kewanee County farm. Three sampling trips were made prior to cover installation, and three trips were made the first year after the cover was in place, and two the second.

The solids separation/aeration system was installed at the Monroe County farm. Although some of the equipment was already in place early in the study, two of the trips were made before the system was operational, and two trips were made each year for two years after all equipment was installed and running.

No practices were installed at the Clark County farm. This was an open feedlot heifer operation that served to provide baseline data only. The initial plan was to install control practices to reduce ambient air concentrations of NH_3 and H_2S, however sampling during the two “before” trips detected negligible levels of these gases. Therefore, this site was a poor candidate for testing control practices.

GENERAL CASE STUDY FORMAT

Data from each case study is examined in detail in the following sections. The basic format of the examination provides a general background explanation of the farm and what the testing was intended to measure, followed by a discussion of the results. Results are presented visually in graphics, some of which are contained within the Project Data Supplement. This material is provided separately so that those who wish may refer to both documents at the same time, without having to turn pages back and forth to examine figures discussed in the text.

Each of the discussion sections is divided into a General Sampling Overview which provides an outline of sampling which occurred on the facility; a section on Ambient Sampling, wherein the results of most samples are discussed; and a section on Manure Surface Sampling, which presents the results of flux chamber sampling on the lagoon surfaces. The final section pertaining to the ammonia and hydrogen sulfide sampling from each case study is a summary of key findings, where any conclusions that we can draw from our data are presented.

It should be noted that the majority of the discussion regarding ammonia and hydrogen sulfide results is based on the time integrated samples collected at the site. The readings collected on a real-time basis for hydrogen sulfide using the Jerome meter are only brought into the discussion when they help clarify results of the ambient sampling. The survey results are not comprehensively reported herein.

Discussion of the odor sampling and analysis is included following each key findings summary, in the Project Focus Key Comparison sections. Comparisons between odor on different farms are made in these sections.

One of the goals of this study was to ground-truth the odor standard contained in the Livestock Facility Siting rule (ATCP 51). Farms that are applying for a Siting permit within Wisconsin must comply with the odor standard, if they are expanding beyond 1,000 animal units, or building new facilities for over 500 animal units. To comply, they must show that their planned facility is not predicted to create unacceptable odor levels for their nearest neighbor. Filling out the odor score worksheet (or an electronic spreadsheet) provides them with their predicted odor score. A farm must achieve an odor score of 500 or more to pass. An analysis of how the Nasal Ranger™ field data compared to the calculated odor score for the control practices being demonstrated is included in each of the six case studies.

Following the case studies is a comparison section wherein the chemical data that can be compared is discussed. It should be noted that not all of our data is readily comparable between the different facilities, and that extreme variations encountered between trips to the same farm lead to a situation where often the magnitude of variation within a farm is greater than the difference between farms. This situation greatly reduces confidence that we can distinguish between the different farms and the manure management practices employed on them.

PROJECT FOCUS: SIX CASE STUDIES OF LAGOON/PIT ODOR CONTROL MEASURES

Case Study 1: Anaerobic Digester (Waupaca County)

Background

The Waupaca County farm was our digester test site. It was a large modern dairy built adjacent to an older existing operation. The separation between the two operations, and the open, flat terrain in the area, made it possible to isolate the new operation for our study (see Figure 1.0).

Figure 1.0
Waupaca County Farm Layout

At the start of our study 1,540 cows were being housed in the new freestall barns. All manure and wastewater was being sent to a 22 million gallon HDPE lined storage lagoon after passing through a below-grade anaerobic digester. Gasses from the digester were being used to fuel a 270 kW generator set. The electricity produced was used on farm, with excess capacity being sold back to the local utility. Digested solids were dewatered using FAN separators and stockpiled for use as bedding material in the freestall barns, at a great savings over purchased bedding. The freestall barns were manually scraped three times each day. The wastes flowed by gravity through cross channels to a reception tank, where they were then pumped to the digester inlet.

At the conclusion of our study 310 more cows had been added to the operation, for a total of 1,850 cows being housed and milked. A new freestall barn had been constructed for these additional animals, and plans were underway to build up to two more. Other than this change, however, the basic layout and operation of the farm remained the same throughout our study.

Case Study 1 Results Discussion

General Sampling Overview

A total of three sampling runs have been conducted at the Waupaca County site. A total of 112 samples for each of NH_3 and H_2S have been collected, with 100 and 101 respectively being submitted to the lab for analysis. The invalid samples are evenly distributed between the sampling trips, and no single run experienced sufficient sample loss to invalidate it. Standard sampling protocols have been followed for all tests conducted at this site.

A summary of the test dates and general conditions is shown in the following table. Parameters include the testing start date and the vector mean wind speed, wind direction and temperature (in degrees Celsius) for both the daytime (AM) and nighttime (PM) sampling runs. Note that the test continued to the day following the test date.

Date	AM			PM		
	VMWS	VMWD	T(C)	VMWS	VMWD	T(C)
06/06/2007	11.0	200	18.0	9.0	170	17.1
08/13/2007	4.0	160	26.7	7.6	220	19.4
09/04/2007	8.1	220	29.5	3.8	210	21.2

Table 1.0
Waupaca County Test Dates and Basic Meteorology

This site proved to be ideal for comparison between digested and undigested manure storage pits. Unfortunately, it was not until late in the second run that the existence of the undigested manure pit was recognized, so samples were only collected around it during the third and final run. No additional manure surface sampling was conducted on this pit.

Several non-lagoon samples were collected at this facility, including an upwind/downwind series of samples were collected around the barns when they were upwind of the main lagoon; an upwind sample on the fenceline during the second run and a sample collected downwind of the feed area during the third run. The final location was sampled because feed was being harvested and added to storage during sampling. All samples from the latter two locations were non-detects. The samples collected around the barns are discussed with the ambient results following.

Only four successful duplicate pairs were collected at Waupaca (two of both H_2S and NH_3 pairs). All sampling pairs passed quality criteria. One of the H_2S duplicate samples showed qualitative agreement, while the other yielded identical results (RPD of 0.0%). The average RPD of the NH_3 samples is 7.2%, well within quality criteria.

Two blanks collected show detectable quantities of H_2S, with an average of 4.8 µg/sample. The blank levels were subtracted from the results reported by the lab. All other blanks contained non-detectable levels of the parameters.

Ambient Sampling

Figures showing the results described herein are located in the Project Data Supplement in chronological sequence.

Concentrations around the main pit (digested manure) during our sampling visits showed significantly elevated ammonia concentrations on the downwind side. On two out of the three trips, a significant number of samples yielded results in excess of 1,000 micrograms per cubic meter ($\mu g/m^3$) for this compound. Ammonia concentrations around the smaller, undigested manure pit were generally similar to those around the main pit during that sampling visit, although the highest concentration observed during the entire study was obtained on the downwind side during the overnight sample.

Hydrogen sulfide levels around the main lagoon, however, were frequently undetectable. Of a total of 65 samples collected around this lagoon, 37 were non-detects, and only two showed concentrations in excess of 150 $\mu g/m^3$. With the low levels observed, no day/night pattern was discernable with results from this pit. Results for both parameters tended to show widespread elevation on the downwind side of the pit, indicating that there probably were no significant localized hotspots.

In contrast, the results around the smaller, undigested manure pit yielded a definite day/night difference in hydrogen sulfide concentrations. Levels during the day are comparable to those obtained around the main pit during that day, but the night time downwind samples are elevated by about a factor of five on the smaller pit. This hints at the possibility of the same type of day/night pattern observed with the hydrogen sulfide concentrations at the Manitowoc County farm.

Whether the limited observations comparing the digested and undigested manures represent a true difference, or is the result of variability in our sampling is unknowable based on our data set. It seems significant, however, that the undigested lagoon, with its smaller surface area, was able to generate higher concentrations around it than the larger, digested manure lagoon.

The tables following summarize the top three observed concentrations on the downwind side of the lagoons. Reported parameters include the average, maximum and minimum values, as well as the relative standard deviation (RSD), a measure of the variability of our results. In addition to a summary for each sampling period, the tables for the digested manure lagoon show an overall summary of results, as well as a day and night sample comparison. The small undigested manure results are not summarized, as only the single day/night series of samples was collected. Note that the larger variability in the results from the smaller lagoon is a direct result of the limited number of samples collected around it (the three most concentrated samples were not always directly downwind).

	Run 1	Run 1e	Run 2	Run 2e	Run 3	Run 3e	Overall	Day	Night
Average	760	633	1557	737	2085	1843	1269	1467	1071
Max	913	720	2205	801	2293	2233	2293	2293	2233
Min	587	518	994	683	1860	1485	518	587	518
RSD	21.6%	16.4%	39.2%	8.2%	10.4%	20.4%	51.6%	45.5%	57.3%

Table 1.1
Downwind Ammonia Concentrations Near the Digested Manure Pit

	Run 1	Run 1e	Run 2	Run 2e	Run 3	Run 3e	Overall	Day	Night
Average				120	162	115	111	117	106
Max	63	37	36	126	262	206	262	262	206
Min	ND	ND	ND	111	93	54	36	36	37
RSD				6.6%	54.6%	70.4%	61.2%	75.3%	52.9%

Table 1.2
Downwind Hydrogen Sulfide Concentrations Near the Digested Manure Pit

NH3	Run 3	Run 3e	H2S	Run 3	Run 3e
Average	1186	1614	**Average**	165	495
Max	1606	3070	**Max**	207	1129
Min	902	384	**Min**	119	50
RSD	31.3%	84.0%	**RSD**	26.6%	114.0%

Table 1.3
Downwind Concentrations Near the Un-digested Manure Pit

The figures on the following pages represent this data in max/min charts. The value (Y) axis is in micrograms per cubic meter. The scale for the ammonia results has been equalized for the larger and smaller lagoons; however, the hydrogen sulfide values vary too significantly and have separate scaling values. Note that the variation between the test runs is significant enough that no statistically significant patterns are clear.

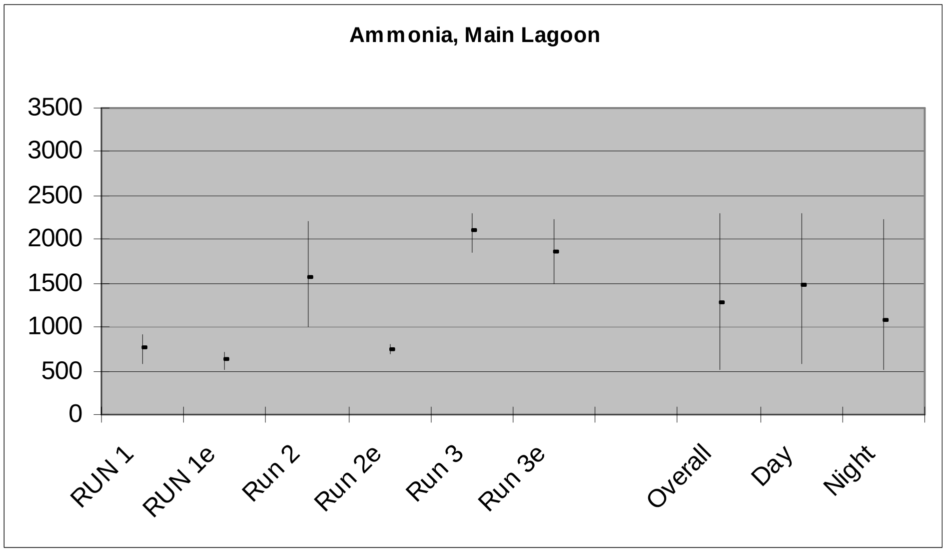

Figure 1.1
Ammonia, Main Lagoon (Waupaca County)

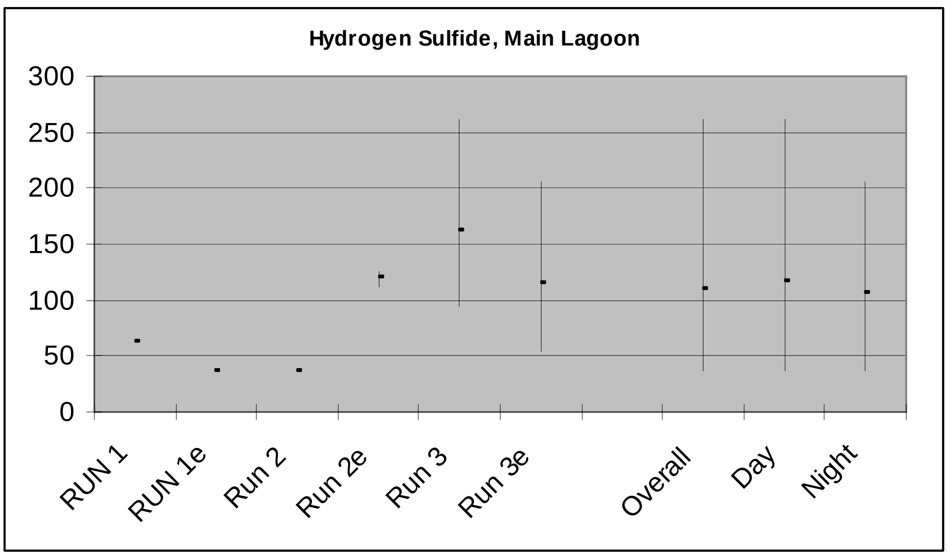

Figure 1.2
Hydrogen Sulfide, Main Lagoon (Waupaca County)

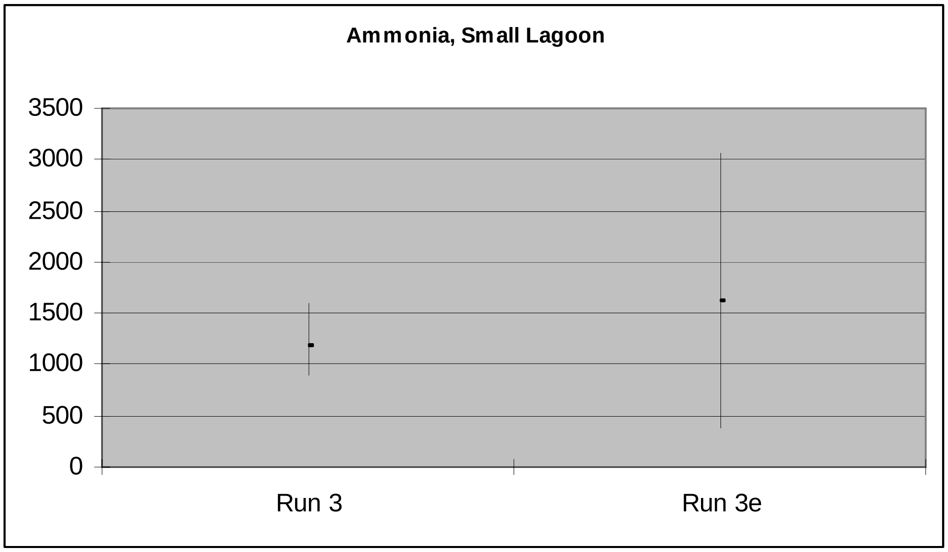

Figure 1.3
Ammonia, Small Lagoon (Waupaca County)

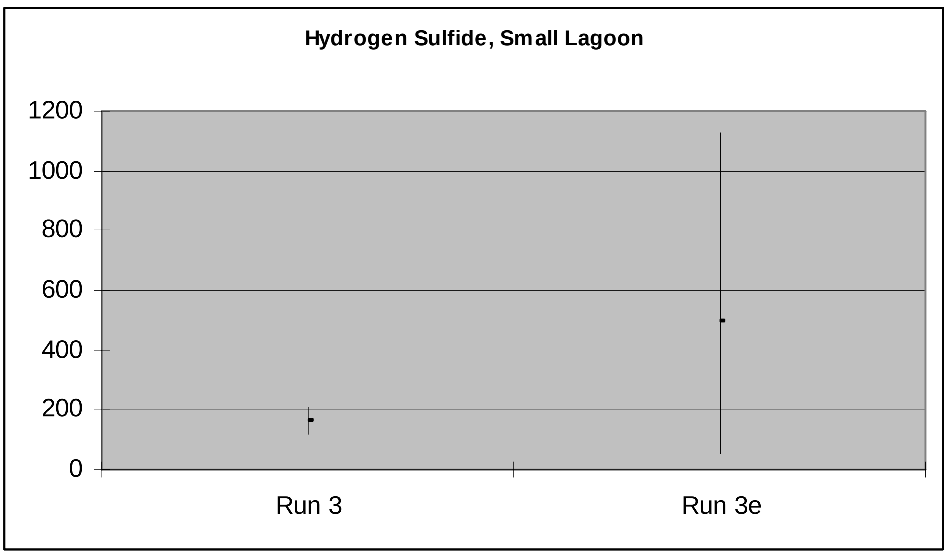

Figure 1.4
Hydrogen Sulfide, Small Lagoon (Waupaca County)

During the setup for the June 4, 2007 sampling run, the barns were directly upwind of the main lagoon, and so a series of barn oriented samples were collected to account for any potential influence they may have on the concentrations observed around the lagoon. Two upwind and two downwind locations were established and sampled during both the day and nighttime sampling periods. The downwind locations were about halfway between the barns and the lagoon edge.

All hydrogen sulfide samples, both upwind and downwind of the barns, were non-detects and are not further discussed. The ammonia results, however, clearly show the barns influencing downwind concentrations. Both day and night upwind samples are non-detects, but downwind concentrations range from 174 to 352 micrograms per cubic meter. Samples collected on the upwind side of the lagoon at the same time show concentrations elevated above background as well. These results clearly indicate that dairy housing is an ammonia source that can have downwind implications.

It should be noted that although this first series of barn oriented samples are the only successful ones collected from this facility, there are indications on other sampling days that the barns may have been impacting the upwind side of the lagoon. Locations 6 and 7 on the south side of the lagoon frequently show elevated ammonia concentrations, even though the winds during our sampling trips were generally from the south or southwest.

These results are documented in the following table. Results are expressed as micrograms per cubic meter.

Daytime			Nighttime		
Upwind	Downwind	Pitside	Upwind	Downwind	Pitside
ND	174	48	ND	308	70
	352	48		256	92

Table 1.4a
Ammonia Concentrations in Barn Oriented Samples, June 4, 2007

Manure Surface Sampling
Sampling was, unfortunately, conducted on the surface of the digested manure lagoon only. This facility would have been ideal for the comparison of undigested and digested manure storage. However, the fact that there was a second lagoon containing undigested manure was not apparent until late in the second sampling visit. Logistical difficulties during the third sampling trip made collecting extra samples from the small pit surface impractical.

The figures below display the results obtained from these tests. Concentration units are micrograms per cubic meter, presented on a logarithmic scale. Note that results from this site track well between visits, with relatively consistent results obtained throughout the study.

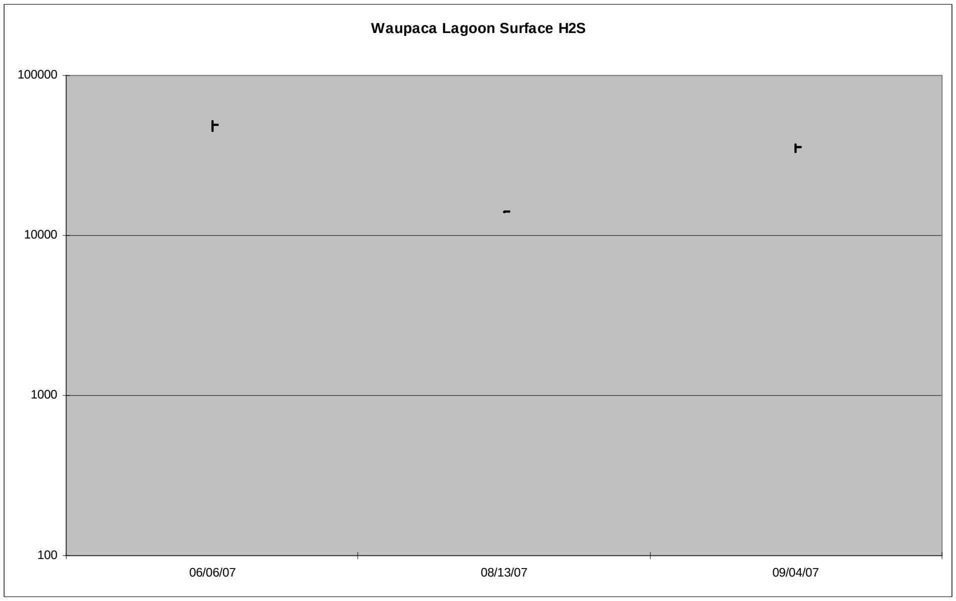

Figure 1.5
Lagoon Surface H_2S (Waupaca County)

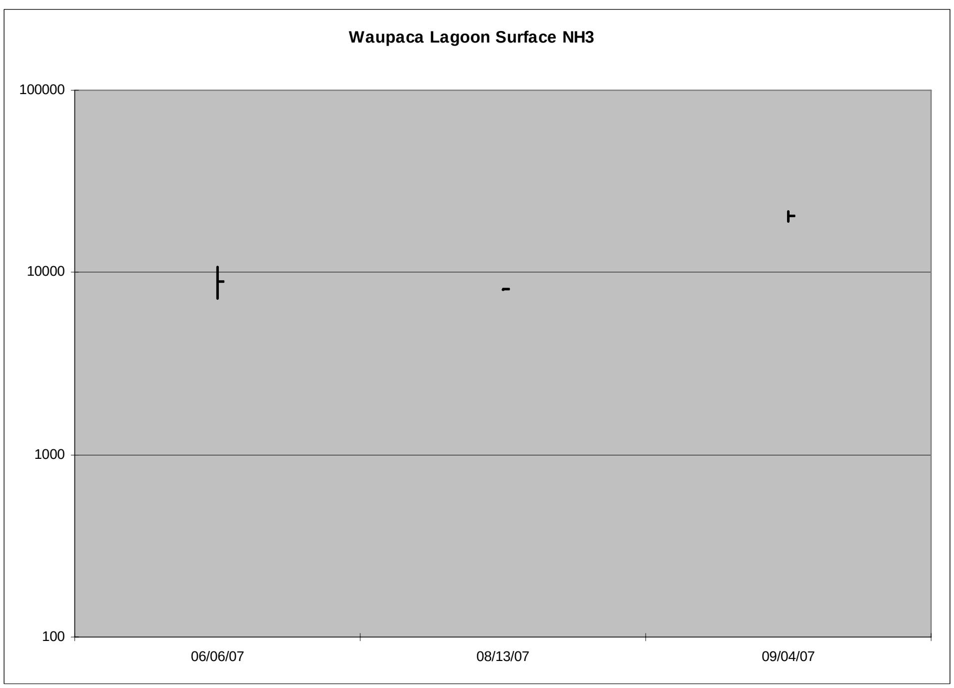

Figure 1.6
Lagoon Surface NH_3 (Waupaca County)

Case Study 1 Key Findings Summary Statements

Ammonia levels were observed to be more generally elevated than hydrogen sulfide around the digested manure lagoon at this facility. Elevated ammonia concentrations were more widespread and consistent than H_2S, and the maximum concentrations observed exceed the maximum H_2S significantly.

This situation was different around the smaller, undigested manure lagoon. The concentrations of ammonia and daytime H_2S observed around this pit were generally similar to those around the main pit, but the nighttime hydrogen sulfide concentrations were significantly elevated. The highest lagoon oriented ammonia concentration observed anywhere during this study was collected around the undigested manure pit at this facility.

The lagoon surface concentrations observed at this facility were generally consistent between visits. Whether this represents an actual consistency in surface conditions, or simply more consistent sampling technique is unknown.

Project Focus Key Comparison ~ Case Study 1: Anaerobic Digester (Waupaca County) vs. Case Study 6: Manure Storage Lagoon (Manitowoc County)

A key objective of this project is to assess whether process changes wrought on manure processed by anaerobic digestion can have a measurable impact on odors associated with manure in storage lagoons. The discussion that follows presents an analysis and comparison of our findings from the study of odors from a lagoon which is storing manure that has been processed through a mesophilic (low temperature) anaerobic digester, which is best compared to a lagoon storing undigested wastes, presented in more detail later in this report. See the Project Focus Case Study Comparison ~ Case Study 2 for discussion related to thermophilic digestion and manure storage.

The figures representing the odor transects conducted on the three trips to the Waupaca County farm (with digester) and to the Manitowoc County farm (no digester) are presented in the Project Data Supplement for each of the case studies.

Comparing these two sets of figures, it is difficult to conclude with any certainty that the lagoon containing digested manure generates any less odor than the lagoon containing undigested wastes. This is counter-intuitive, and yet seemed to be the case during all our trips.

Graphing the odor readings from these two lagoons, some reduction in odor appears to be provided by the digester, especially near the lagoon (see Figure 1.7). By averaging the results from each set of trips, this difference is about a 15% reduction in odors overall. Since the accuracy of data provided by the Nasal Ranger™ is typically +/-10%, this would not be considered a statically significant decrease. Note that the variability of the data, represented through the vertical bars in the following graph, shows considerable overlap at most of the distances tested.

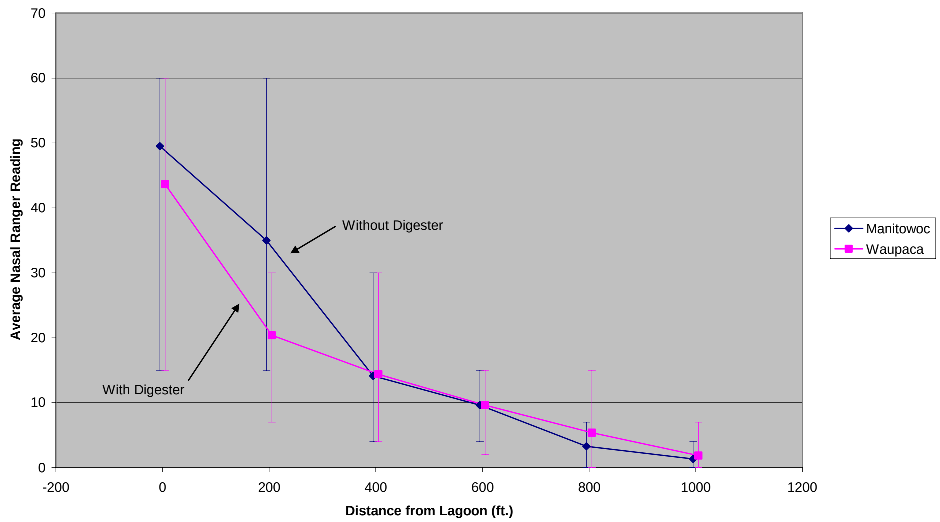

Figure 1.7
Average Nasal Ranger™ Reading at 200 ft Intervals
Mesophilic Digester Fed Lagoon (Waupaca County) vs.
Manure Storage Lagoon – No Digester (Manitowoc County)

An explanation for this might be that although a digester breaks down the organic compounds in manure, it does so only partially, based on residence time. The economically optimum throughput is higher than what would be needed for complete digestion. Also, the digester does nothing to the sulfur content of the manure, and actually shifts the nitrogen to a more highly volatile form. Lastly, because the digester operates under anaerobic conditions, the discharge from it can be quite odiferous.

The landowner recognized that odors continued to impact his neighbors after the installation of the digester, and being an innovative manager, he engineered a gas treatment system to address this. This system uses a blower to capture the fugitive emissions from the digester outlet and sends them to a tank where they are bubbled through water. This causes the H_2S to be absorbed by the water, forming a weak acid solution that is then combined with other wastes in the storage lagoon. Although fairly simple in design, this system is very effective at controlling gaseous emissions from the digester. He has made other modifications as well, such as installing a more reliable gas flare. These improvements are described in more detail later in the Lessons Learned section of this report.

The flux chamber tests from these two farms did not mirror our Nasal Ranger™ readings. Figure 1.8 below is a bar graph depicting the laboratory-determined odor intensities of our flux chamber samples. The first three bars are for samples taken from the control farm (no digester – Manitowoc County) and the last three are from the mesophilic digester farm (Waupaca County).

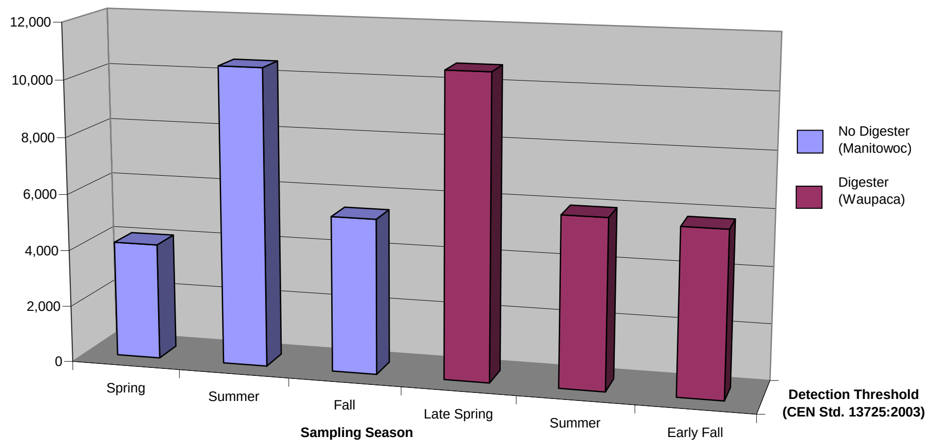

Figure 1.8
Flux Chamber Seasonal Average Detection Threshold
Mesophilic Digester Fed Lagoon (Waupaca County) vs.
Manure Storage Lagoon – No Digester (Manitowoc County)

These data indicate that odor generation rates are about the same, or perhaps slightly higher from the lagoon receiving digested manure than they are from the lagoon receiving undigested manure. Due to variables beyond the control of this study, these differences are probably not statistically significant. One of these variables is the inconsistency in surface conditions across the lagoons. At times the surface appeared very uniform and selecting a representative spot to sample was possible. At other times, areas of foam or floating solids created variable surface conditions, making a representative sample very difficult to obtain.

To further determine how a digester may influence odor from waste storage, we compared the volatile fatty acid (VFA) levels in the lagoons on these two farms. It has been well documented that VFAs can contribute significantly to the odors generated by stored manure. Figure 1.9 below depicts the findings of the VFA analyses.

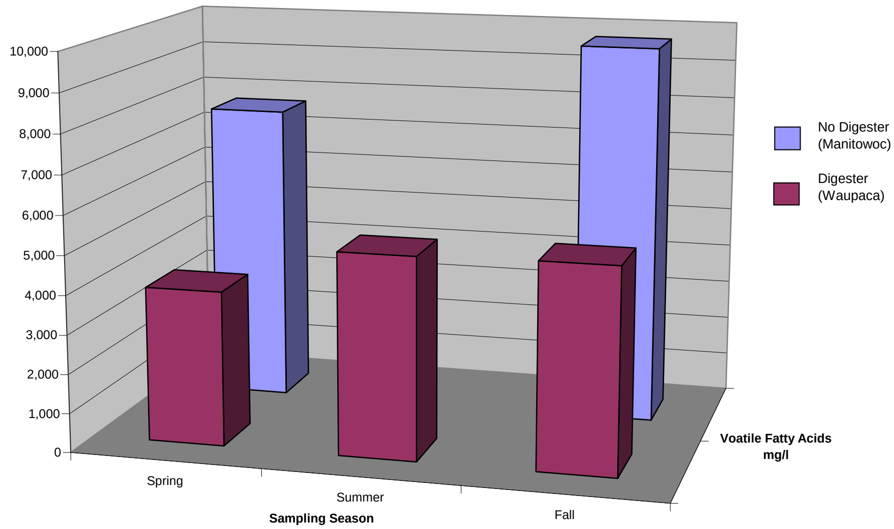

Figure 1.9
Volatile Fatty Acids, mg/l
Mesophilic Digester Fed Lagoon (Waupaca County) vs.
Manure Storage Lagoon – No Digester (Manitowoc County)

It appears from these results that the digested manure has significantly lower VFA levels than the undigested manure, and therefore should generate less odor. However, due to other factors, such as the increased volatility of ammonia in digested manure, a reduction in odor cannot be determined from these data alone.

Figure 1.10 below shows the comparison of Nasal Ranger™ readings taken in the field at our Manitowoc and Waupaca study farms, to the odor scores for the waste storage lagoons, as determined using the odor model in ATCP 51. The odor score was calculated for the lagoons assuming the nearest neighbor was located at various distances downwind. These scores were plotted against separation distance to create an odor score curve. The Nasal Ranger™ odor results were then plotted against distance on the same graph. This allowed us to determine the actual average odor level at the distance that corresponds to a passing odor score of 500.

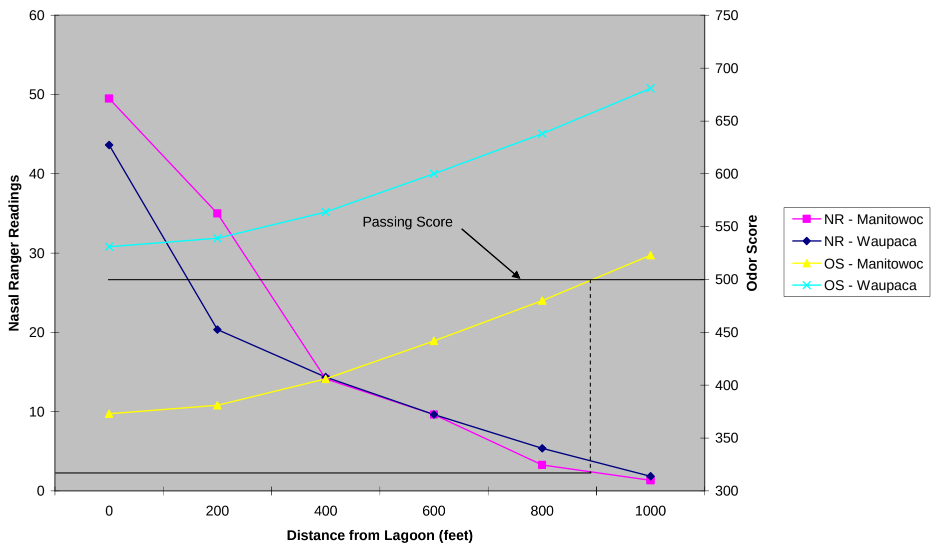

Figure 1.10
Comparison of Nasal RangerTM Readings to the Odor Score
Mesophilic Digester Fed Lagoon (Waupaca County) vs.
Manure Storage Lagoon – No Digester (Manitowoc County)

Looking at these results, we see a very good correlation between the field readings and the predicted odor score at the Manitowoc farm. The yellow line with triangles is the odor score curve, and the red line with squares is the Nasal Ranger^{TM} field readings curve. Drawing a horizontal line at a passing odor score of 500, and then dropping down from where that line intersects the odor score curve, we see that the point corresponds with a separation distance of just under 900 feet. At this distance the Nasal Ranger^{TM} field readings averaged about 2, the lowest measureable reading. This result indicates that for medium sized waste storage lagoons (4.2 acres) the odor standard was collaborated by our field odor measurements.

Unfortunately, this is not the case for the digested lagoon at the Waupaca County farm. There was a poor correlation between the field readings and the predicted odor score for that lagoon. The blue line with X's is the odor score curve, and the black line with diamonds is the Nasal Ranger^{TM} field readings curve. Nowhere does the odor score curve drop below 500, indicating that a passing score can be achieved at any separation distance, a significant improvement over the undigested lagoon. In the field, however, the Nasal Ranger^{TM} readings showed virtually no improvement in odors over the undigested lagoon at distances of 400 feet and beyond. This indicates the need to further investigate the odor control potential of digesters and possibly adjust the credit given to them in the odor standard.

Case Study 2: Impermeable Cover (Dunn County)

Background

Our Dunn County farm was the site where an impermeable cover was installed on a manure storage basin. Drumlins and moderately sloped fields created a more challenging site for air monitoring, however, separation distances between structures were favorable (see Figure 2.0).

Figure 2.0
Dunn County Farm Layout

At the start of our study, this farm housed about 875 milking and dry cows in two large freestall barns bedded on separated digester solids. The freestalls are manually scraped three times each day. The wastes flow by gravity through cross channels to a reception tank, where they are then pumped to the digester inlet. Although his farm has an anaerobic digester, some of the time it was inoperable, therefore the wastes in the 10 million gallon storage lagoon were a combination of digested and undigested wastes. The landowner wished to install a cover not only to control residual odors, but also to capture more gas for use in the 775 kW generator.

The cover that was installed is 60 mil. high density polyethylene (HDPE), similar to what is used for lining manure storage lagoons. It is sealed around its perimeter, making it airtight, and trapped gases are piped to the digester generator set, or optionally to a flare. The cover is also fitted with two surface pumps to remove captured rainwater and send it to drainage swales.

By the end of our study, an additional freestall barn had been built on site to accommodate 300 heifers that had previously been raised on a satellite farm. However, the barn had not yet been populated, therefore this change did not impact our study.

Case Study 2 Results Discussion

General Sampling Overview

A total of 5 sampling runs were conducted at the Dunn county site; three before installation of the impermeable cover, and two following. During these tests, a total of 157 samples for ammonia and 145 samples for hydrogen sulfide were collected, with 14 hydrogen sulfide and 15 ammonia samples invalidated in the field. Invalid samples were somewhat evenly distributed between several runs, and no single run experienced sufficient sample loss to invalidate it.

A summary of the test dates and general conditions is shown in the following table. Parameters include the testing start date and the vector mean wind speed, wind direction and temperature (in degrees Celsius) for both the daytime (AM) and nighttime (PM) sampling runs. Note that, with the exception of the first run, the tests continued to the day following the test date.

In addition, note that the on-site meteorological station malfunctioned during the initial part of the second test, and during the entire test on 9/23/2008. Filling this data was accomplished through first comparing existing on site data with data available on the Internet from nearby airports (Menomonee and Eau Claire). The comparison showed that the Menominee data was more consistent with that from on site, and thus it was used.

Date	AM			PM		
	VMWS	VMWD	T(C)	VMWS	VMWD	T(C)
10/31/2006	15.8	260	0.6			
05/07/2007				3.7	250	16.6
07/09/2007	4.4	200	20.1	0.2	220	17.7
09/23/2008	7.8	200	23.8	4.4	210	17.7
10/07/2008	1.2	280	12.9	7.5	290	9.3

Table 2.0
Dunn County Test Dates and Basic Meteorology

The first trip to this facility was the initial sampling run of the entire project, and numerous details of the sampling protocol were still being evaluated at that point. Results from this run helped clarify the final standard procedures. Major specific differences between this first run and all subsequent runs at all farms include using a lower sample flow rate and only sampling during the daytime.

The effect of the lower sampling rate was to lead to higher detection limits and far fewer samples with detectible quantities of the species of interest. The effect of increasing the sample rate was checked on a limited sampling run to Kewaunee County prior to the official start of sampling at that location, where several samplers at different flow rates were run side by side at a single high concentration location. Results from this showed that increasing the flow rate would enhance sample collection.

An additional measure to increase the number of samples with detectible quantities of NH_3 and H_2S was to increase sampling time as well. This two fold approach resulted in a greater than 10 fold increase in sample volume, with a correspondingly significant decrease in detection limits, thereby greatly increasing the utility of the data collected for this study.

An additional effect of running the samples later in the day was to make collecting a second series of samples overnight during the same trip practical, thereby doubling the overall potential number of samples.

In addition to the samples collected directly around the manure pit, a number of other locations were sampled during these tests, including fenceline locations to the north and south of the pits, and inside the separator room. The former locations were sampled to provide an indication of how diffuse concentrations become over the distance to the fenceline, while the separator room samples were obtained to provide an estimate of the worst case on-farm concentrations.

There were four successful H_2S duplicate sampling pairs submitted to the laboratory, all of which showed qualitative agreement (both samples were non-detects). A total of 9 NH_3 sample pairs were submitted of which 3 show qualitative agreement, while one showed disagreement (one sample a detect, the other a non-detect). Of the remaining 5 NH_3 pairs, one failed at 35.2% RPD, while the other four passed with RPDs below 12%. The average RPD for these samples is 6.0%.

A total of 8 H_2S and 8 NH_3 blanks were submitted from sampling efforts at this facility. Of these, 6 of the H_2S blanks showed detectible quantities, including the highest detect of 69 micrograms per sample. This particular blank was from a lot obtained from a separate manufacturer from which a few samples were deployed during run 2, when the primary sampling media source was temporarily back ordered. While it is not known which of the samples were collected using the alternate media, there are no results that stand out as being anomalous during this run. The average H_2S amount detected in the blanks, when the anomalous high value is excluded, was 6.1 micrograms per sample. There was no NH_3 detected in the blank samples.

Ambient Sampling

Figures showing the results described herein are located in the Project Data Supplement in chronological sequence.

Samples collected along the side of the lagoon at this facility tended to show little to no hydrogen sulfide, before or after installation of the impermeable cover. Out of a total of 38 valid pit-side H_2S samples collected before installation, and 44 afterwards, only 6 detected the compound before, and 3 afterwards. Of these, 5 of the pre-cover detects and all of the post-cover detects were in single sampling runs (specifically the night-time samples on May 7-8, 2007, and the daytime samples on October 7, 2008).

What differed about those runs is not known, and the possibility of widespread sampling error must be considered for the large number of non-detects in an area where the presence of hydrogen sulfide would be expected (alongside a manure lagoon). However, there is support for the observed results among the Jerome survey results.

There was hydrogen sulfide detectable to the instrument during almost every Jerome survey. The separator room and its outfall to the pit is where the highest concentrations were observed. Instantaneous values observed near this location ranged widely, with maxima frequently in excess of 10 ppm. Away from this location, detectible quantities were generally sporadic, and frequently did not exceed the charcoal tube sample detection limits, even on an instantaneous basis.

The one significant exception to this general rule was during the morning of May 8^{th}, 2007, where an extensive area along the north side of the lagoon showed instantaneous Jerome meter concentrations in excess of 1 ppm. Correspondingly, all time integrated samples collected from locations on that side of the lagoon were positive for hydrogen sulfide.

On July 9 and 10, 2007, however, observed real-time values at the outfall did not exceed 0.2 ppm during any of the Jerome surveys, and levels throughout the facility were generally low. Correspondingly, there were no detects among the ambient hydrogen sulfide samples collected on this run.

Following installation of the cover (which included piping the separator outfall underneath the cover without exposure to the air), hydrogen sulfide was typically only observed around the separator room using the Jerome meter. The very few ambient detects following installation are consistent with the real time results observed while on site. However, there was not a dramatic drop in observed values before and after installation, because the pre-installation values were already low.

Ammonia results show a much more dramatic difference before and after installation of the impermeable cover. Prior to installation, ammonia was detected in the majority of samples, with the July 9 and 10, 2007 sample runs returning many samples with concentrations in excess of 1000 micrograms per cubic meter. Following installation, there were far more non-detects than detects, and most of these were barely above the detection limits (which are typically around 30 – 35 $\mu g/m^3$).

Summaries of the downwind samples for each parameter are presented in the following tables. Values documented in the tables are the averages, maxima and minima of the three highest downwind results, as well as the relative standard deviation (RSD), which is a measure of the variability of the results. Note that “ND” indicates that no samples showed detectable quantities of the parameter of interest. In determining the overall average, tests with no detects are averaged in at zero.

	Run 1	Run 2	Run 2e	Run 3	Run 3e	Overall
Average	455	446	482	2076	1645	1059
Max	565	464	619	2279	1960	2279
Min	357	426	345	1864	1016	345
RSD	23.0%	4.3%	40.3%	10.0%	33.1%	73.0%

Table 2.1
Dunn County Pre-Installation Downwind NH_3 Concentrations

	Run 4	Run 4e	Run 5	Run 5e	Overall
Max	33	157	ND	ND	157
Min		97			ND
Avg		127			69
RSD		23.6%			97.7%

Table 2.2
Dunn County Post-Installation Downwind NH_3 Concentrations

H2S Pre	Run 1	Run 2	Run 2e	Run 3	Run 3e	Overall
Max	97	ND	174	ND	ND	174
Min			96			ND
Avg			123			66
RSD			35.9%			102.0%

Table 2.3
Dunn County Pre-Installation Downwind H_2S Concentrations

H2S Post	Run 4	Run 4e	Run 5	Run 5e	Overall
Max	ND	ND	93	ND	93
Min			21		ND
Avg			60		30
RSD			61.3%		134.2%

Table 2.4
Dunn County Post-Installation Downwind H_2S Concentrations

Results tabulated above are shown in the following graphs. Note that the y-axis scale of the graphs represent $\mu g/m^3$, and the before and after scales have been set the same to allow direct comparison of the difference in results.

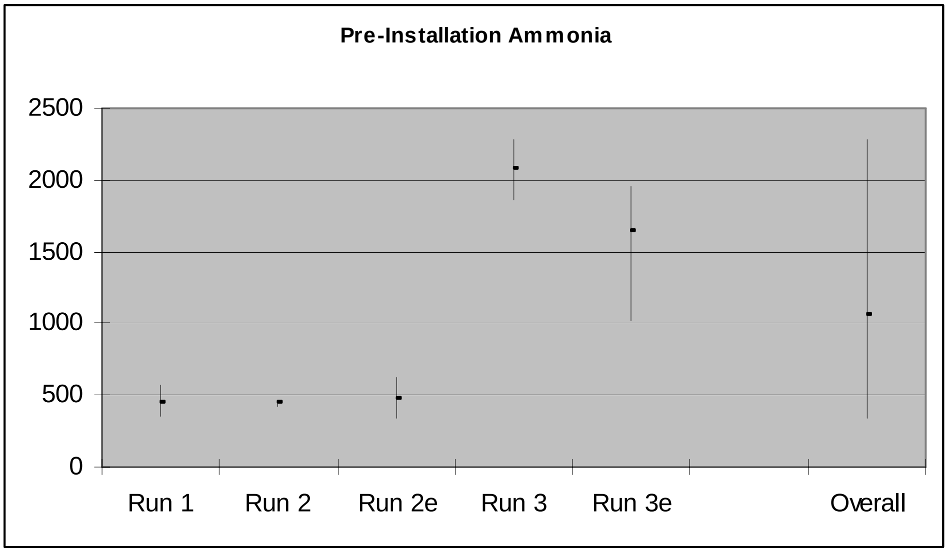

Figure 2.1
Pre-Installation Ammonia (Dunn County)

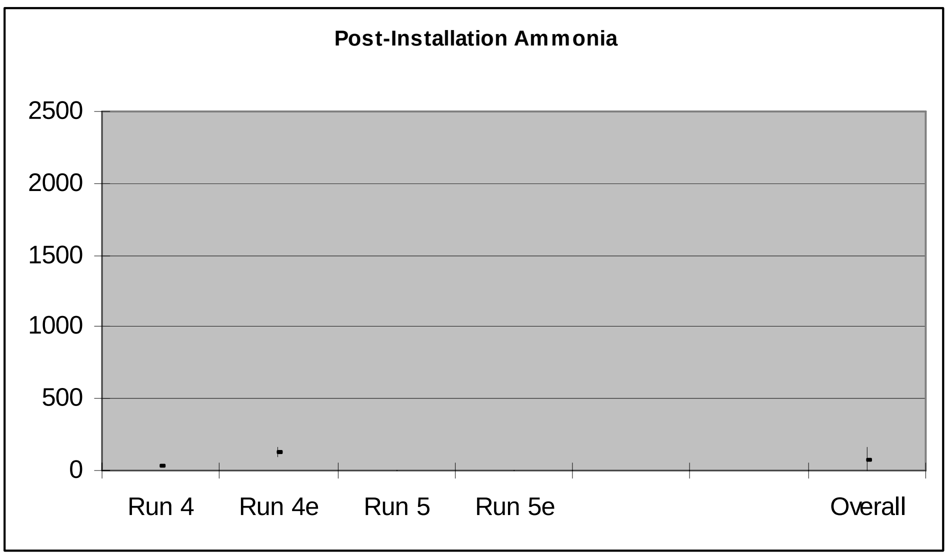

Figure 2.2
Post-Installation Ammonia (Dunn County)

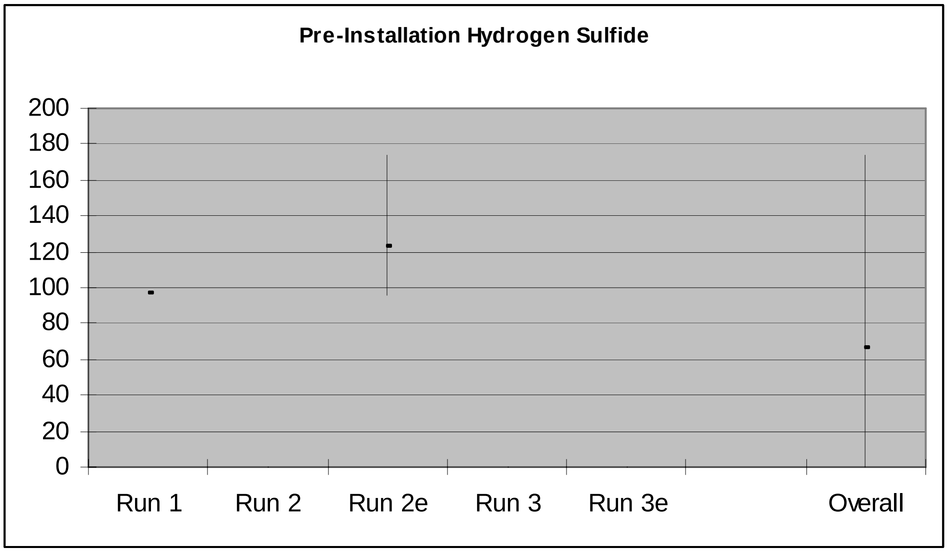

Figure 2.3
Pre-Installation Hydrogen Sulfide (Dunn County)

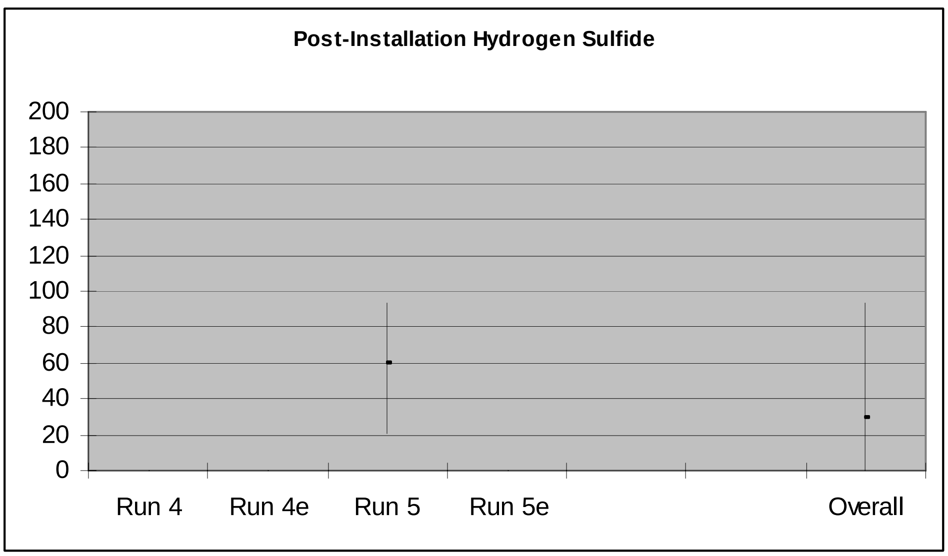

Figure 2.4
Post-Installation Hydrogen Sulfide (Dunn County)

Manure Surface Sampling

The graphs below show the maximum, minimum and average values from flux samples collected from the manure surface before and after the installation of the permeable cover. Samples to the left and right represent those collected before and after installation of the cover, respectively. It should be noted that following installation of the cover, there were significant challenges in maintaining a seal between the flux chamber and the surface sufficient to allow collection of samples. Sampling on the cover was actually conducted in puddles of accumulated water to enable a seal to develop.

Note that a logarithmic scale is used for the value axis, which is in micrograms per cubic meter. Both H_2S and NH_3 results following installation were non-detects, so that the graph shows the maximum possible values. Sampling flow rates were increased for these samples to decrease the detection limit and improve the quality of the data.

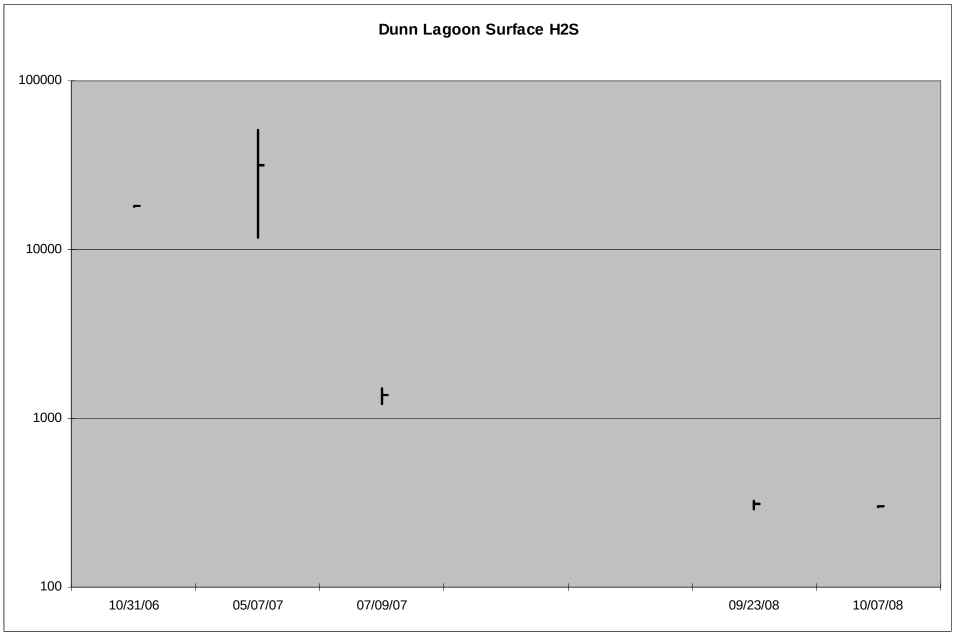

Figure 2.5
Lagoon Surface H_2S (Dunn County)

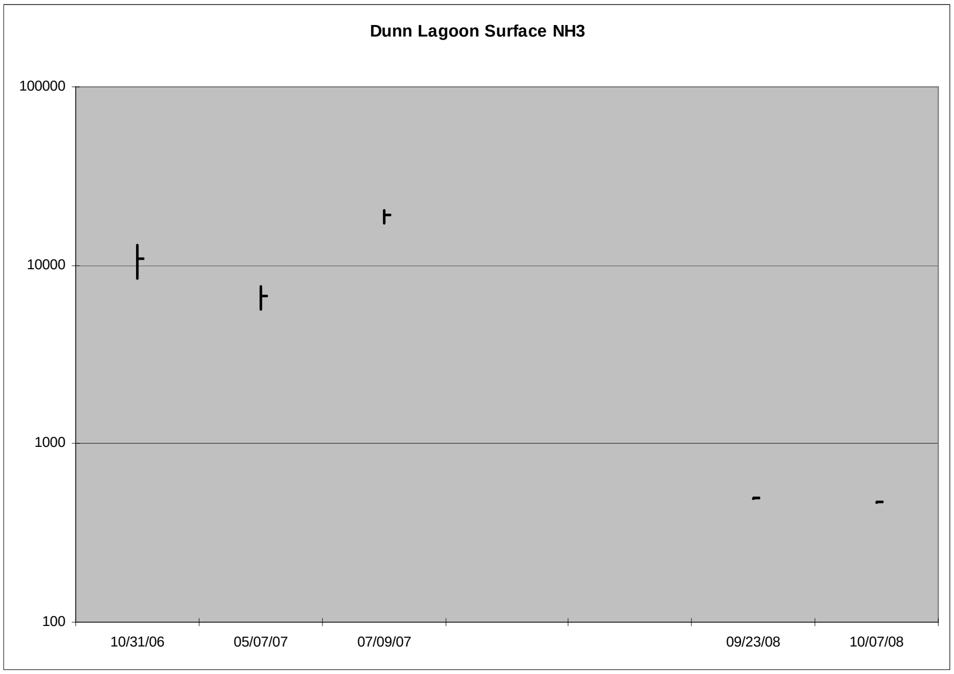

Figure 2.6
Lagoon Surface NH_3 (Dunn County)

Case Study 2 Key Findings Summary Statements

This facility represents two practices; both manure digestion (with added substrate) and an impermeable cover. Pre-installation results represent digested manure, while post-installation results represent both digestion and the cover.

Both prior to and following installation of the cover, ambient hydrogen sulfide results were quite low, with only sporadic detectable quantities. The low levels make it difficult to truly evaluate the effect of the cover on the basis of these samples, however, the low levels observed before installation may demonstrate the effectiveness of the digestion process in reducing hydrogen sulfide concentrations. Hydrogen sulfide concentrations observed at the lagoon surface through the flux chamber samples did show a dramatic drop following installation of the cover.

Ammonia samples collected both around the lagoon and from the surface show a dramatic difference, with an obvious and significant drop in concentration following installation of the cover.

Overall, installation of the impermeable cover has been unambiguously shown to reduce on-farm concentrations of hydrogen sulfide and ammonia significantly. However, our tests do not allow conclusions to be drawn concerning the entire life cycle of the manure, as we did not collect any samples during spreading of the manure. Differences in air quality impacts of manures from covered storage versus uncovered are unknown and outside of the scope of this study.

Odor Control Results

The outcome of the odor transects conducted on the three follow-up trips to the Dunn County farm is depicted in three graphics in the data supplement. These represent the odors being generated by the same lagoon, however with an impermeable (HDPE) cover installed.

Comparing these three "with cover" figures with the three "without cover" figures it becomes clear that the cover was highly effective at controlling odors. The significant odors observed coming from the lagoon initially were virtually non-existent during the later visits. The dominant odors on the farmstead after the cover was installed were identified as feed or freestall rather than lagoon odors. This is not surprising since now all gases generated by the lagoon were being contained.

Graphing the odor readings from this lagoon, both with and without the cover, it becomes clear how effectively the cover controls odors (see Figure 2.7). By averaging the results from each set of the trips, the overall reduction in odor is virtually 100%.

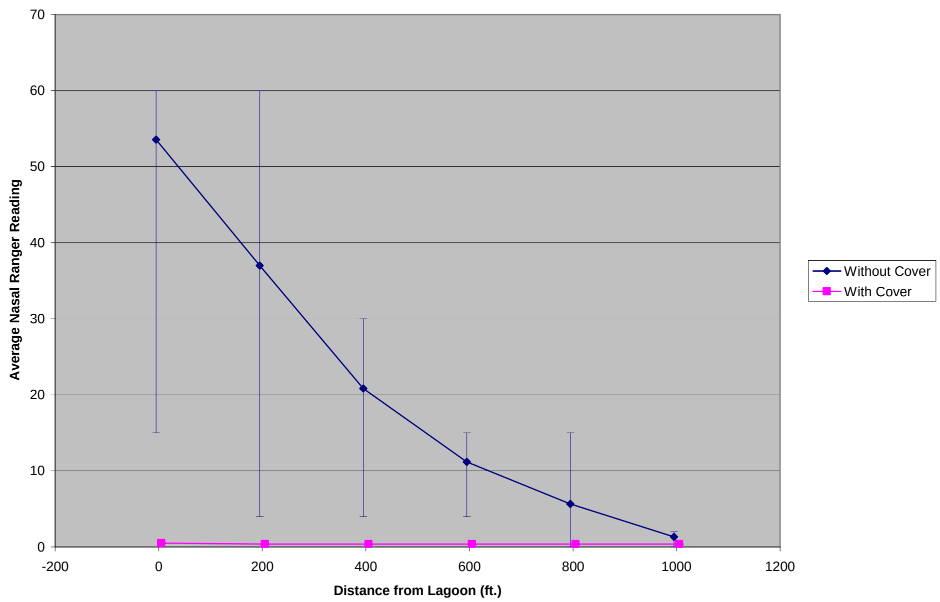

Figure 2.7
Average Nasal Ranger™ Reading at 200 ft Intervals
Thermophilic Digester Fed Lagoon (Dunn County)

The flux chamber testing from this lagoon, with and without the cover, mirrored our Nasal Ranger™ readings. Figure 2.8 below is a bar graph depicting the laboratory-determined odor intensities of our flux chamber samples. The first two bars are for samples taken from the lagoon before the cover was installed, and the second two bars are for samples taken directly off the HDPE cover.

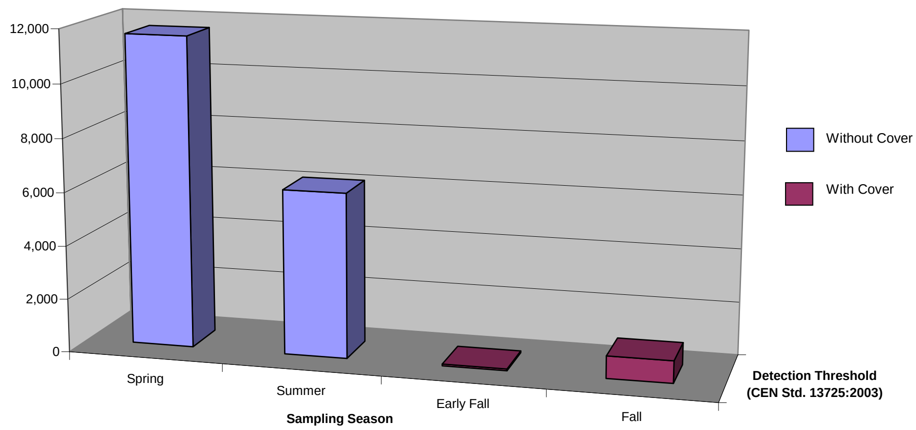

Figure 2.8
Flux Chamber Seasonal Average Detection Threshold
Thermophilic Digester Fed Lagoon (Dunn County)
With Impermeable Cover vs. Without Cover

Not surprisingly, these data support the findings that an impermeable cover provides virtually 100% odor control. Of course, other factors come into play when considering installing a cover for odor control, such as cost and impacts on the operation and maintenance of the lagoon. These items are discussed further in the Lessons Learned section of this report.

Figure 2.9 below shows the comparison of Nasal Ranger^{TM} readings taken in the field at our Dunn County farm (with cover in place), to the calculated odor score for the covered waste storage lagoon, using the odor model in ATCP 51. The odor score was calculated for the covered lagoon assuming the nearest neighbor was located at various distances downwind. These scores were plotted against separation distance to create an odor score curve. The Nasal Ranger^{TM} odor results were then plotted against distance on the same graph. This allowed us to determine the actual average odor level at the distance that corresponds to a passing odor score of 500.

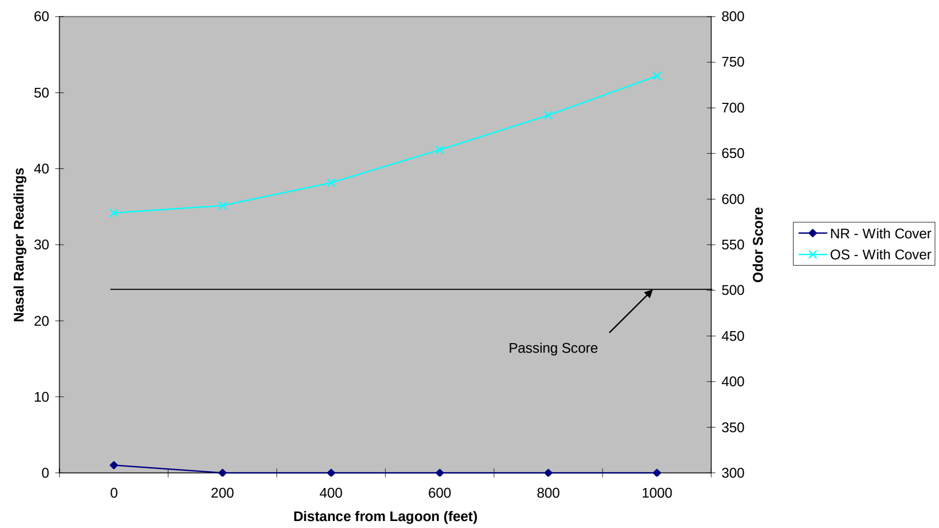

Figure 2.9
Comparison of Nasal Ranger™ Field Readings to the Odor Score
Thermophilic Digester Fed Lagoon (Dunn County)
With Impermeable Cover Installed

Looking at these results, we see a very good correlation between the field readings and the predicted odor score. The blue line with X's is the odor score curve with the cover installed, and the black line with diamonds is the field odor readings curve. Drawing a horizontal line at a passing odor score of 500, we see that at no point does the odor score curve drop below 500, meaning that the system passes at any separation distance. We also see that all Nasal Ranger™ readings are 1 or below, a very acceptable level. This indicates that for waste storage lagoons with impermeable covers the odor control credit in the odor standard was collaborated by our field odor measurements.

Project Focus Key Comparison ~ Case Study 2: Anaerobic Digester (Dunn County) vs. Case Study 6: Manure Storage Lagoon (Manitowoc County)

Our second case study farm, in Dunn County, was unique in that it allowed us to evaluate two separate practices. This farm was selected because, like the Waupaca farm, it had an anaerobic digester already installed and fully operational. Unlike Waupaca, however, this digester was a *Microgy* design, which operated in a warmer (thermophilic) temperature range. This gave us the opportunity to observe differences between these two types of digesters.

Similar to the situation in Waupaca County, the landowner in Dunn County continued to receive occasional odor complaints after the digester was installed. Because of this, he was considering installing an impermeable cover on his lagoon. His hope was that a gas-tight cover would provide him with multiple benefits. First, it would control all odors from his lagoon, second, it would capture additional gasses to power his generator, and third, it would keep precipitation out of his manure to save on hauling costs. By assisting him with installing an impermeable cover, we could test in a real world setting how well it met these expectations.

The outcome of the odor transects conducted on the three initial trips to the Dunn County farm are depicted in the data supplement. These represent the odors being generated by a lagoon that is storing manure that has been processed through a thermophilic (high temperature) anaerobic digester. And as with case study #1, we compared this to our control lagoon in Manitowoc County. The outcome of the odor transects conducted on the three trips to that farm are also depicted in the data supplement. These represent the odors being generated by a lagoon that is storing manure that has not been processed through a digester.

Comparing these two sets of figures, it appears that odors may be somewhat increased by the digester rather than being decreased as was expected. As with the Waupaca farm, all our initial trips to Dunn County seemed to bear this out.

Graphing the odor readings from these two lagoons, an increase in odor appears to be caused by the digester (see Figure 2.10). By averaging the results from each set of trips, this difference is about a 15% increase in odors overall. Since the accuracy of data provided by the Nasal Ranger™ is typically +/-10%, this would not be considered a statically significant increase. Note that the vertical lines representing the range of values observed at each data point display considerable overlap.

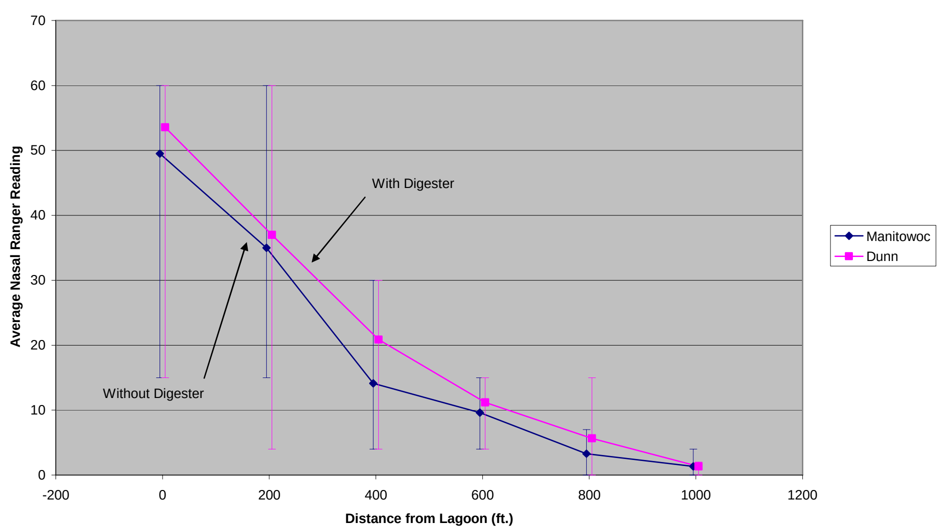

Figure 2.10
Average Nasal Ranger™ Reading at 200 ft Intervals
Thermophilic Digester Fed Lagoon (Dunn County) vs.
Manure Storage Lagoon – No Digester (Manitowoc County)

The flux chamber testing from these two farms mirrored our Nasal Ranger™ readings. Figure 2.11 below is a bar graph depicting the laboratory-determined odor intensities of our flux chamber samples. The first three bars are for samples taken from the control farm and the last two are from the thermophilic digester farm.

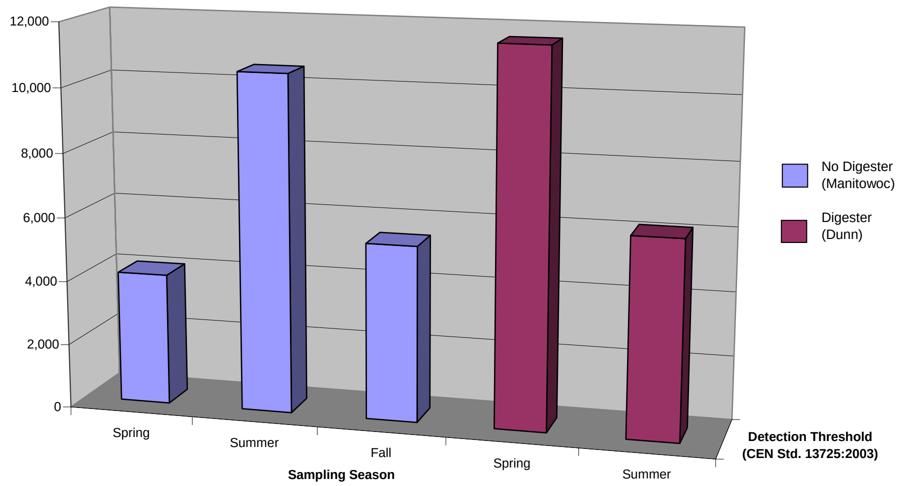

Figure 2.11
Flux Chamber Seasonal Average Detection Threshold
Thermophilic Digester Fed Lagoon (Dunn County) vs.
Manure Storage Lagoon – No Digester (Manitowoc County)

These data seem to verify our Nasal Ranger™ readings of a slight increase in odor from the lagoon receiving digested manure as compared to the lagoon receiving undigested manure.

We theorized that the main reason for this was incomplete digestion, as with the Waupaca digester, but other factors were at play here as well. For one, because this digester operated at a higher temperature, the discharged manure exited at about 120^{o} F. Odors in and around the discharge point were quite elevated, which may have affected the downwind Nasal Ranger™ readings. Also, there had been times when the digester was shut down for repairs. During this downtime undigested manure was sent directly to the lagoon. Also, substrate fats and oils were being added to this digester on a regular basis. This is a common practice with many digesters to help boost gas production. Our sampling indicated that the volatile fatty acid levels in the digested manure were occasionally higher than in the feed manure (see Figure 2.12 below). The added fats and oils could account for this finding. All of these factors; partially undigested manure, higher temperatures, gas flare failures, and elevated VFAs could help to explain why odor levels were slightly higher than what we observed at the control farm.

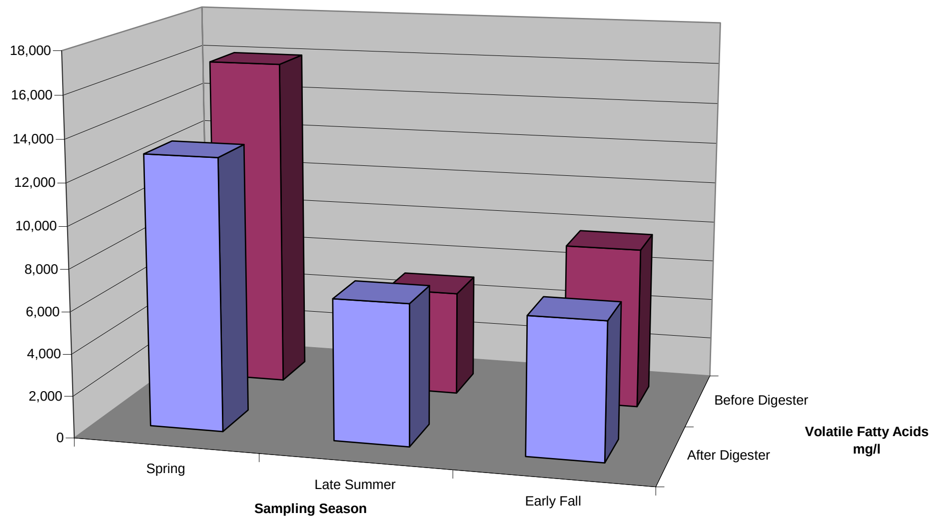

Figure 2.12
Volatile Fatty Acids, mg/l
Seasonal Sample Results, Thermophilic Digester Fed Lagoon (Dunn County)
Before Digester vs. After Digester

Comparing the volatile fatty acid levels in the lagoon at this farm to the levels in the lagoon on our control farm also supports our findings that thermophilic digestion can lead to increased odors (see Figure 2.13 below). Although these results are not as consistent as what was found at the Waupaca farm, it is clear that VFA levels are not always reduced. Again, this may be due to the addition of the fats and oils as a substrate material.

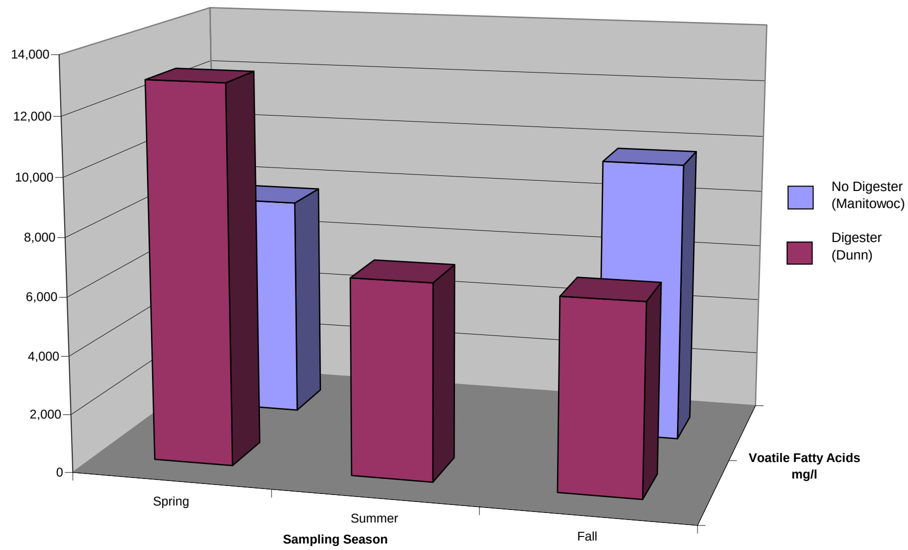

Figure 2.13
Volatile Fatty Acids, mg/l
Thermophilic Digester Fed Lagoon (Dunn County) vs.
Manure Storage Lagoon – No Digester (Manitowoc County)

Taking all this information into account, it appears that this thermophilic digester did not reduce odors, when compared to a lagoon receiving undigested manure, and may actually have resulted in a slight (15% +/-10%) increase in odors.

Figure 2.14 below shows the comparison of Nasal Ranger^{TM} readings taken in the field at the Manitowoc and Dunn County farms, to the odor scores for the waste storage lagoons on those same farms, using the odor model in ATCP 51. The odor score was calculated for the lagoons assuming the nearest neighbor was located at various distances downwind. These scores were plotted against separation distance to create an odor score curve. The Nasal Ranger^{TM} odor results were then plotted against distance on the same graph. This allowed us to determine the measured average odor level at the distance that corresponds to a passing odor score of 500.

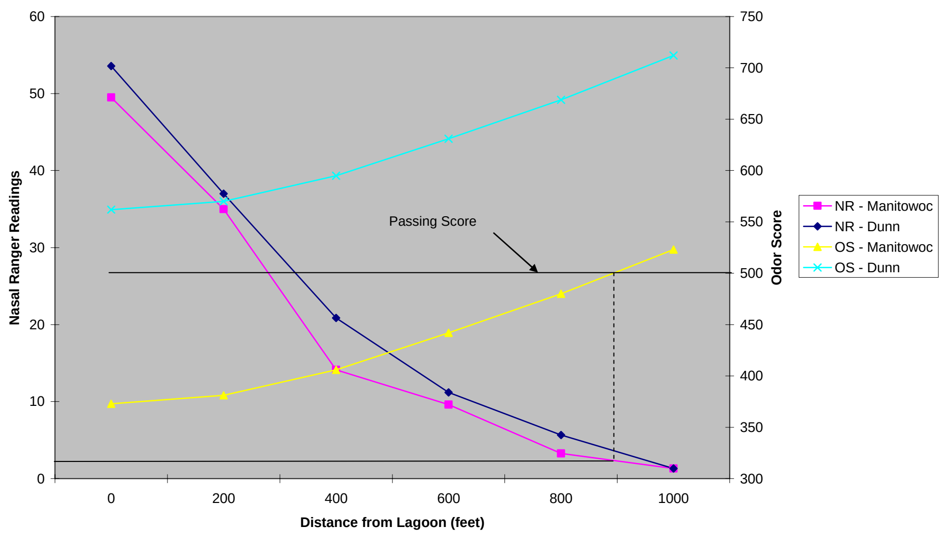

Figure 2.14
Comparison of Nasal RangerTM Readings to the Odor Score
Thermophilic Digester Fed Lagoon (Dunn County) vs.
Manure Storage Lagoon – No Digester (Manitowoc County)

Looking at these results, we see a very good correlation between the field readings and the predicted odor score at the Manitowoc farm. The yellow line with triangles is the odor score curve, and the red line with squares is the Nasal Ranger^{TM} field readings curve. Drawing a horizontal line at a passing odor score of 500, and then dropping down from where that line intersects the odor score curve, we see that the point corresponds with a separation distance of just under 900 feet. At this distance the Nasal Ranger^{TM} field readings averaged about 2, the lowest measureable reading. This result indicates that for medium sized waste storage lagoons (4.2 acres) the odor standard was collaborated by our field odor measurements.

Unfortunately, this is not the case for the digested lagoon at the Dunn County farm. There was a poor correlation between the field readings and the predicted odor score for that lagoon. The blue line with X's is the odor score curve, and the black line with diamonds is the Nasal Ranger^{TM} field readings curve. Nowhere does the odor score curve drop below 500, indicating that a passing score can be achieved at any separation distance, a significant improvement over the undigested lagoon. In the field, however, the Nasal Ranger^{TM} readings showed a slight increase in odors over the undigested lagoon at all distances up to 1,000 feet. This indicates the need to further investigate the odor control potential of digesters and possibly adjust the credit given to them in the odor standard.

Case Study 3: Permeable Lagoon Cover (Kewaunee County)

Background

Our Kewaunee County farm was a large dairy situated on very open and flat terrain. The manure storage lagoons were separated from all other farm structures by over 400 feet. This arrangement made for almost ideal conditions for an air sampling study. For most wind conditions it was possible to isolate the lagoons from the other sources on the farm and thus minimize background interference (see Figure 3.0).

Figure 3.0
Kewaunee County Farm Layout

At the start of the study, the farm housed 1,500 milking cows in two large sand-bedded freestall barns. These barns were manually scraped three times daily into cross gutters that were flushed with recirculated wastewater pumped from the second waste storage lagoon. A sand separation channel was used to reclaim a majority of the sand for reuse as bedding. After passing through the sand channel the wastes went to a 2 million gallon primary waste storage lagoon, where the remainder of the sand was allowed to settle out, and then overflowed to a 13 million gallon secondary lagoon. Our study treated the two lagoons as one larger one. Since only a narrow berm separated the two, it was not possible to isolate one from the other, especially under variable wind conditions.

At the end of our study, the farm had undergone an expansion of 500 animals, added a new freestall barn, and dug a new 15 million gallon waste storage lagoon adjacent to the second lagoon. Despite these changes, it was still possible to monitor the existing lagoons without interference from the added structures, due to favorable wind conditions during our follow-up visits.

The odor control practice that was evaluated at this farm was a permeable geotextile membrane cover on the waste storage lagoon (see Figure 3.1). Both the large secondary lagoon and the newly built lagoon were fitted with covers. The small primary lagoon was not, however that lagoon consistently had a thick organic crust on it, making a cover unnecessary. The theory behind permeable covers is that they should function much like a natural crust. Gases and precipitation pass through, however the waste/wind interface is broken up, reducing the rate at which gases are stripped from the manure. These covers may also serve as a medium for aerobic breakdown of the wastes near the surface of the lagoon.

Figure 3.1
Permeable Cover on Lagoon #2, Kewaunee County Farm

During our first monitoring visit to this farm, we observed that the sand separation channel was a source of odors. Spot checks with the Jerome meter verified that there were significant H_2S concentrations around this structure. On subsequent visits, air samplers were positioned around the sand channel, in addition to the ones placed around the waste storage lagoon, in an attempt to quantify our observations.

This is also the farm that we selected to conduct a survey of the surrounding neighbors. Survey forms were mailed out to all nearby neighbors before the cover was installed, and then again after installation. The survey particulars and results are described in Appendix C to this report.

Case Study 3 Results Discussion

General Sampling Overview

A total of eight sampling runs have been conducted at the Kewaunee County site to date: three before installation of the permeable cover, three during the first year following, and two during the second year following. During these tests, a total of 361 samples for each parameter have been collected, with 13 H_2S and 14 NH_3 being invalid for reasons in the field. The majority of the invalid samples were collected during the evening of the first sampling trip, which was subject to a rain event without the protection provided by the shelters. The entire evening run for the first sampling trip has been declared invalid because of the paucity of results, and is not considered further.

A summary of the test dates and general conditions is shown in the following table. Parameters include the testing start date and the vector mean wind speed, wind direction and temperature (in degrees Celsius) for both the daytime (AM) and nighttime (PM) sampling runs.

Date	AM			PM		
	VMWS	VMWD	T(C)	VMWS	VMWD	T(C)
06/18/2007	15.6	190	28.8	8.7	240	18.5
08/27/2007	11.9	170	21.9	9.4	180	21.2
09/17/2007	14.2	170	18.6	12.4	170	17.0
05/12/2008	5.5	90	11.6	5.2	160	6.4
06/23/2008	3.7	90	22.2	1.5	170	14.9
07/21/2008	3.5	40	21.3	5.2	0	17.0
05/05/2009	13.0	174	14.0	11.8	180	11.0
06/02/2009	5.5	182	16.9	5.1	35	11.8

Table 3.0
Kewaunee County Test Dates and Basic Meteorology

Standard sampling protocols have been followed for all tests conducted at this site. Additional sampling was conducted around the sand channel on all sampling runs except the first, with results included separately in Section 3.1 following. In addition, sampling was conducted along the berm between the primary and secondary manure storage lagoons (locations 32 and 33) during most sampling runs. Results from these samples are discussed separately from the majority of the ambient samples, as they represent a special case and are less directly comparable to other facilities. No other additional sampling was practical at this facility.

A significant fraction of all successful duplicate samples were collected at Kewaunee (17 of both H_2S and NH_3 pairs) Of these, five H_2S and two NH_3 sampling pairs failed quality criteria. The average RPD of all H_2S duplicate samples is 42.9%, while excluding the worst of these samples (144.3% RPD) results in an average RPD of 30.3%, which is slightly outside of quality limits. The effect of this is to reduce confidence in our data somewhat. The average RPD of the NH_3 samples is 14.7%, well within quality criteria.

Two blanks collected during the 6th sampling run, and one during the 8th, showed detectable quantities of H_2S, with an average of 8.2 µg/sample. The blank levels were subtracted from the results reported by the lab. All other blanks contained non-detectable levels of the parameters.

Ambient Sampling
Figures showing the results described herein are located in the Project Data Supplement in chronological sequence.

Ambient sampling around this facility yields some contradictory and ambiguous results. In this section, results collected around the manure pits are documented. This includes samples collected around the perimeter of the primary and secondary pits, as well as samples collected on the berm between the two. Results from the latter samples will be discussed separately following presentation of the perimeter sample results. Results from additional samples collected along the sand channel are discussed in section 3.1 following.

Ammonia was consistently detected on the downwind perimeter of the manure storage lagoons throughout the project. Concentrations observed were generally consistent within most runs across the downwind edge of the lagoon, as shown by the relatively low relative standard deviations presented in the results tables following. This implies a general source (i.e., the lagoon surface), rather than a strong point source. An exception to this is seen in the nighttime run on September 17-18, 2007, where the sample at location 11 is significantly elevated above those collected elsewhere, as well as being the highest ammonia concentration observed along the perimeter of the lagoon at this facility. It is unknown why the ambient concentration at that point was so high at that particular time.

Concentrations observed after installation of the cover are generally less than those observed beforehand. In fact, the maximum downwind concentrations from each sampling run following installation are less than all of the pre-installation sampling run downwind averages, and most of them are less then the minimum values. We have too small a sample size for the differences to be statistically significant, however, so even though there is an apparent reduction, it is difficult to quantify it with assurance.

Similarly, the perimeter hydrogen sulfide results show an apparent drop. Prior to the cover installation, all sampling runs yielded detectable quantities of this substance. Afterwards, the number of detects is reduced, with several runs returning either one or no detects. This observation is generally supported by the real time Jerome Meter readings recorded during the H_2S surveys. Note that one run, the daytime 6th run, returned a single detect at a relatively high level. This sample appears anomalous, however, because it was not downwind of the lagoon or the sand channel, and is the highest result for this compound on the perimeter of the lagoon. With the exception of this sample, the magnitude of detected hydrogen sulfide along the perimeter of the lagoon appears to drop somewhat as well. Note that results obtained during the second year after installation of the cover show consistently low levels of H_2S.

The sampling runs during the nights of July 21 and 22, 2008 and June 2 and 3, 2009 present another anomalous note. These runs are the only ones during which consistent winds from the north were recorded. Under these conditions, the upwind side of the lagoon is downwind of the sand channel, which is across the road to the north of the lagoons. During these runs, the upwind locations (#'s 12, 14 and 15) showed detectible quantities of both parameters, and two of the H_2S results were equal to or greater than 2 of the three most concentrated downwind concentrations.

The implication of this is that the sand channel has as much or more of an impact 100 meters or more downwind than does being right next to the lagoon. Whether or not this situation existed prior to installation of the cover is not known, as there were no sampling runs conducted under northerly winds at that time. Further discussion is included in section 3.1 following.

Summaries of the downwind samples for each parameter are summarized in the following tables. Values documented in the tables are the averages, maxima and minima of the three highest downwind results, as well as the relative standard deviation (RSD), which is a measure of the variability of the results. Note that "ND" indicates that no samples showed detectable quantities of the parameter of interest. In determining the overall average, tests with no detects are averaged in at zero. The suspect H_2S result from the 6th run is marked with asterisks (*), and not included in the overall calculations.

	Run 1	Run 2	Run 2e	Run 3	Run 3e	Overall	Day	Night
Avg	471	416	429	747	818	576	545	624
Max	624	432	507	848	1384	1384	848	1384
Min	390	405	311	649	467	311	390	311
RSD	28.2%	3.4%	24.2%	13.3%	60.4%	46.5%	32.0%	61.6%

Table 3.1
Downwind Ammonia Concentrations Near the Manure Pit, Pre Installation

	Run 4	Run 4e	Run 5	Run 5e	Run 6	Run 6e	Overall	Day	Night
Avg	299	199	344	268	164	215	248	269	227
Max	328	234	429	331	327	309	429	429	331
Min	271	152	186	236	79	131	79	79	131
RSD	9.4%	21.2%	39.7%	20.5%	86.7%	41.5%	40.6%	47.8%	28.3%

Table 3.2
Downwind Ammonia Concentrations Near the Manure Pit, Post Installation

	Run 7	Run 7e	Run 8	Run 8e	Overall	Day	Night	ALL Post Install
Avg	129	98	209	61	124	169	79	198
Max	181	132	369	102	369	369	132	429
Min	95	73	56	37	37	56	37	37
RSD	35.5%	31.1%	74.9%	59.3%	74.4%	66.5%	45.7%	57.4%

Table 3.2a
Downwind Ammonia Concentrations Near the Manure Pit, Post Installation 2nd Year and Overall

	Run 1	Run 2	Run 2e	Run 3	Run 3e	Overall	Day	Night
Avg	36	68	157	133	90	104	89	124
Max	65	155	173	262	132	262	262	173
Min	ND	24	136	65	68	ND	ND	68
RSD	91.3%	111.8%	12.1%	84.4%	40.0%	65.8%	91.6%	36.2%

Table 3.3
Downwind Hydrogen Sulfide Concentrations Near the Manure Pit, Pre Install

	Run 4	Run 4e	Run 5	Run 5e	Run 6	Run 6e	Overall	Day	Night
Avg			31	97	ND	57	52	18	66
Max	ND	ND	39	137	*330*	90	137	31	137
Min			25	62		40	ND	ND	ND
RSD			22.7%	39.0%		48.5%	84.2%	88.2%	67.2%

Table 3.4
Downwind H_2S Concentrations Near the Manure Pit, Post Installation

	Run 7	Run 7e	Run 8	Run 8e	Overall	Day	Night	ALL Post Install
Avg	25	51	38	35	37	31	43	46
Max	28	54	59	37	59	59	54	137
Min	23	45	24	31	23	23	31	0
RSD	11.4%	9.4%	48.5%	9.8%	34.3%	43.9%	22.3%	65.6%

Table 3.4a
Downwind H_2S Concentrations Near the Manure Pit, Post Installation 2nd Year and Overall

Results tabulated above are shown in the following graphs. Note that the y-axis scale of the graphs represent $\mu g/m^3$, and the before and after scales have been set the same to allow direct comparison of the difference in results. The anomalous H_2S result from the 6th run is included in figure 3.5.

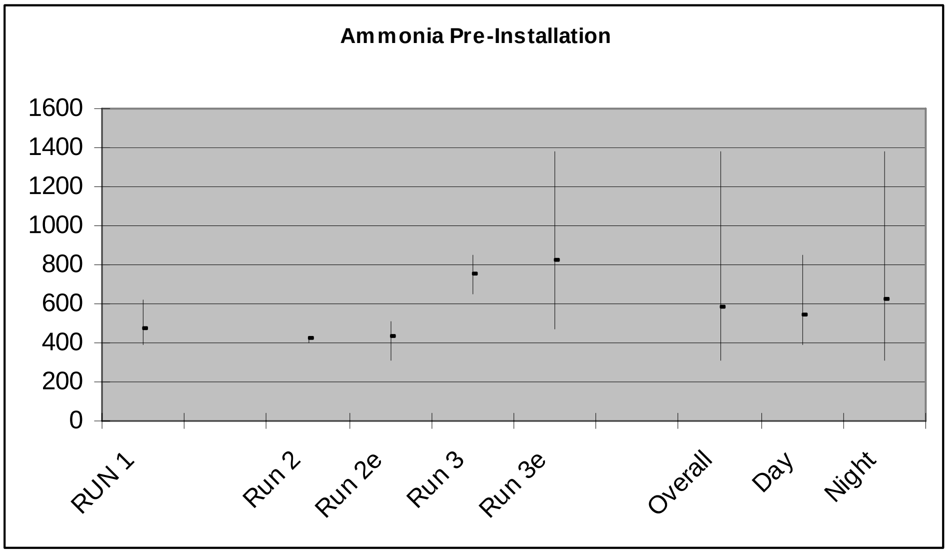

Figure 3.2
Ammonia Pre-Installation (Kewaunee County)

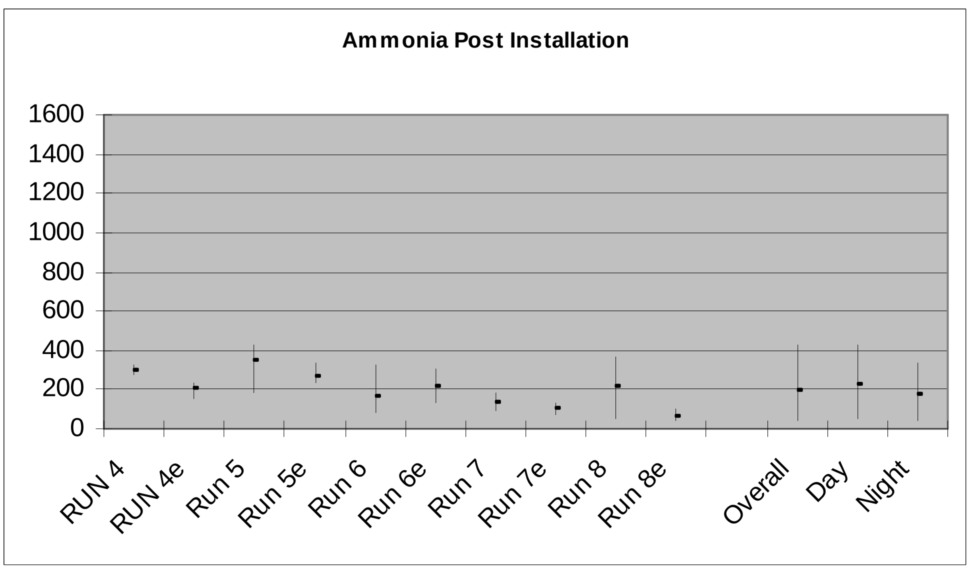

Figure 3.3
Ammonia Post-Installation (Kewaunee County)

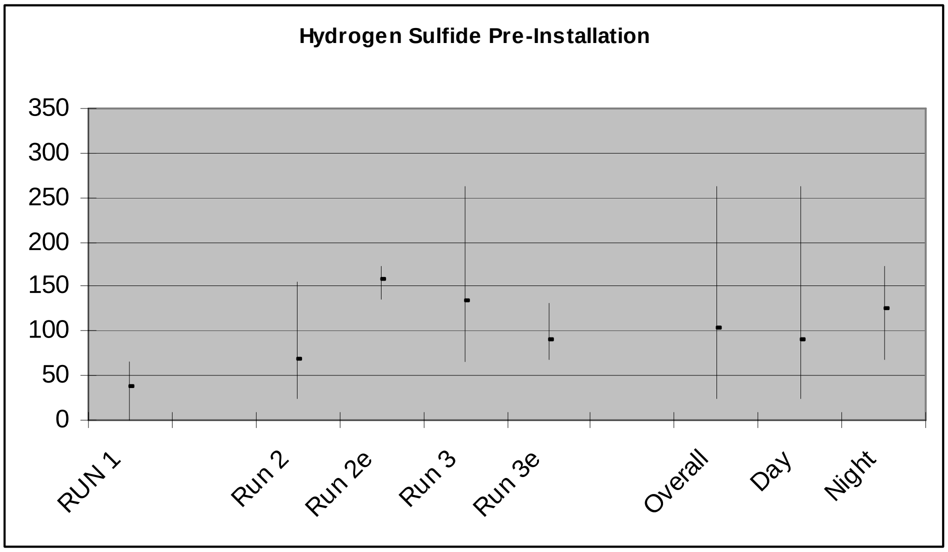

Figure 3.4
Hydrogen Sulfide Pre-Installation (Kewaunee County)

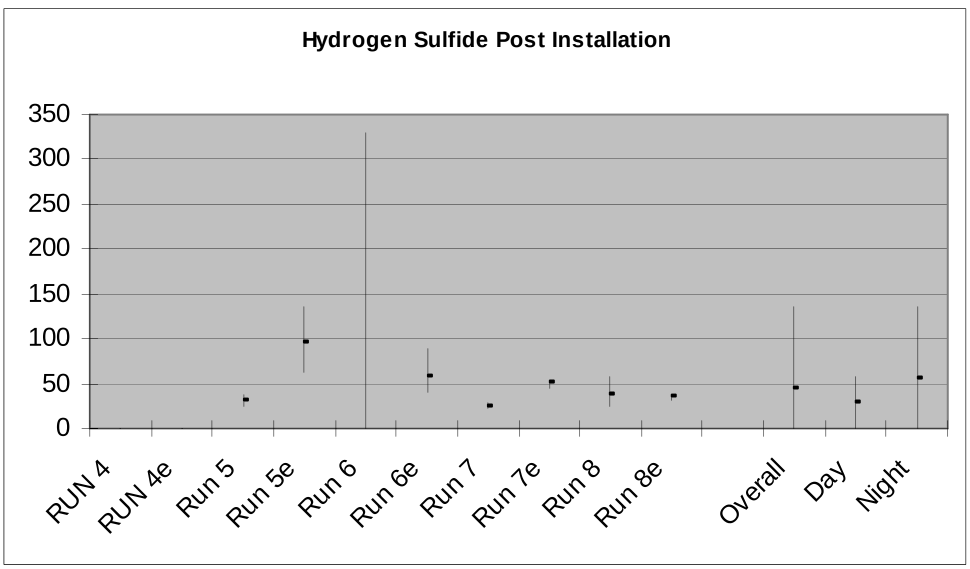

Figure 3.5
Hydrogen Sulfide Post-Installation (Kewaunee County)

While the lagoon perimeter results appear to support the efficacy of the semi-permeable cover in reducing local concentrations of ammonia and hydrogen sulfide, the samples collected on the berm between the primary and secondary lagoons tell a slightly different story.

Prior to the installation of the cover, the outfall between the two pits was an open spillway. This was adopted as a sampling location following the first test (location 32 in the figures), largely because of the significant hydrogen sulfide concentrations observed using the Jerome Meter. Following installation of the cover, the spillway was replaced with a buried pipe leading under the cover, thereby significantly reducing the agitation to the manure during its transfer from the primary to the secondary lagoon. In addition to continuing to sample at this point, a second point on the berm was added for additional coverage (location 33).

Prior to installation, both parameters were consistently detected at the outfall spillway. Interestingly, the maximum daytime hydrogen sulfide value is significantly less than the minimum nighttime value, thus apparently showing the nighttime increases observed also at Manitowoc and around the undigested manure pit at Waupaca. This pattern was not apparent from the other samples collected around this lagoon. Following installation of the cover, however, results observed on the berm changed significantly.

Ammonia results appear to increase somewhat, from an average of about 100 μg/m^3 to about 250 μg/m^3 at the outfall. Hydrogen sulfide results are even more variable, with none detected half of the time, but the other half returning an average value (675 μg/m^3) greater than the maximum value before installation (405 μg/m^3), as well as the highest lagoon associated H_2S concentration observed at this facility. It should be noted that the nighttime increases continue to manifest for samples where there is a detectable quantity of H_2S. Samples collected during the second year following installation yielded uniformly lower results for both parameters.

At this point it is indeterminable whether the trend in our data is a sampling artifact resulting from the relatively few trips made to the facility, or whether the increases observed along the interior berm of the lagoons is an unexpected result attributable somehow to the cover. The general consistency of the observed increases does suggest a real pattern, however. The increases are even more remarkable given the replacement of the open spillway with an enclosed pipe.

The following table presents the results from the spillway and berm samples before and after the installation of the cover. In addition to each individual result, averages and relative standard deviations are provided.

Spillway, Pre	**Run 2**	**Run 2e**	**Run 3**	**Run 3e**			**Avg**	**RSD**
H2S	45	405	118	169			184	84.3%
NH3	56	56	176	118			102	56.6%
Spillway Post	**RUN 4**	**RUN 4e**	**Run 5**	**Run 5e**	**Run 6**	**Run 6e**	**Avg**	**RSD**
H2S	ND	ND	108	1643	ND	273	337	192.2%
NH3	246	129	258	372	245	297	258	30.8%
Spillway Post	**RUN 7**	**RUN 7e**	**Run 8**	**Run 8e**	**Avg Yr 2**	**RSD**	**Avg All**	**RSD**
H2S	**ND**	**ND**	**69**	**54**	**31**	**117.1%**	**215**	**237.1%**
NH3			**69**	**30**	**49**	**56.1%**	**206**	**57.3%**
Berm Post	**RUN 4**	**RUN 4e**	**Run 5**	**Run 5e**	**Run 6**	**Run 6e**	**Avg**	**RSD**
H2S	ND	ND	68	205	ND	42	53	152.3%
NH3	218	133	334	244	169	125	204	38.7%

Table 3.5
Ammonia and Hydrogen Sulfide Concentrations Between the Lagoons

The spillway results are shown graphically in the following figure. Concentration values are in micrograms per cubic meter.

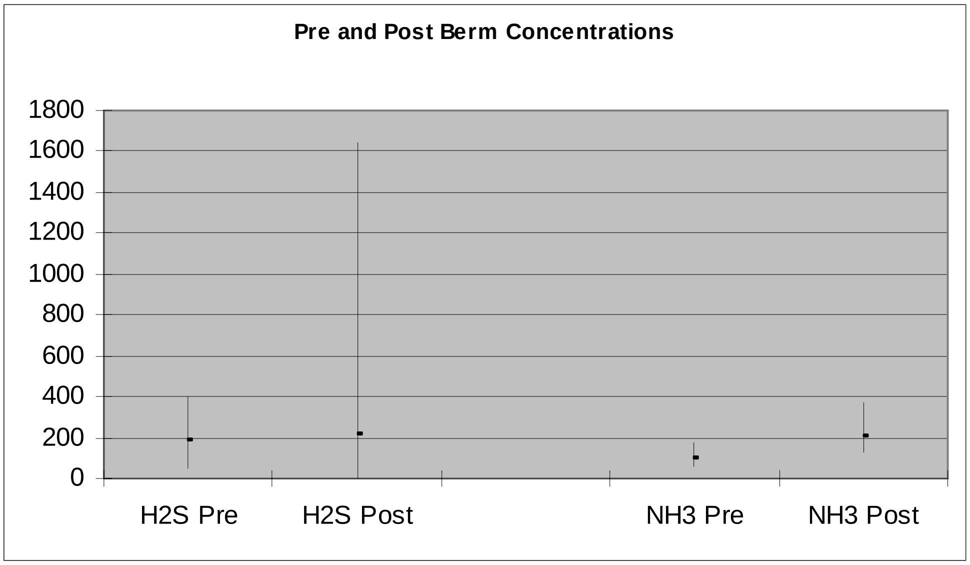

Figure 3.6
Pre- and Post-Berm Concentrations (Kewaunee County)

Manure Surface Sampling
Sampling at the manure surface using the flux chamber was conducted solely on the larger, second manure pit. The graphs below show the maximum, minimum and average values from flux samples collected from the manure surface before and after the installation of the permeable cover. Samples to the left and right represent those collected before and after installation of the cover, respectively.

It should be noted that following installation of the cover, there were significant challenges in maintaining a seal between the flux chamber and the surface sufficient to allow collection of samples. In addition to these difficulties, there was a general interest in sampling from different portions of the cover, so during one sample run the flux chamber might be in a puddle, while during the next it is on a dry patch. These differences contribute to the wide range seen in the results. It should also be noted that due to operator error, surface samples were not collected during the 7^{th} sample run.

Note that a logarithmic scale is used for the value axis, which is in micrograms per cubic meter. Note that the H_2S results following installation were non-detects, so that the graph shows the maximum possible values. These values are somewhat higher than desirable, and any future sampling at this location should use an increased sampling rate to reduce the detection limit.

All NH_3 samples showed detectable quantities both with and without the cover. It is interesting to note that the permeable cover has significantly reduced the H_2S concentrations observed at the lagoon surface, while not significantly affecting the NH_3 concentrations.

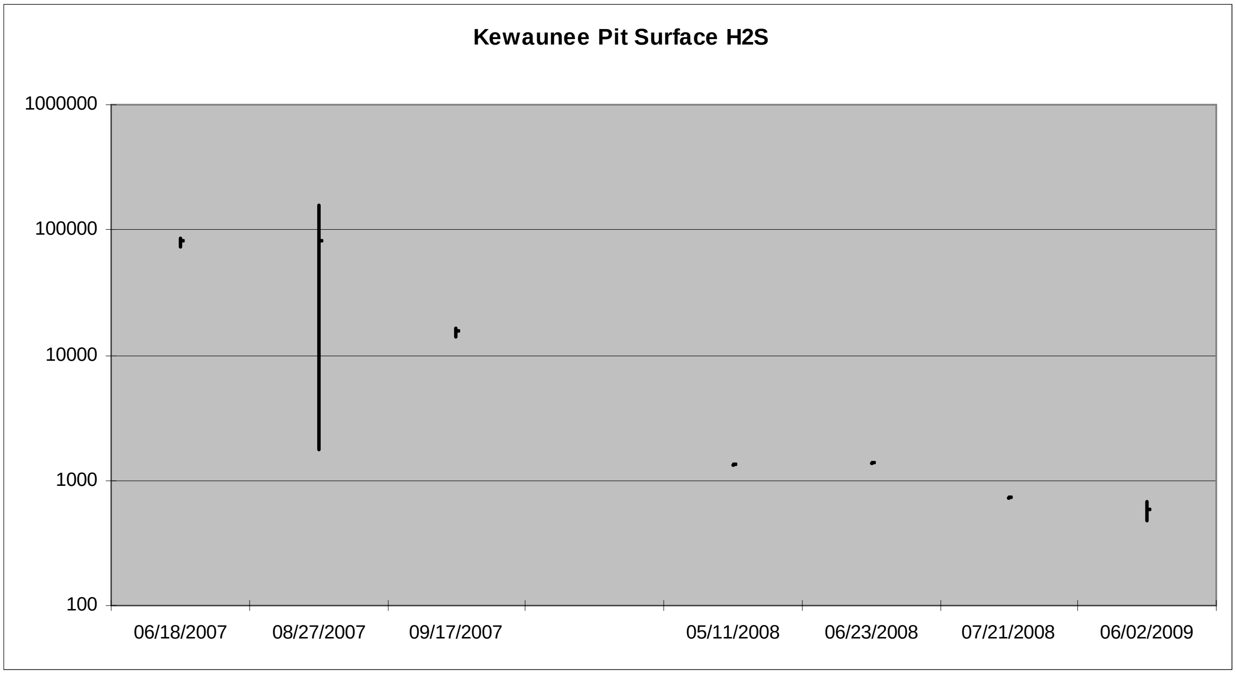

Figure 3.7
Lagoon Surface H_2S (Kewaunee County)

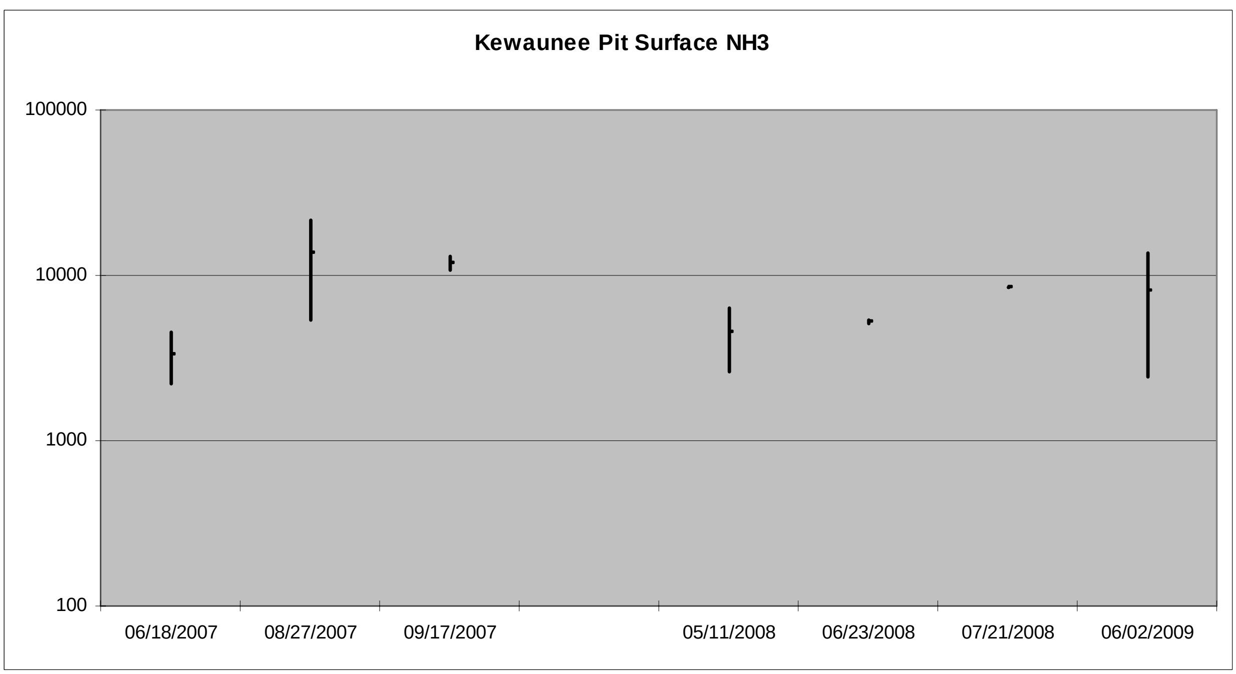

Figure 3.8
Lagoon Surface NH_3 (Kewaunee County)

Case Study 3 Key Findings Summary Statements

Installation of the semi-permeable cover appears to have led to reductions in lagoon perimeter ambient concentrations of both ammonia and hydrogen sulfide, although there is some ambiguity in this conclusion.

Ambient concentrations of both parameters observed near the spillway between the primary and secondary lagoons appear to increase following installation of the cover, in spite of the reduction of exposed surface area and turbulence afforded by replacing the open spillway with a submerged pipe.

Lagoon surface concentrations of hydrogen sulfide have been significantly reduced by installation of the cover, which reduced them to levels below the detection limit. The effect of the cover in reducing surface concentrations of ammonia was slight, if present at all.

Project Focus Key Comparison ~ Case Study 3: Permeable Cover (Kewaunee County) – Before Cover vs. After Permeable Cover

The outcome of the odor transects conducted on the three initial trips to the Kewaunee County farm are depicted in the data supplement. These represent the odors being generated by a typical earthen lagoon without a cover. The outcome of the odor transects conducted on the three follow-up trips to the same farm are depicted in the data supplement. These represent the odors being generated by the same lagoon with a permeable (Geotextile) cover installed.

Comparing these two sets of figures it appears that the cover was quite effective at controlling odors. This is not unexpected since the cover is acting like an artificial crust, which has been shown to reduce odors from lagoons on other farms.

Graphing the odor readings from this lagoon, both before and after the installation of the cover, it becomes clear how effectively the cover controlled odors (see Figure 3.9). By averaging the results from each set of trips, the overall reduction in odor is about 80% (+/-10%) for the first year, and about 60% (+/- 10%) for the second year. However, note that the vertical lines representing the range of values observed at each location display some overlap in the data.

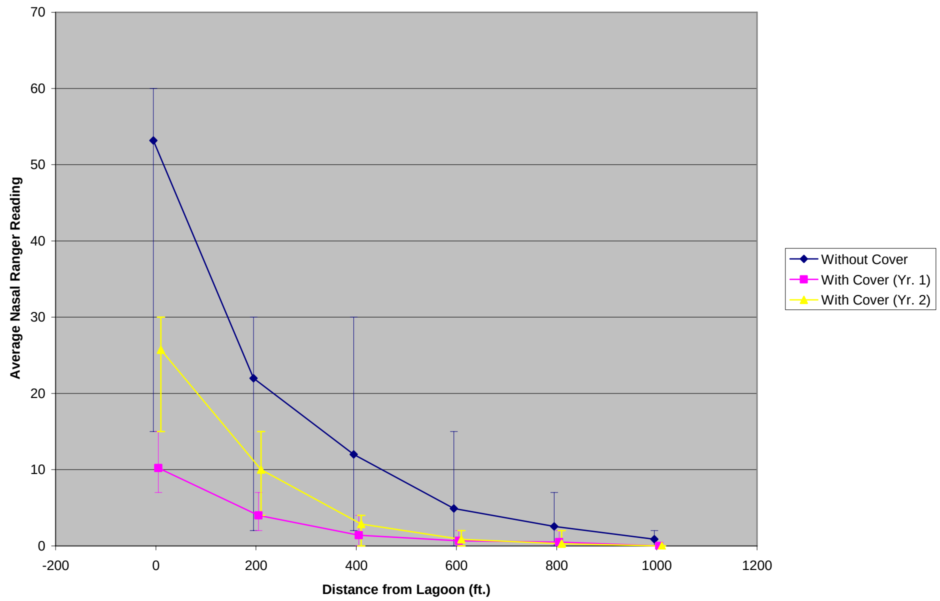

Figure 3.9
Average Nasal Ranger™ Reading at 200 ft Intervals
Before Cover vs. After Permeable Cover (Kewaunee County)

The flux chamber testing from this lagoon, with and without the cover, mirrored our Nasal Ranger™ readings. Figure 3.10 below is a bar graph depicting the laboratory-determined odor intensities of our flux chamber samples. The first three bars are for samples taken from the lagoon surface before the cover was installed, and the last four bars are for samples taken directly off the geotextile cover.

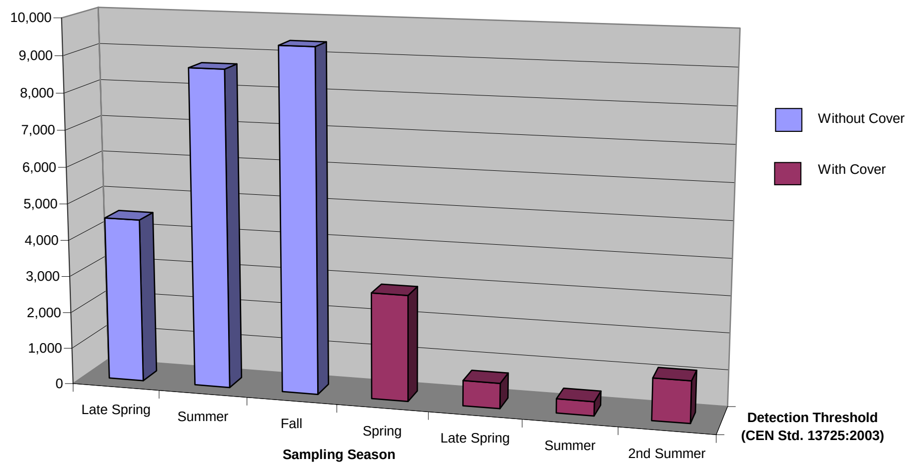

Figure 3.10
Flux Chamber Seasonal Average Detection Threshold
Before Cover vs. After Permeable Cover (Kewaunee County)

These data support the Nasal Ranger™ findings that a permeable cover can provide a high level of odor control. The follow-up data from the second year seem to indicate that the level of control dropped off over time, however, the overall performance was still very good. We hope to continue to monitor this installation to determine the long term performance of this control technology.

Figure 3.11 below shows the comparison of Nasal Ranger™ readings taken in the field at our Kewaunee County farm, to the calculated odor scores for the waste storage lagoon on that farm. The odor score was calculated for the lagoon assuming the nearest neighbor was located at various distances downwind. These scores were plotted against separation distance to create an odor score curve. The Nasal Ranger™ odor results were then plotted against distance on the same graph. This allowed us to determine the measured average odor level at the distance that corresponds to a passing odor score of 500.

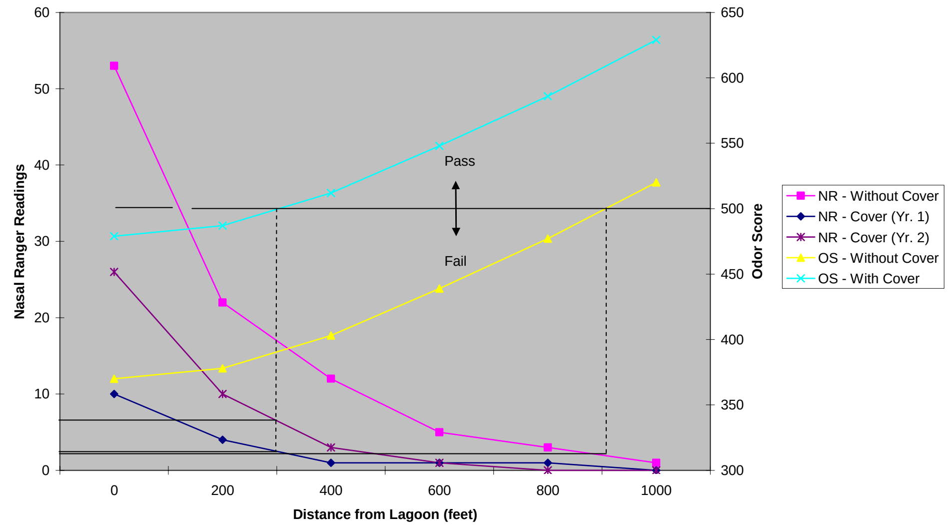

Figure 3.11
Comparison of Nasal Ranger™ Field Readings to the Odor Score Before Cover vs. After Permeable Cover (Kewaunee County)

Looking at these results, we see a very good correlation between the field readings and the predicted odor score. The yellow line with triangles is the odor score curve before a cover was installed, and the red line with squares is the "before" field readings curve. Drawing a horizontal line at a passing odor score of 500, and then dropping down from where that line intersects the odor score curve, we see that the point corresponds with a separation distance of just over 900 feet. At this distance the Nasal Ranger™ field readings averaged around 2, the lowest measureable reading. This indicates that for medium sized waste storage lagoons (3.8 acres) the odor standard was collaborated by our field odor measurements.

Following the same exercise with the permeable cover installed, the horizontal passing score line intersects the blue curve with X's at a separation distance of 300 feet. This in turn corresponds with an average "after" Nasal Ranger™ reading the first year (black curve with diamonds) of just over 2 and an average reading the second year (yellow line with triangles) of about 6, both acceptable levels. This indicates that the odor control credit given for permeable covers in the odor standard was collaborated by our field odor measurements.

Case Study 4: Solids Separation and Aeration (Monroe County)

Background

Our Monroe County farm was the smallest of our farms in the study, as well as being the newest. This was a green field site where a state-of-the-art dairy was built from the ground up in about two year's time (see Figure 4.0). The freestalls house 357 milking cows, 30 freshening heifers, and 50 calves. The cows are bedded on sand; however, the plan is to eventually bed them on separated manure solids, once the system is fully functional. Flushing the alleys with recirculated waste from the secondary basin cleans the single freestall barn multiple times daily.

Figure 4.0
Monroe County Farm Layout

The practice being evaluated for our study was solids separation and basin aeration (see Figures 4.1 & 4.2). This is a proprietary system developed by *Integrity Co.*, Chambersburg, PA. Flushed wastes coming from the freestall barn are passed through a screen press separator, which removes most of the liquids from the manure. These liquids are piped to a 1 million gallon primary waste storage lagoon, which then overflows to a 4 million gallon secondary lagoon. Manure solids (containing about 80% moisture) are stockpiled on a concrete pad. The recovered solids are currently being used as a soil amendment, however as mentioned earlier, they eventually will be used as bedding material in the freestall barn.

Figure 4.1
***Integrity Co.*, Solids Separators**

Figure 4.2
Floating Aerator on Secondary Basin

The small primary waste storage lagoon is equipped with a single floating aerator and the large secondary lagoon is equipped with two. The following explanation provided by the system developer describes the theory behind how the system functions:

> "Two *Integrity* Roller Press Separators are utilized to remove the coarse solids matter to allow for proper operation of the aeration system and to allow for irrigation and flushing of the separated effluent. All of the flushed manure, bedding, and parlor inputs are processed through these units. They are controlled via automatic level controls for operation throughout the day.
>
> Separated liquids flow via gravity into a dual stage lagoon system. The first stage is approximately 948,000 gallons with the secondary basin being 4.1 million gallons. The first basin is designed as a primary treatment basin allowing for increased detention of the liquid flow for additional treatment. One 5 HP aspirating style aerator will be used on this basin using a facultative treatment approach. The basin is maintained at a full liquid level throughout the year, with the exception of periodic sludge removal events.
>
> The secondary aerated treatment basin performs a treatment role primarily through induced settling and a storage function for wastewater inputs. It is also the location from which primary recycled flushwater and land applied liquids will be withdrawn. This basin will also use a facultative style treatment approach in which two 5 HP floating aspirating style aerators will be used to induce oxygen into the upper three feet of the basin. This facultative style treatment, rather than full aerobic treatment,

helps minimize horsepower and operating inputs. A dissolved oxygen level equal to or greater than 0.1 mg/L will be the target maintenance level. These aerators work by using a directly connected motor to spin a hollow shaft fitted with a propeller at the far end. This creates a venturi effect that draws air down through the main aerator tube where it is injected below the surface and is forced forward by the propeller. A minimum depth will be maintained in the treatment basins so as to not force settled solids off the bottom.

The aeration is not designed to fully treat the BOD load, rather it is meant to improve the overall quality of the recycled water in relation to odor level and mucous content. The lower aeration level also helps to minimize sludge production from aerobic treatment processes. Aerated liquids from the upper levels of the secondary basin will be drawn off and used for flushing the freestall barn. When it is necessary to lower the basin level, some of these liquids will occasionally be drawn off for land application." (Source: Provided by *Integrity Co.* <http://www.integrityagsystems.com/>)

During our first visits to this farm the solids separation equipment had been installed and tested, but was not running, therefore unseparated wastes were being sent directly to the first basin. Also, the floating aerators were on site, but had yet to be installed. This provided an opportunity for us to do some "before" sampling. On our subsequent visits the following year, the two separators and three aerators were all operational, giving us an "after" picture.

Case Study 4 Results Discussion

General Sampling Overview

A total of six sampling runs were made to this facility, with two performed before the aerator was turned on, and two during each of the next two years following. Solids separation was functioning for all runs. During the first sampling run, the second manure pit was nearly empty. A total of 278 samples for NH_3 and 278 for H_2S have been collected, of which 258 NH_3 and 263 H_2S have been submitted to the laboratory for analysis. Void samples are evenly distributed and no single run experienced sufficient sample loss to invalidate it.

A summary of the test dates and general conditions is shown in the following table. Parameters include the testing start date and the vector mean wind speed (in meters/sec.), wind direction (in degrees from north) and temperature (in degrees Celsius) for both the daytime (AM) and nighttime (PM) sampling runs. Note that the test continued to the day following the test date.

Date	AM			PM		
	VMWS	VMWD	T(C)	VMWS	VMWD	T(C)
06/11/2007	7.7	170	26.8	1.1	60	16.4
10/29/2007	4.9	200	14.0	2.3	180	7.7
06/09/2008	8.1	250	22.8	1.2	140	15.9
07/07/2008	4.5	170	24.4	4.7	210	20.6
05/19/2009	10.9	195	26.4	10.4	180	24.3
06/16/2009	13.2	100	22.4	3.9	80	15.6

Table 4.0
Monroe County Test Dates and Basic Meteorology

Standard sampling protocols have been followed for all tests conducted at this site. Additional sampling was conducted in several locations, including inside the second manure pit near the outfall pipe during the first sampling run when the pit was nearly empty, near the separator building, and multiple barn oriented samples.

A significant fraction of all successful duplicate samples were collected at Monroe (17 of both H_2S and NH_3 pairs) Of these, four H_2S and six NH_3 sampling pairs failed quality criteria. The average RPD of all H_2S duplicate samples is 17.3%, and the average RPD of the NH_3 samples is 42.3%. Removing the two worst NH_3 duplicates from consideration provides an RPD of 26.2%.

Four H_2S blanks collected showed detectable quantities, with an average of 5.9 μg/sample. The blank levels were subtracted from the results reported by the lab. All other blanks contained non-detectable levels of the parameters.

Ambient Sampling

Figures showing the results described herein are located in the Project Data Supplement in chronological sequence.

This facility is relatively unique among the farms we have chosen to sample. It is by far the smallest operation in terms of animals on site. It is the newest operation, although some of the facilities added on during the course of our study and therefore have newer portions. The initial manure storage lagoon has the smallest surface area of any of the manure lagoons sampled. The size of this lagoon allowed for us to deploy a greater coverage of samplers than anywhere else in our study, thereby providing much a much tighter spatial distribution of results. Especially during some of the later sample sets, distances between samplers could be as low as 25 feet or less.

Interpretation of results obtained from sampling around the lagoons at this facility is complicated by the fact that the farm was new from the ground up, and during the initial sampling run (in June, 2007) the secondary storage lagoon was almost empty. The following sampling trip occurred at the end of October 2007, in significantly cooler weather than the post-practice installation sampling runs. The comparison between the different trips is radically impacted because of these conditions.

For example, during the first sampling run, conducted on June 11 and 12, 2007, ambient concentrations observed around the second manure lagoon (locations 11 – 21) are generally lower than those around the smaller lagoon. This is undoubtedly related to the smaller lagoon being full, and the second being nearly empty.

While this situation was rectified by the time of the second sampling trip in October 2007, and concentrations around the lagoons are similar, the overall magnitude of the concentrations is significantly less than the maximum samples observed during all other testing runs. The cause of this is likely related to the cooler weather, but fully evaluating the impact of this based on our results is not really feasible.

The combination of these factors, plus the very limited sampling conducted around this facility (2 tests pre-installation, and 2 tests post), leads to a situation wherein there are apparently significant increases in nearby ammonia and hydrogen sulfide concentrations following installation of the aerators, especially during the first year following installation. Discerning the validity of this observation is the challenge in evaluating this dataset.

Summaries of the downwind samples for each parameter are tabulated in the following tables. Values documented in the tables are the averages, maxima and minima of the three highest downwind results, as well as the relative standard deviation (RSD), which is a measure of the variability of the results. Note that “ND” indicates that no samples showed detectable quantities of the parameter of interest. In determining the overall average, tests with no detects are averaged in at zero.

UPPER	Run 1	Run 1e	Run 2	Run 2e	Overall	Day	Night
Avg	743	450	232	272	424	488	361
Max	817	586	282	345	817	817	586
Min	611	375	186	219	186	186	219
RSD	15.5%	26.1%	20.7%	24.2%	52.9%	59.6%	36.0%
LOWER							
Avg	105	121	241	154	155	173	138
Max	125	207	312	169	312	312	207
Min	92	51	152	130	51	92	51
RSD	16.0%	65.8%	33.7%	13.6%	47.6%	52.4%	40.1%

Table 4.1
Downwind Ammonia Concentrations
Near Upper & Lower Manure Lagoons, Pre-Installation

UPPER	Run 3	Run 3e	Run 4	Run 4e	Overall	Day	Night
Avg	725	1068	843	600	809	784	834
Max	1036	1211	871	837	1211	1036	1211
Min	542	855	798	373	373	542	373
RSD	37.4%	17.6%	4.6%	38.7%	30.9%	23.6%	38.2%
LOWER							
Avg	1364	487	802	664	829	1083	576
Max	1890	699	945	775	1890	1890	775
Min	897	292	624	576	292	624	292
RSD	36.6%	41.9%	20.4%	15.2%	50.7%	41.8%	30.2%

Table 4.2
Downwind Ammonia Concentrations
Near Upper & Lower Manure Lagoons, Post-Installation

UPPER	Run 5	Run 5e	Run 6	Run 6e	Overall	Day	Night	All Post
Avg	600	431	755	545	596	677	499	707
Max	1082	476	951	657	1082	1082	657	1211
Min	307	386	431	438	307	307	386	307
RSD	70.0%	14.7%	37.5%	20.1%	43.7%	48.9%	20.9%	38.4%
LOWER								
Avg	439	402	365	297	377	410	349	613
Max	923	670	702	373	923	923	670	1890
Min	170	83	29	230	29	29	83	29
RSD	95.6%	73.9%	130.4%	24.2%	75.0%	93.5%	57.7%	68.9%

Table 4.2a
Downwind Ammonia Concentrations
Near Upper & Lower Manure Lagoons, 2nd Year Post-Installation

UPPER	Run 1	Run 1e	Run 2	Run 2e	Overall	Day	Night
Avg	90	47	27	52	54	59	49
Max	122	63	31	76	122	122	76
Min	55	37	23	34	23	23	34
RSD	37.5%	30.1%	14.9%	41.6%	55.6%	69.3%	33.5%
LOWER							
Avg			19		45		
Max	122	ND	22	ND	122		
Min			15		15		
RSD			19.3%		114.9%		

Table 4.3
Downwind Hydrogen Sulfide Concentrations
Near Upper & Lower Manure Lagoons, Pre-Installation

UPPER	Run 3	Run 3e	Run 4	Run 4e	Overall	Day	Night
Avg	454	253	306	452	358	365	352
Max	495	454	527	685	685	527	685
Min	413	109	149	69	69	149	69
RSD	12.8%	70.7%	64.5%	74.0%	59.5%	44.9%	74.7%
LOWER							
Avg	78	76	55	37	61	66	57
Max	146	126	65	54	146	146	126
Min	36	49	46	14	14	36	14
RSD	76.6%	57.1%	18.2%	56.7%	60.6%	60.7%	65.7%

Table 4.4
Downwind Hydrogen Sulfide Concentrations
Near Upper & Lower Manure Lagoons, Post-Installation

UPPER	Run 5	Run 5e	Run 6	Run 6e	Overall	Day	Night	All Post
Avg	357	373	261	240	302	309	293	330
Max	697	569	549	356	697	697	569	697
Min	186	178	86	178	86	86	178	69
RSD	82.6%	74.1%	96.3%	41.8%	68.9%	81.1%	58.5%	62.9%
LOWER								
Avg	140	159	45	61	101	93	110	81
Max	231	182	89	88	231	231	182	231
Min	36	128	18	40	18	18	40	14
RSD	70.1%	17.6%	83.4%	40.2%	68.8%	90.9%	53.2%	71.7%

Table 4.4a
Downwind Hydrogen Sulfide Concentrations
Near Upper & Lower Manure Lagoons, 2nd year Post-Installation

The figures below and on the following pages represent this data in max/min charts. The values on the (Y) axis are in micrograms per cubic meter.

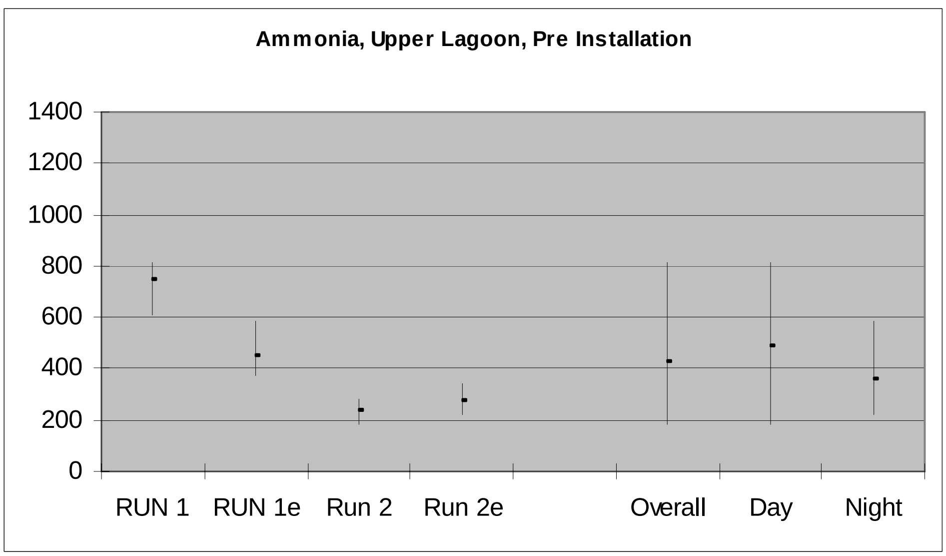

Figure 4.3
Ammonia, Upper Lagoon, Pre-Installation (Monroe County)

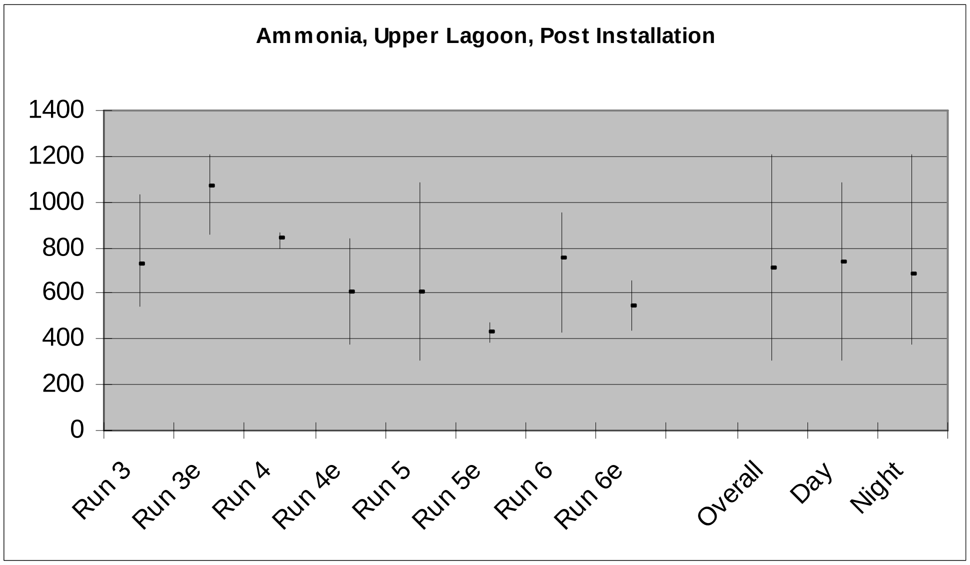

Figure 4.4
Ammonia, Upper Lagoon, Post-Installation (Monroe County)

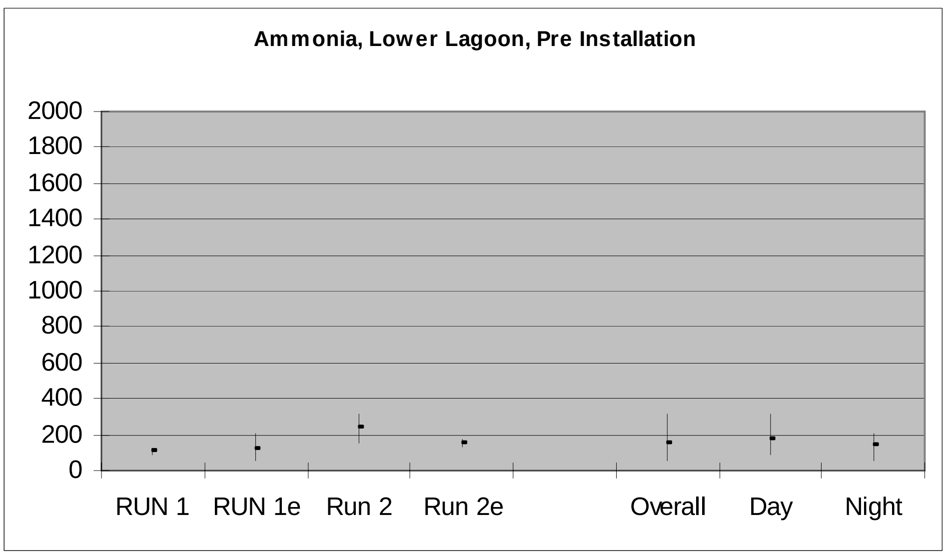

Figure 4.5
Ammonia, Lower Lagoon, Pre-Installation (Monroe County)

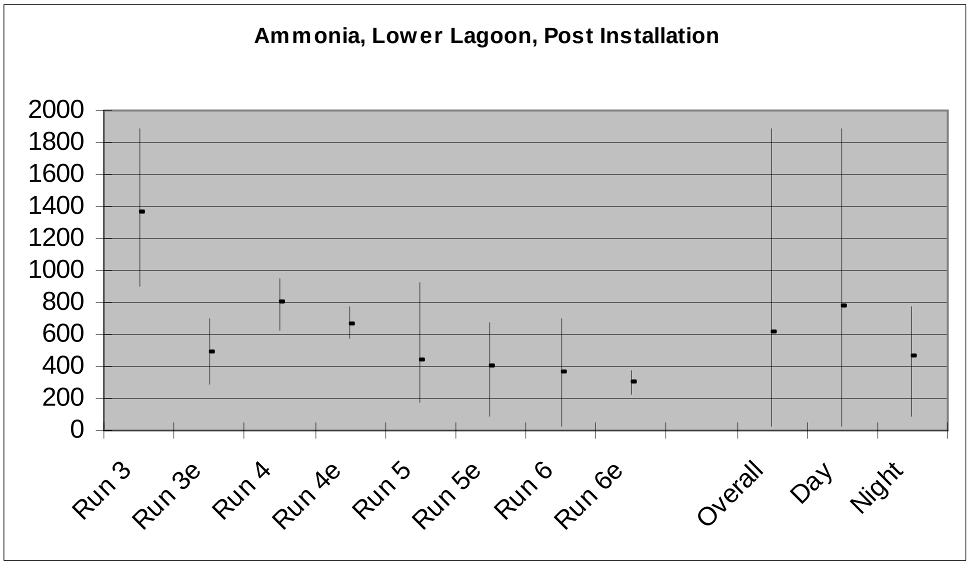

Figure 4.6
Ammonia, Lower Lagoon, Post-Installation (Monroe County)

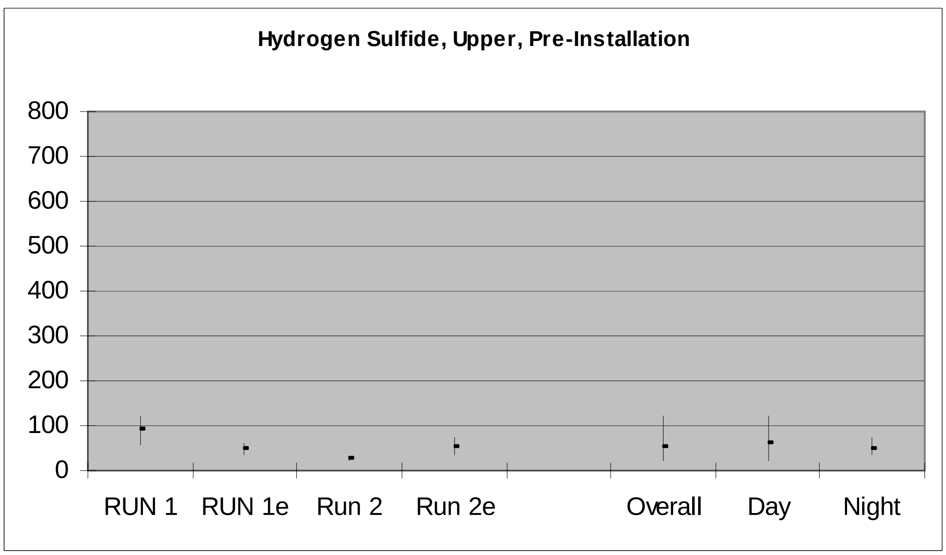

Figure 4.7
Hydrogen Sulfide, Upper Lagoon, Pre-Installation (Monroe County)

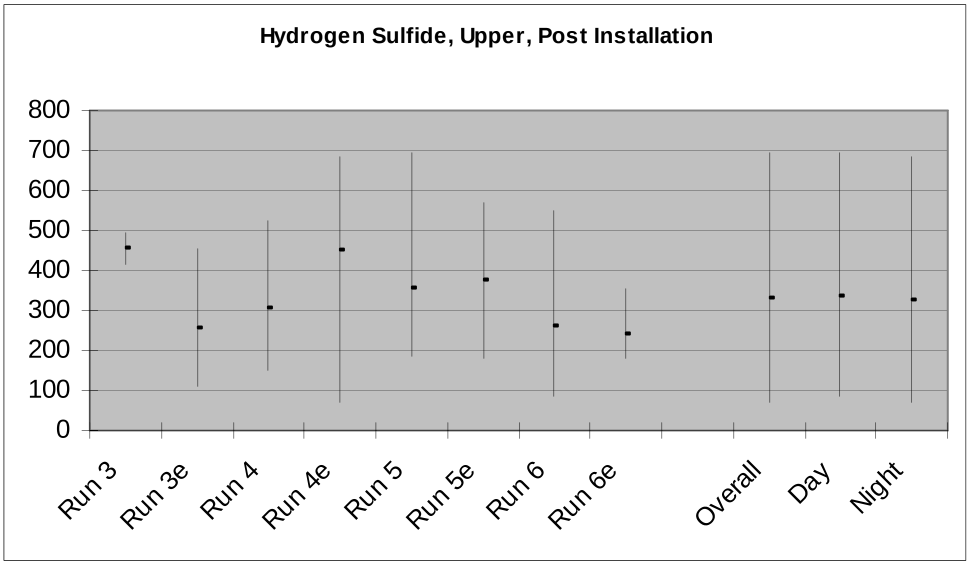

Figure 4.8
Hydrogen Sulfide, Upper Lagoon, Post-Installation (Monroe County)

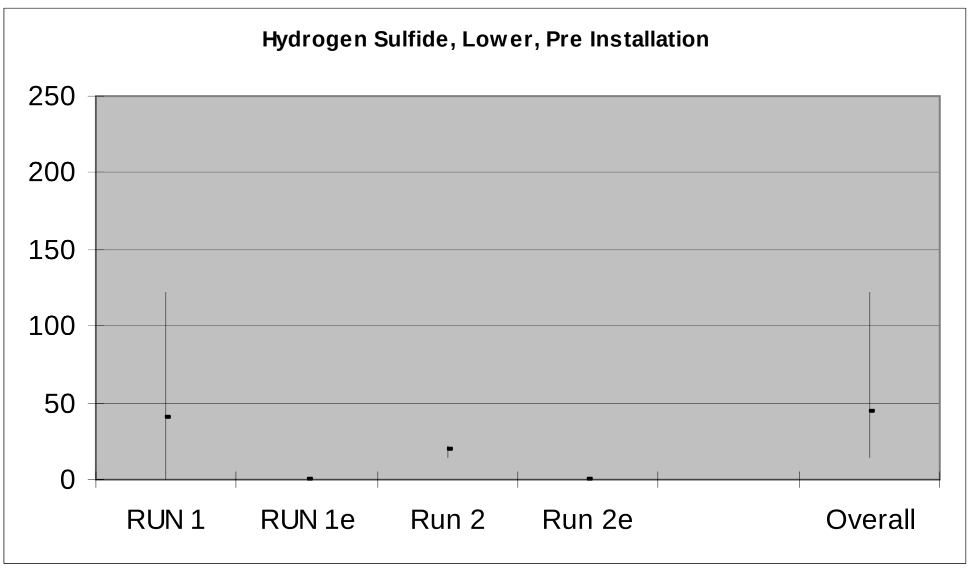

Figure 4.9
Hydrogen Sulfide, Lower Lagoon, Pre-Installation (Monroe County)

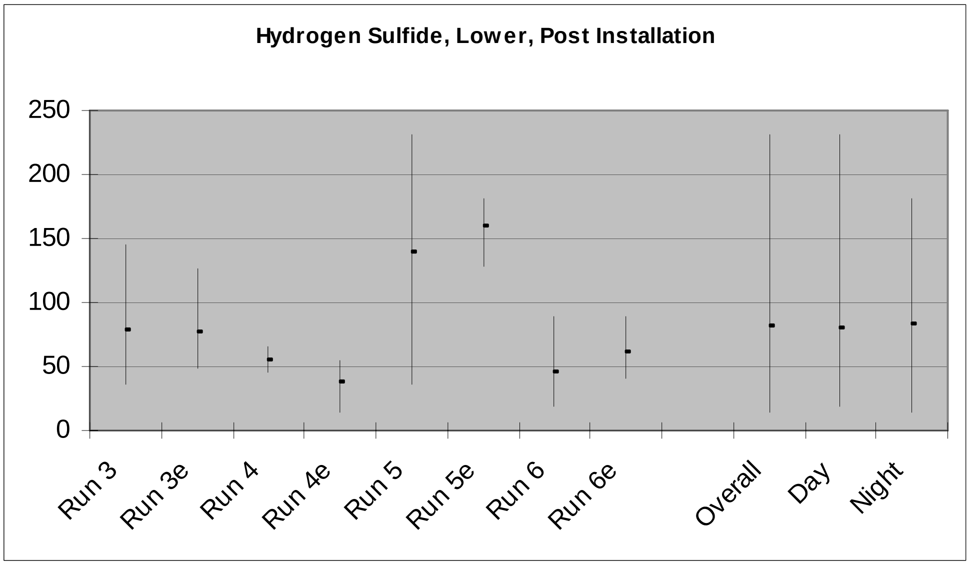

Figure 4.10
Hydrogen Sulfide, Lower Lagoon, Post-Installation (Monroe County)

Data in the tables appears to support the contention that ambient concentrations of both parameters increased following installation of the aeration system, especially hydrogen sulfide concentrations around the upper lagoon. It is important to note, however, that the impacted area appears to be quite small, with adjacent samples returning radically divergent results, even though as little as 25 feet or less may be between them.

The probable cause of this is likely related directly to the aeration units themselves. When a sampler just happens to be directly downwind of one of the aeration units, significantly elevated concentrations are likely to be observed. This situation probably pertains to the large lagoon as well, although results don't necessarily illustrate this point, perhaps because none of our samplers were located directly downwind, or because a greater minimum separation distance was present between the berm and the aeration units, or possibly because the surface of the manure in the larger lagoon was lower relative to the surrounding berm than it was for the smaller lagoon. It should be noted that it is also possible that less hydrogen sulfide is present around the larger lagoon because, in fact, the amount of this compound available in the manure may be reduced.

While none of our sampling sets truly has enough depth for statistically significant conclusions to be drawn from them, and all of the facilities altered on-farm conditions during the study, the data from this farm is the weakest overall. While individual sampling runs are as solid as any of the others, the situational differences between the sampling runs are huge, thereby rendering our sample set inadequate, especially in terms of the pre-installation samples.

In addition to the lagoon oriented ambient sampling, several barn oriented samples were collected during the course of the visits to this facility. These samples include several from downwind of the freestalls, and two pair collected at either end of the eastern freestall.

The locations downwind from the freestalls were about 35 – 50 meters north of the structures during the first sampling run. Two samplers were deployed, one directly to the north of each freestall. During the second sampling trip, the easternmost of these locations was retained, while a second location was established in the corn field about 30 – 40 meters to the east of the freestall, about halfway along its length. During the final sampling run, two extra samplers were available and were deployed just inside the eastern freestall.

Samples collected downwind of the freestalls showed no detectable hydrogen sulfide (with detection limits ranging from 12 – 18 μg/m^3). Ammonia results from these samples are shown in the table below, along with both ammonia and hydrogen sulfide results from the samples collected inside the barns. Note that the "upwind" barn samples were not only still inside the barn, they were downwind of the upper manure lagoon.

	Ammonia	**Ammonia In**		**Hydrogen Sulfide In**	
	Downwind	**Upwind**	**Downwind**	**Upwind**	**Downwind**
Average	87	191	1963	24	32
Max	139	223	2453	32	37
Min	38	160	1473	15	26
RSD	40.6%	23.2%	35.3%	50.9%	23.1%

Table 4.5
Barn Related Ammonia and Hydrogen Sulfide Results

Manure Surface Sampling

During the first run it was only possible to sample on the surface of the small upper manure lagoon because the second lagoon did not hold sufficient material. Following this run, both pits were sampled. Results are shown in the following figures, with the upper pit results to the left and the lower to the right. Note that sampling in 2007 was conducted prior to aeration, while 2008 sampling runs occurred after the system was operating. Sample units are micrograms per cubic meter, presented on a logarithmic scale. Note that while initial H_2S values obtained at the surface of the manure appear to decrease following aeration, second year results are not as clear in this respect. The ammonia values show a general increase during the first year, and a possible increase the second year.

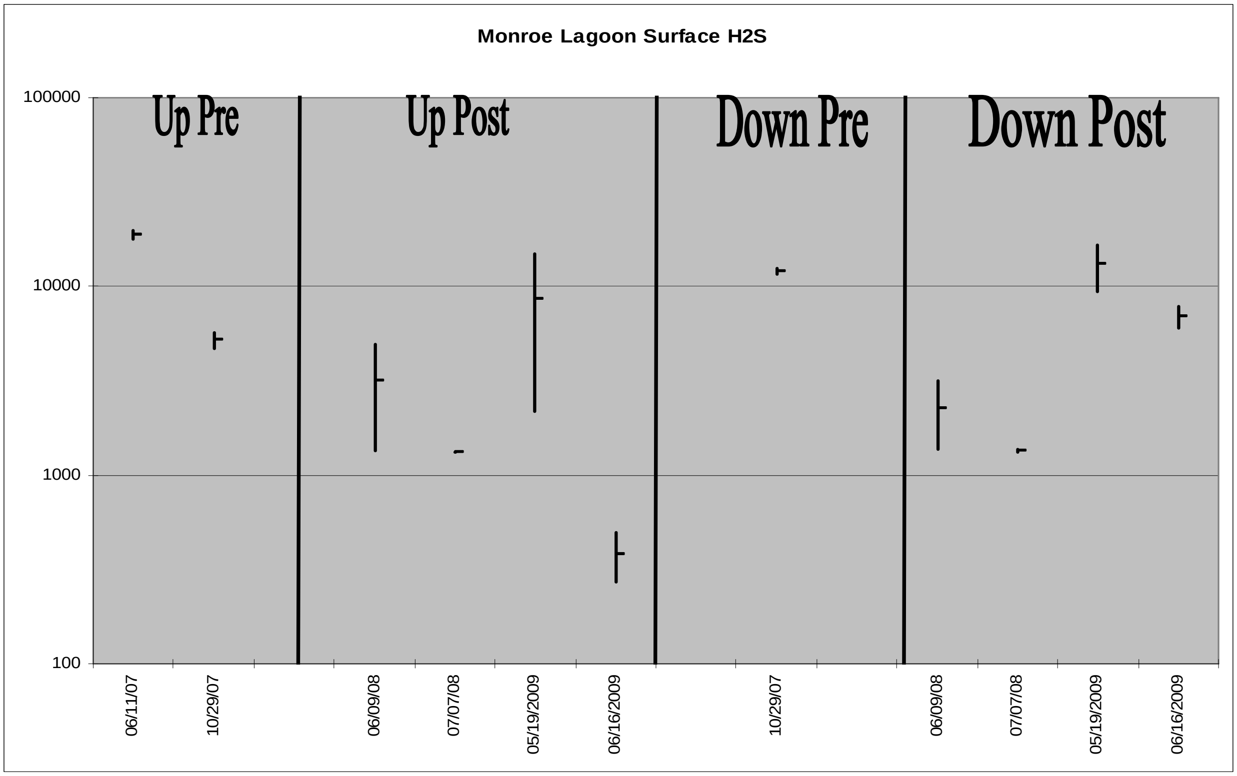

Figure 4.11
Lagoon Surface H_2S (Monroe County)

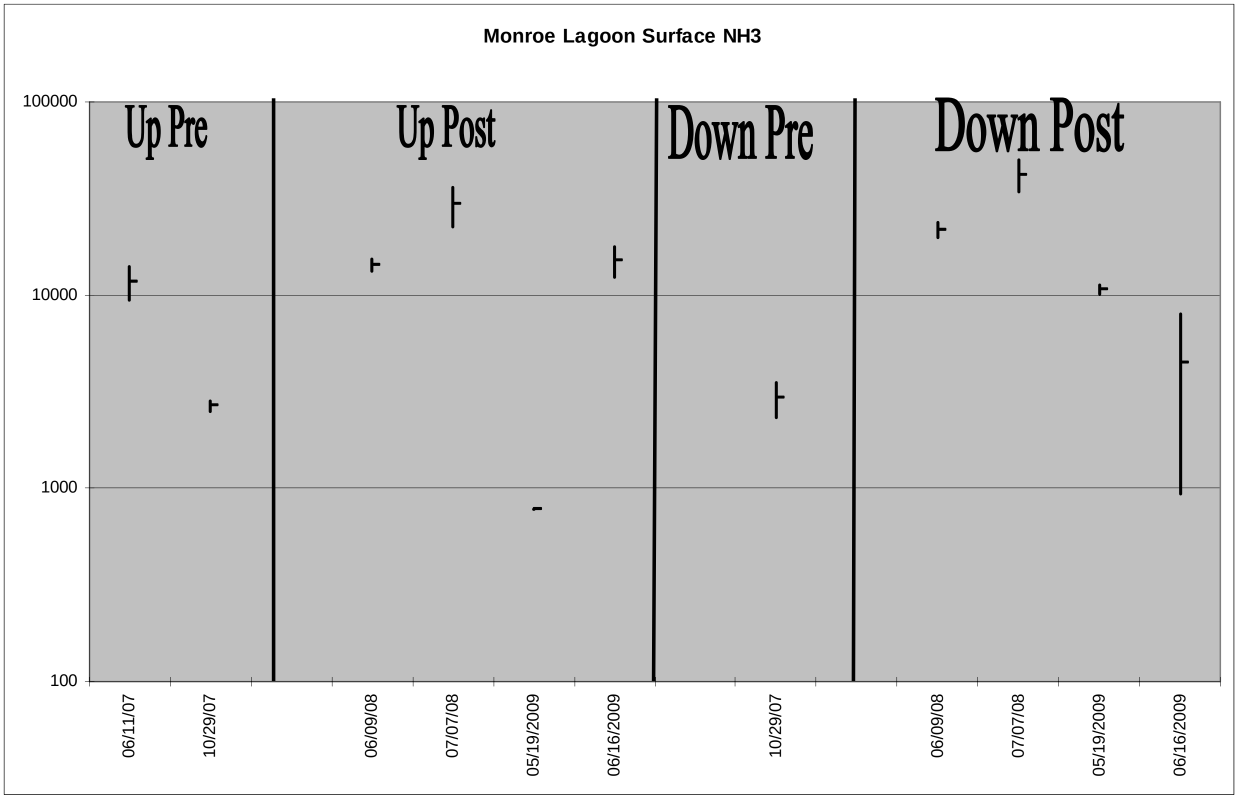

Figure 4.12
Lagoon Surface NH_3 (Monroe County)

Case Study 4 Key Findings Summary Statements

Changes on this farm during the sampling process, combined with the fewest sampling trips before and after installation of a practice, render this data set our most tenuous.

Aeration appears to induce ambiguous and potentially contradictory changes to the parameters we measured during this project. Local concentrations of hydrogen sulfide appear to be significantly elevated after installation, but on a very limited spatial scale. Meanwhile, surface concentrations of this parameter appear to be significantly reduced following aeration. A possible explanation of this combination of factors is that the aeration process is simply aspirating the hydrogen sulfide out of the surface layers of the lagoon, thus reducing surface concentrations while raising ambient concentrations directly downwind.

The effect of aeration on ammonia generation by the lagoons is less clear. Local ambient concentrations may be increased, but insufficient pre-installation data was obtained for this to be a firm conclusion. Surface concentrations of this parameter appear to be significantly elevated following aeration, but potential causes of this possible outcome are entirely unknown at this time.

Project Focus Key Comparison ~ Case Study 4: Solids Separation and Aeration (Monroe County) – Before Practice vs. After Solids Separation and Aeration

The outcome of the odor transects conducted on the two initial trips to the Monroe County farm are depicted in the data supplement. These represent the odors being generated by a typical two-stage earthen lagoon without treatment. The outcome of the odor transects conducted on the four follow-up trips to the same farm are depicted in the data supplement. These represent the odors being generated by the same lagoons after a solids separation and aeration system was installed.

Comparing these two sets of figures it appears that this proprietary system was only slightly effective at controlling odors. Although odors were somewhat reduced overall, the agitation of the lagoon surface caused by the aerators created localized areas of high odor levels.

Graphing the odor readings from these lagoons, both before and after the installation of the system, some reduction in odor appears to be provided by solids separation and aeration, especially beyond 100 feet from the lagoons (see Figure 4.13). By averaging the results from each set of trips, this difference is about a 20% (+/-10%) reduction in odors the first year, and about a 25% (+/-10%) reduction the second year. Note that the vertical lines representing the range of values observed at each data point display considerable overlap. The apparent spike in odor levels adjacent to the lagoons after the system was installed could be attributed to the localized areas of high odor caused by the aerators agitating the lagoon surface. This localized effect quickly dissipates at distances of 100 feet and more from the lagoons.

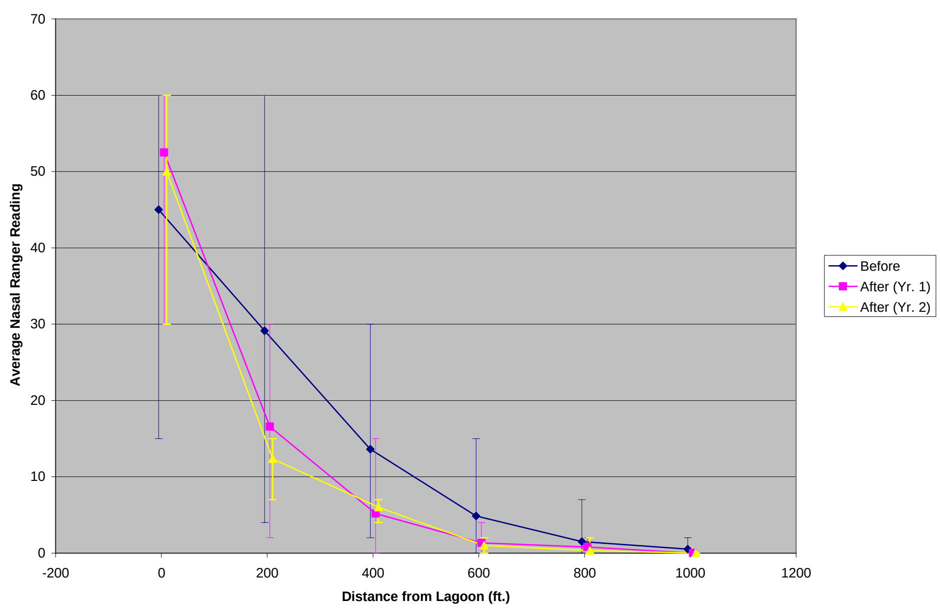

Figure 4.13
Average Nasal Ranger^{TM} Reading at 200 ft Intervals
Before Practice vs. After Solids Separation and Aeration (Monroe County)

The flux chamber testing from these lagoons, before and after the practice was installed, indicated somewhat better odor control than did our Nasal Ranger™ readings. Figure 4.14 below is a bar graph depicting the laboratory-determined odor intensities of our flux chamber samples. The blue bars are for samples taken from the lagoons before the system was installed, and the magenta bars are for samples taken after the system was in place and operational.

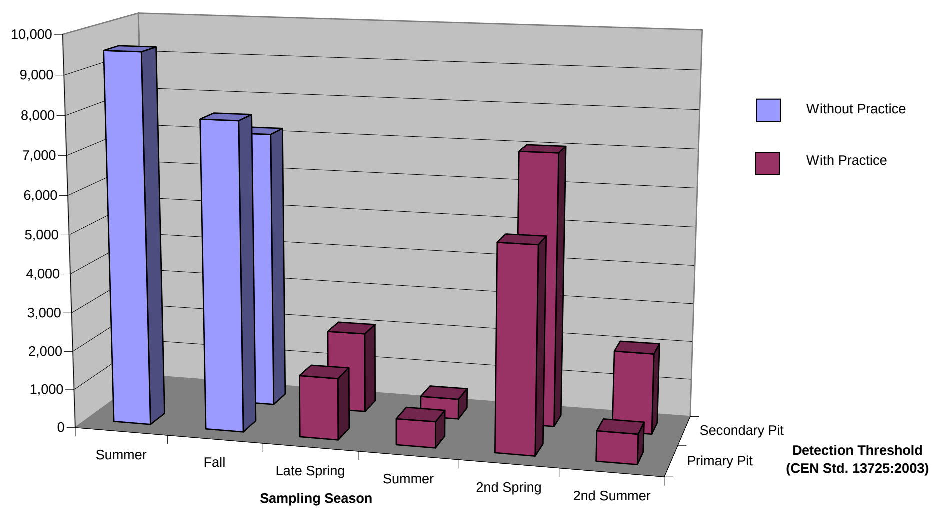

Figure 4.14
Flux Chamber Seasonal Average Detection Threshold
Before Practice vs. After Solids Separation and Aeration (Monroe County)

These data are more encouraging than our Nasal Ranger™ findings, however they may be biased due to the fact that we could not sample the surface near the aerators, because of turbulence. Again, getting a representative sample with the flux chamber was quite challenging. Also of note are the high readings in the spring of the second year. This may be attributable to the fact that these samples were taken earlier in the year, and it had been a cool spring, therefore the biological system may not have had a chance to become fully operational.

Comparing the volatile fatty acid levels in the lagoons before and after the installation of this system seems to indicate that it could lead to increased odors (see Figure 4.15 below).

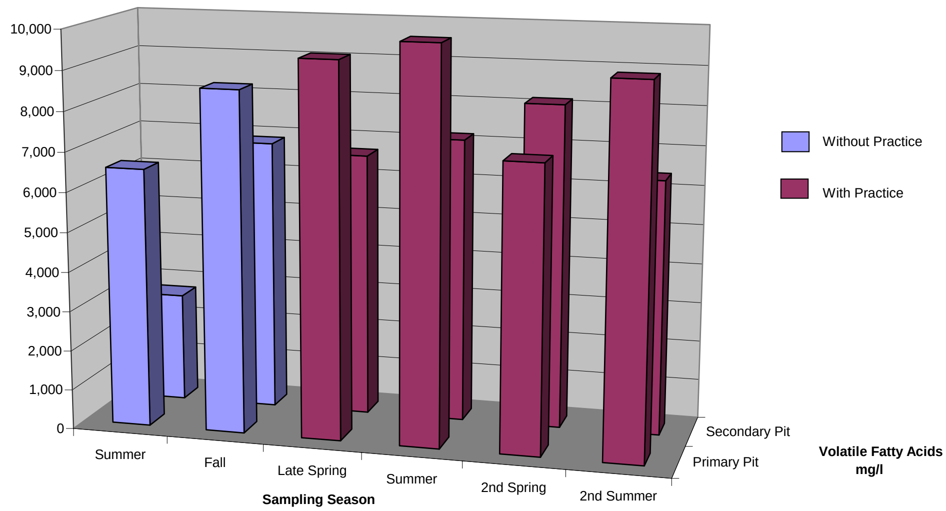

Figure 4.15
Volatile Fatty Acids, mg/l
Before Practice vs. After Solids Separation and Aeration (Monroe County)

The blue bars are the volatile fatty acid levels prior to the system being installed, and the magenta bars are the levels following installation. These results run counter to our field observations of reduced odor after the system was installed. This further supports conventional thinking that no one parameter can be used to accurately predict odor emissions from manure pits. Rather, odors are a result of many components operating in synergy.

Anecdotally, the landowner indicated that he was very pleased with this system. When he land applied manure from these pits in early spring he noticed far less solids accumulation than before. And he said that his neighbors actually commented to him about how fewer odors there were coming from his fields compared to years past.

Figure 4.16 below shows the comparison of Nasal Ranger™ readings taken in the field at our Monroe County farm, to the calculated odor scores for the small waste storage lagoon, using the odor model in ATCP 51. The odor score was calculated for the primary lagoon assuming the nearest neighbor was located at various distances downwind. These scores were plotted against separation distance to create an odor score curve. The Nasal Ranger™ odor results were then plotted against distance on the same graph. This allowed us to determine the measured average odor level at the distance that corresponds to a passing odor score of 500.

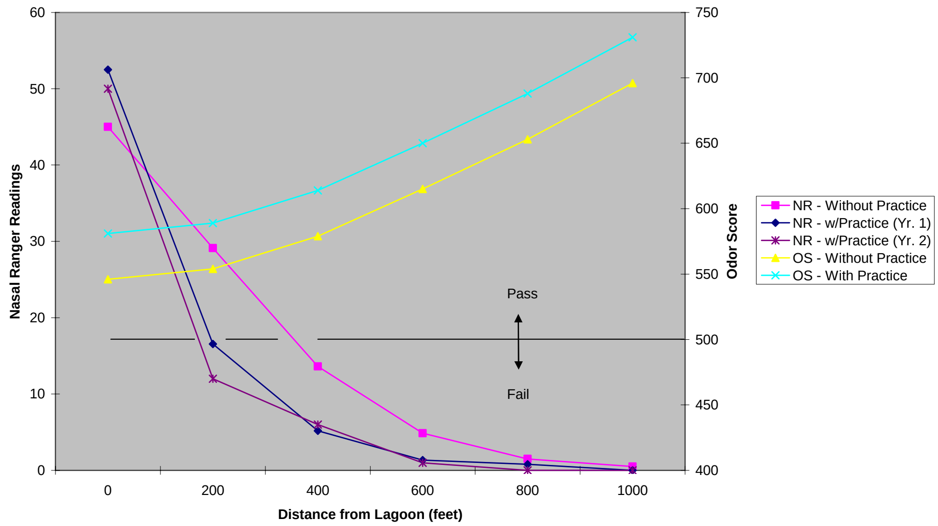

Figure 4.16
Comparison of Nasal Ranger™ Field Readings to the Odor Score Before Practice vs. After Solids Separation and Aeration (Monroe County)

Looking at these results, we see a poor correlation between the field readings and the predicted odor score. The yellow line with triangles is the odor score curve before the solid separation and aeration system was installed, and the red line with squares is the "before" field readings curve. Drawing a horizontal line at a passing odor score of 500, nowhere does the odor score drop below it, indicating that a passing score can be achieved at any separation distance. However, the average Nasal Ranger™ field readings indicate unacceptable odors as far away as 750 feet from the lagoon. This indicates that the odor standard may under predict odors from small waste storage lagoons (0.38 acre in this case) and may have to be adjusted when the Livestock Siting rule is revised.

Following the same exercise with the solid separation and aeration system installed, the blue odor score curve with X's never point drops below the horizontal passing score line. However, the average "after" Nasal Ranger™ field readings for the first year (black curve with diamonds), and for the second year (magenta line with triangles) both indicate unacceptable odors as far away as 550 feet from the lagoon. This says that the odor control credit given for solid separation and aeration in the odor standard is too generous and may have to be lowered when the Livestock Siting rule is revised.

Case Study 5: Animal Feedlot (Clark County)

Background

Our Clark County farm was the site where an existing outside feedlot configuration was to be monitored and later upgraded. Due to management changes, however, this site was removed from the monitoring program prior to the feedlot improvements being made. The terrain around this farm is characterized by gently rolling farmland with large open areas broken up by trees at fencelines (see Figure 5.0). This farm was a satellite heifer raising site for a large dairy farm several miles away. Cows of all ages, from weaning through bred heifers just prior to calving, are housed at this site in open bedded sheds with constant access to large earthen exercise lots.

Figure 5.0
Clark County Farm Layout

At the time of our study, the farm housed approximately 500 cows, 180 heifers, and 300 calves in a combination of bedded pack loose housing and outside lots of either dirt or concrete. The feed alleys located inside the barns were regularly scraped with a skid steer every few days. The outside concrete lot was scraped as required when manure accumulated to a couple of inches in depth. This concrete lot was seldom used due to the poor performance of the runoff buffering system leading to contaminated discharge onto the neighbor's property. The outside earthen lots were not regularly scraped, and were only maintained occasionally to repair soft spots, etc. Manure scraped from the barn feed alleys was hauled to either the on-site earthen manure storage basin, or immediately field spread on nearby cropland. The bedded pack was periodically hauled directly to cropland.

The landowners planned to install additional open housing bedded pack barns, as well as additional manure storage, and abandon the concrete lot nearest the road. Their proposed plan also included reducing the size of the earthen lots and creating grazing paddocks. The paddocks were to also serve as vegetated buffers around the production facility to improve runoff quality. As part of the planned outside lots, fence line feeding systems and a runoff containment basin were to be installed to reduce overall building costs and simplify scraping of the lots and feed lanes. The proposed improvements to the manure handling system and increased manure storage capacity would have improved labor efficiency and facilitated manure application to cropland during appropriate times of the year. The intent of the modifications was to improve air quality by allowing a larger percentage of manure to be collected and field applied. Another goal was to reduce the amount of bare soil exercise lots and replace them with vegetated paddock areas. This was intended to control dust from the bare earthen lots, and thus possibly reduce odor emissions.

Ultimately, the landowner decided not to make these improvements in lieu of relocating about half of the animals to new housing facilities constructed at the main farm. The reduction in animals at the satellite farm effectively addressed the dust and runoff issues, making the installation of control practices unnecessary.

Case Study 5 Results Discussion

General Sampling Overview

The Clark County site was in some ways the most difficult to sample for this project. In the first place, a much wider area was involved in the study, which surrounded the entire feedlot area with samplers on the fenceline. In addition to the extra effort involved in setting up, monitoring and collecting the samplers over such a wide area, the low concentrations encountered at this distance from relatively diffuse sources required altering the sampling protocol.

A summary of the test dates and general conditions is shown in the following table. Parameters include the testing start date and the vector mean wind speed, wind direction and temperature (in degrees Celsius) for both the daytime (AM) and nighttime (PM) sampling runs. Note that the test continued to the day following the test date.

Date	AM			PM		
	VMWS	VMWD	T(C)	VMWS	VMWD	T(C)
05/21/2007	7.9	170	22.7	6.4	130	15.2
07/17/2007	4.2	190	26.2	0.7	140	20.1
09/10/2007	2.1	160	10.9	8.3	230	9.4

Table 5.0
Clark County Test Dates and Basic Meteorology

The first test was run using the standard setup and flow rates. Efforts to improve the detection limit for the samples were made following this, with subsequent tests employing flow rates up to about 1.5 liters per minute for some samples, allowing for the collection of up to 3 times the volume collected by the regular sampling protocol. Sampling at this flow rate required removing the sample splitters, so that only single samples were collected with each pump. Minimum theoretical detection limits for the higher volume samples were about 4 micrograms per cubic meter for hydrogen sulfide and about 7 $\mu g/m^3$ for ammonia.

A small number of samples were collected around the more concentrated sources, including the small manure pit and immediately next to two of the barns. The purpose of these samples was to provide a sense of the source magnitude to both demonstrate how quickly concentrations may disperse from area sources and provide some basis of comparison with other farms tested.

A total of 86 H_2S and 96 NH_3 samples were collected during the three tests at this facility, of which 78 H_2S and 89 NH_3 samples were submitted to the laboratory for analysis.

There were six successful H_2S duplicate sampling pairs submitted to the laboratory, all of which showed qualitative agreement (both samples were non-detects). A total of 7 NH_3 sample pairs were submitted of which two show qualitative disagreement (one sample a detect, the other a non-detect). Of the remaining 5 NH_3 pairs, one failed at 64.9% RPD, while the other four passed with RPDs below 30%. The average RPD for these samples is 16.9%.

A total of 6 H_2S and 6 NH_3 blanks were submitted from sampling efforts at this facility. Of these, 2 of the H_2S blanks showed detectible quantities, with an average detection level of 6.8 micrograms per sample. The single NH_3 blank detect was obtained from this site, with a level of 8.3 μg/sample, while the remaining five blanks showed no trace of ammonia.

Ambient Sampling

Figures showing the results described herein are located in the Project Data Supplement in chronological sequence.

Sampling points along the north, south and east of the facility were generally located along the property line, in an attempt to measure the overall concentrations of ammonia and hydrogen sulfide leaving the feedlot. The western edge was sampled along a transect located in the neighboring corn field, as the property line was too distant to be practical.

In addition to these points, several others were sampled one or more times, including the loading chute gate located near the old barn which was sampled on all site visits (sampling point #4), next to the small manure storage pit (#21) and next to the barns (#'s 22 and 23). The final three sampling points were only sampled during the second site visit.

In general, most concentrations encountered around this facility were quite low, with a high rate of non-detects, especially for the hydrogen sulfide samples, for which there were only two detects throughout the study, both of which were between the limit of detection and the limit of quantitation, and thus of relatively low analytical reliability. After the first sample run, hydrogen sulfide was sampled only at more limited locations to conserve sampling budget and resources.

The first hydrogen sulfide detect on the evening of the first sampling trip was at location 9, which was actually upwind of the facility. While an upwind detect can represent the effect of a neighboring operation, in this case it is more likely to represent random background contamination in the sampling tube.

The second H_2S detect occurred during the evening of the second trip. While it was downwind of the facility, and relatively close to the barns, it is a suspect result because there was no detectable H_2S closer to the barns. The low concentration observed increases the possibility that the sampling tube contained more than the average amount of sulfur, thus generating a false positive result.

This low level of hydrogen sulfide was supported by the Jerome Hydrogen Sulfide meter results, which only rarely showed any H_2S above the instrument detection limit of 3 parts per billion. This concentration is equivalent to about 4.5 micrograms per cubic meter, and represents a lower concentration than can be reliably detected by the charcoal tube sampling method under even the modified conditions employed after the first trip to this facility.

While the hydrogen sulfide sample results from this location were generally unfruitful, the ammonia results were quite revealing. Though this compound was frequently detected, concentrations observed in most locations were relatively low. Most often, the highest concentrations were observed at the gate of the loading chute. Typically there would be a significant fraction of the herd congregating nearby this location.

Of special interest is the sampling run on the evening of July 16 – 17, 2007. During this run, samples close to the most concentrated source (the barns) were collected. These samples revealed high concentrations (between 672 and 1,966 $\mu g/m^3$), and yet downwind samples collected 100 – 300 meters away yielded results of less than 100 $\mu g/m^3$. This hints at the dispersion even short distances can cause.

In this particular case, our results are more comparable to NR445 than the remaining tests. This is because our sampling was conducted along the property line, and thus our locations are equivalent to the area of regulatory concern. While our sampling was not designed to capture 24 hour average values, and our three visits over the course of 4 months are not truly representative of typical conditions at the farm, our results can give a hint of whether or not this type of operation is likely to exceed levels of concern.

The table following summarize the top three observed ammonia concentrations on the downwind side of the property. Note that no table for hydrogen sulfide results is included, as there was little to none detected. Reported parameters include the average, maximum and minimum values, as well as the relative standard deviation (RSD), a measure of the variability of our results. In addition to a summary for each sampling period, the table shows an overall summary of results, as well as a day and night sample comparison.

	Run 1	**Run 1e**	**Run 2**	**Run 2e**	**Run 3**	**Run 3e**	**Overall**	**Day**	**Night**
Average	84	120	53	97	57	33	74	65	84
Max	143	209	96	115	74	49	209	143	209
Min	50	54	26	83	36	17	17	26	17
RSD	62.0%	66.2%	70.6%	17.0%	34.3%	48.5%	63.9%	56.4%	68.1%

Table 5.1
Downwind Ammonia Concentrations Near the Property Line

The figure on the following page represents this data in a max/min charts. The value (Y) axis is in micrograms per cubic meter. Note that the variation between the test runs is significant enough that no statistically significant patterns are clear.

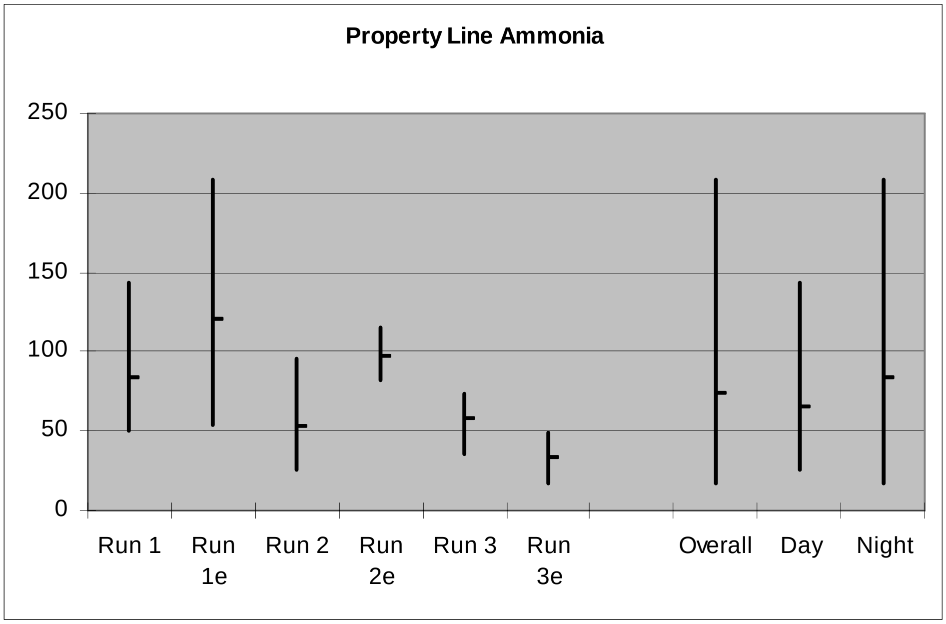

Figure 5.1
Property Line Ammonia (Clark County)

The NR445 ambient action concentration for ammonia is 418 μg/m^3 on a 24 hour average basis. At no point along the property line did observed concentrations exceed 100 μg/m^3 during this study. The NR445 ambient action concentration for hydrogen sulfide is 336 μg/m^3 on a 24 hour average basis. This value is well above detection limits, and was not approached within an order of magnitude anywhere sampled on this facility during this test.

Case Study 5 Key Findings Summary Statements

Essentially no hydrogen sulfide was observed on this facility during any of the sampling visits. The open nature of the lot and relatively low population density of the animals, combined with minimal collection and dry handling of manure probably lead to this relatively pristine condition. Observations made around this feedlot should not be extrapolated to higher density lots where the ground does not have the opportunity to dry out.

While ammonia concentrations were observed throughout the sampling, fenceline concentrations were generally low. The few “source” area samples obtained show much higher values, but dispersion over the relatively short distances to the property line was sufficient to reduce concentrations significantly during the testing periods.

Project Focus Key Baseline ~ Case Study 5: Baseline Animal Feedlot (Clark County)

The outcome of the odor transects conducted on the three trips to the Clark County farm are depicted in the data supplement. These represent the odors being generated by a large earthen feedlot. Because the decision was made to not install odor control practices on this farm no “after” sampling took place. Despite this fact, the data gathered during the initial visits are still useful as baseline information.

Graphing the odor readings from this farm, it can be seen that large low density feedlots of this type do not appear to be a significant source of odors (see Figure 5.2).

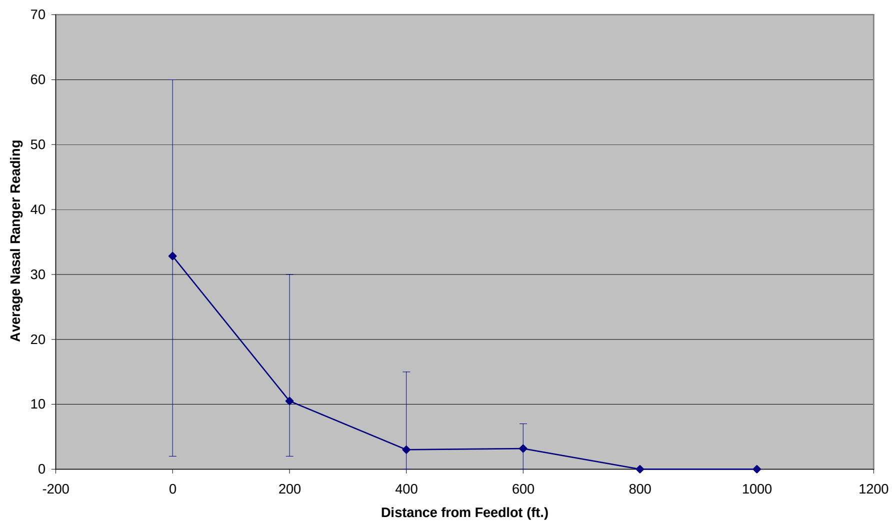

Figure 5.2
Average Nasal Ranger™ Reading at 200 ft Intervals
Baseline Animal Feedlot (Clark County)

Although a reading over 30 could be described as very noticeable, at a distance of only 200 feet the average reading was around 10, which is noticeable, but not evident. And at 400 feet and beyond the average reading was 4 and below, which is barely detectable. Caution should be used when applying these results to other animal feedlot operations. Size, stocking densities, and overall management can all influence odor generation rates.

Figure 5.3 below shows the comparison of Nasal Ranger™ readings taken in the field at our Clark County farm to the calculated odor scores for that animal feedlot, using the odor model in ATCP 51. The odor score was calculated for the feedlot assuming the nearest neighbor was located at various distances downwind. These scores were plotted against separation distance to create an odor score curve. The Nasal Ranger™ odor results were then plotted against distance on the same graph. This allowed us to determine the measured average odor level at the distance that corresponds to a passing odor score of 500.

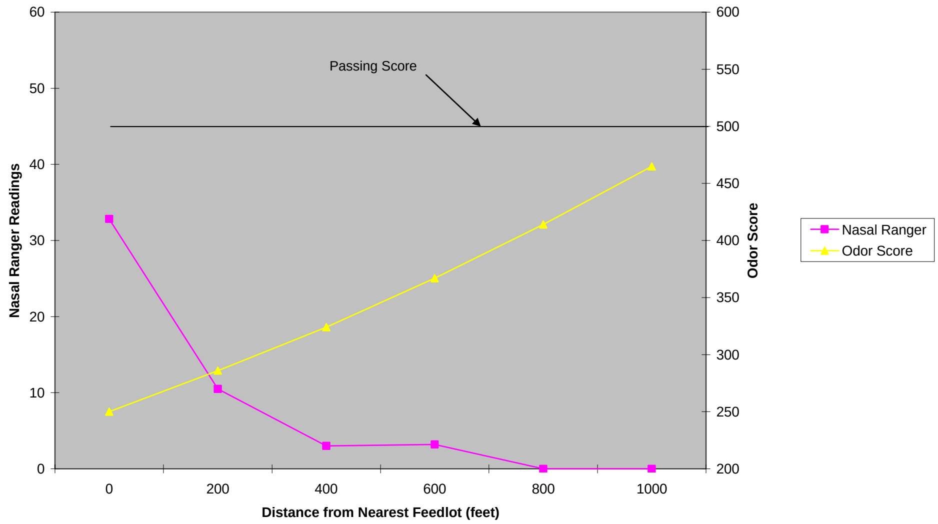

Figure 5.3
Comparison of Nasal RangerTM Field Readings to the Odor Score
Baseline Animal Feedlot (Clark County)

Looking at these results, we see a very poor correlation between the field readings and the predicted odor score. The yellow line with triangles is the odor score curve, and the red line with squares is the Nasal Ranger™ field readings curve. Drawing a horizontal line at a passing odor score of 500, we see that at all points the odor score curve is below passing, meaning that the feedlot fails at all separation distances up to and including 1,000 feet. However, looking at the Nasal RangerTM curve (red line with squares) we can see that as close as 650 feet the measured average odors were acceptable, and even as close as 400 feet they were not excessive. This result indicates that for large animal feedlots with low stocking rates (12.5 A.U./acre) the odor standard may not apply. The standard was developed using concrete feedlots with higher stocking rates, whereas the Clark County feedlot is more akin to a heavily used pasture.

Case Study 6: Manure Storage Lagoon (Manitowoc County)

Background

The Manitowoc farm was our baseline operation. It represents a fairly typical large freestall dairy operation in Wisconsin. It is situated on a high spot of the local landscape, but the terrain surrounding it is open and flat, making it a good candidate for air concentration studies (see Figure 6.0).

Figure 6.0
Manitowoc County Farm Layout

At the start of our study, the operation housed 2,700 head of milking and dry cows on sand bedding. Manure is continuously removed from the alleys using automated scrapers, which dump the wastes into a very long cross channel. This channel is flushed using recycled manure, which is routed through a sand separation channel and then returned to the 21 million gallon primary lagoon. After the wastes flow to the far end of the primary lagoon, they are pumped up to the 20 million gallon secondary lagoon. At the opposite end of this lagoon is the pump that recirculates the wastes back to the freestall barns for flushing the cross channel. Sand that is captured in the separation channel is stockpiled and allowed to drain out and dry before being reused as bedding in the freestalls.

At the end of our study, two new freestall barns had been built, adding 500 more cows, for a total of 3,200 head. We had originally selected this farm for comparison with the Waupaca County digester farm. It was opportune that this farm expanded during the course of our study, because the Waupaca farm underwent a size increase as well. This allowed for data from the two farms to be compared over the length of the study.

Case Study 6 Results Discussion

General Sampling Overview

A total of three sampling runs have been conducted at the Manitowoc County site. A total of 143 samples for NH_3 and 143 for H_2S have been collected, with 18 of each being invalid for reasons in the field. The invalid samples are evenly distributed between the sampling trips, and no single run experienced sufficient sample loss to invalidate it.

A summary of the test dates and general conditions is shown in the following table. Parameters include the testing start date and the vector mean wind speed, wind direction and temperature (in degrees Celsius) for both the daytime (AM) and nighttime (PM) sampling runs. Note that the test continued to the day following the test date.

Date	AM			PM		
	VMWS	VMWD	T(C)	VMWS	VMWD	T(C)
07/02/2007	8.0	160	20.7	3.3	180	16.9
10/15/2007	10.1	70	12.2	8.3	100	12.7
05/05/2008	4.4	120	12.4	0.8	140	7.9

Table 6.1
Manitowoc County Test Dates and Basic Meteorology

Standard sampling protocols have been followed for all tests conducted at this site. Additional sampling was conducted around the sand channel on the second and third sampling runs, with results included separately in Section 6.1 following. One additional upwind sample was collected on the first trip, with no ammonia or hydrogen sulfide detected. No additional sampling was practical at this facility.

Only four successful duplicate pairs were collected at Manitowoc (two of both H_2S and NH_3 pairs). All sampling pairs passed quality criteria. The average RPD of the H_2S duplicate samples is 4.0%, while the average RPD of the NH_3 samples is 12.1%, both well within quality criteria.

Three blanks collected show detectable quantities of H_2S, with an average of 7.3 µg/sample. The blank levels were subtracted from the results reported by the lab. All other blanks contained non-detectable levels of the parameters.

Ambient Sampling

Figures showing the results described herein are located in the Project Data Supplement in chronological sequence.

Concentrations of H_2S around the pits during our sampling visits were generally the highest of ambient samples we observed at any of the farms. On two out of the three trips, a significant number of samples yielded results in excess of 1,000 micrograms per cubic meter for both ammonia and hydrogen sulfide. More ambient samples that exceeded this level were collected at this facility than any of the others.

Whether this observation represents a true difference between the manure at this facility and that of the others, or is the result of management practices is unknowable based on our data set. The large surface area of the manure pits exposed to the air as well could also explain our results. The limited nature of our sampling (a mere three to six trips to each facility over the course of more than a year) does not provide enough information to be able to quantitatively compare results with the other farms tested in a manner that conclusively determines what leads to the differences observed.

Results from this facility also demonstrate clearly the extremely variable nature of concentrations observed around manure pits. Not only do the ranges of concentrations vary significantly between sampling trips, but also between adjacent sampling locations, even though some of these are as little as a hundred feet apart of so. Not only does the magnitude of the concentrations vary, but the ratios of H_2S and NH_3 can diverge radically within a short area as well.

For example, the results from the sampling trip conducted on July 2-3, 2007, demonstrate this clearly. Samples were collected at the north end of both pits (locations 8, 9, 21 and 22). During the daytime run, ammonia exceeded hydrogen sulfide at all locations. Ammonia at location 8 was nearly twice that of location 9. The hydrogen sulfide dropped by a factor of nearly 7 over the same distance. Similarly, results obtained during the daytime from location 21 are significantly greater than those at 22, although the differences aren't quite so great.

These differences can be ascribed to the local influence of the circulation of flush water. Location 21 was positioned above the outfall of flush water from the sand channel, and location 8 was positioned near the pump outlet on the upper pit. During the test on July 2^{nd}, both of these sources were open to the air, greatly increasing the potential emission from them. When this was pointed out to the farmer, the simple solution of extending the pipes to beneath the manure surface was employed, and remained the case for both future sampling visits.

That sites nearby are apparently far less impacted than those directly next to the outfalls can be explained by the predominant wind direction, which was such as to move outfall emissions away from the adjacent sampling sites 9 and 22. It is interesting to note, however, that the ammonia concentrations at location 22 are significantly elevated above background (as represented by locations 15, 24 and 26), even though the winds were mostly from open field, with only a small corner of the manure pit between the sampler and the wind.

What proximity to these localized sources does not reveal, however, is what caused the differences observed between day and night on the July 2-3 trip. Nighttime results from the same locations show a significant shift in the ratios of H_2S and NH_3 concentrations. The daytime samples reveal uniformly higher ammonia than hydrogen sulfide concentrations, while at night, those samples collected closest to the outfalls (locations 8 and 21) show significantly more H_2S than ammonia.

The cause of this is unknown, but similar observations can be made for the remainder of the sampling trips at this facility. An extreme case of this is the nighttime run on May 5-6, 2008, during which almost entirely calm wind conditions prevailed. During this sampling run, almost all sampling locations show significantly elevated concentrations of both parameters, but especially hydrogen sulfide. In general, qualitatively more hydrogen sulfide is observed at night than during the day. Sampling at the other facilities does not demonstrate this phenomena so clearly, so it is unknown whether this is a characteristic of the type of manure handling practices employed here, whether it is a location specific phenomenon, or whether it was a chance occurrence based on the timing of our visits.

As can be seen from the examples above, overall hydrogen sulfide concentration trends observed around these lagoons tend to be strongly driven by the samples impacted by the outfalls. For this reason, the following summaries are prepared with this data removed and considered separately. The purpose of this is to better compare results collected around the different lagoons. Outfall impacted results obtained at other farms are treated separately as well.

Summaries of the downwind data are show in the following tables and figures. Note that each manure lagoon is treated separately. The top three non-outfall impacted concentrations observed downwind of each lagoon for both ammonia and hydrogen sulfide are summarized in the following tables. Values shown are the average, maximum and minimum concentrations observed among the three most concentrated downwind samples, as well as the relative standard deviation (RSD), which is a measure of the variability of the data. Concentration values are expressed in micrograms per cubic meter.

Note that the ammonia results typically have a much lower RSD than the hydrogen sulfide results. This is a reflection of the much wider variation seen among the hydrogen sulfide data, which tended to be significantly higher at one site than the others included in this evaluation. The only sampling period this was not true for was the nighttime sampling on May 5-6, 2008, where most locations showed significant elevation.

LOWER	**Run 1**	**Run 1e**	**Run 2**	**Run 2e**	**Run 3**	**Run 3e**	**Overall**	**Day**	**Night**
Avg	852	642	562	512	1655	816	840	1023	657
Max	918	1131	806	756	1751	1116	1751	1751	1131
Min	737	293	126	183	1581	404	126	126	183
RSD	11.8%	67.8%	67.4%	57.7%	5.2%	45.2%	56.4%	51.8%	52.9%
UPPER	**Run 1**	**Run 1e**	**Run 2**	**Run 2e**	**Run 3**	**Run 3e**	**Overall**	**Day**	**Night**
Avg	575	652	497	316	1208	863	685	760	610
Max	738	1092	567	408	1379	934	1379	1379	1092
Min	314	259	453	242	964	766	242	314	242
RSD	39.8%	64.2%	12.4%	26.8%	18.0%	10.0%	50.8%	49.2%	53.0%

Table 6.2
Downwind Ammonia Concentrations Near Upper & Lower Lagoons

LOWER	Run 1	Run 1e	Run 2	Run 2e	Run 3	Run 3e	Overall	Day	Night
Avg	54	145	88	227	106	724	224	83	365
Max	74	254	145	312	140	849	849	145	849
Min	32	81	45	132	77	526	32	32	81
RSD	38.6%	65.0%	57.9%	39.8%	30.1%	23.9%	111.0%	47.3%	79.9%
UPPER	**Run 1**	**Run 1e**	**Run 2**	**Run 2e**	**Run 3**	**Run 3e**	**Overall**	**Day**	**Night**
Avg	54	54	95	289	40	400	155	63	248
Max	80	88	143	323	59	574	574	143	574
Min	29	29	67	237	28	235	28	28	29
RSD	47.3%	56.6%	43.7%	15.7%	41.8%	42.4%	100.5%	56.8%	71.4%

Table 6.3
Downwind Hydrogen Sulfide Concentrations Near Upper & Lower Lagoons

The figures on the following pages represent this data in max/min charts. Note that the variation between the test runs is significant enough that no statistically significant patterns are clear, even though qualitatively it appears that daytime ammonia concentrations may be higher than those observed during the night, while the reverse may be true for hydrogen sulfide. The upper and lower lagoons are not readily distinguished in this manner, either.

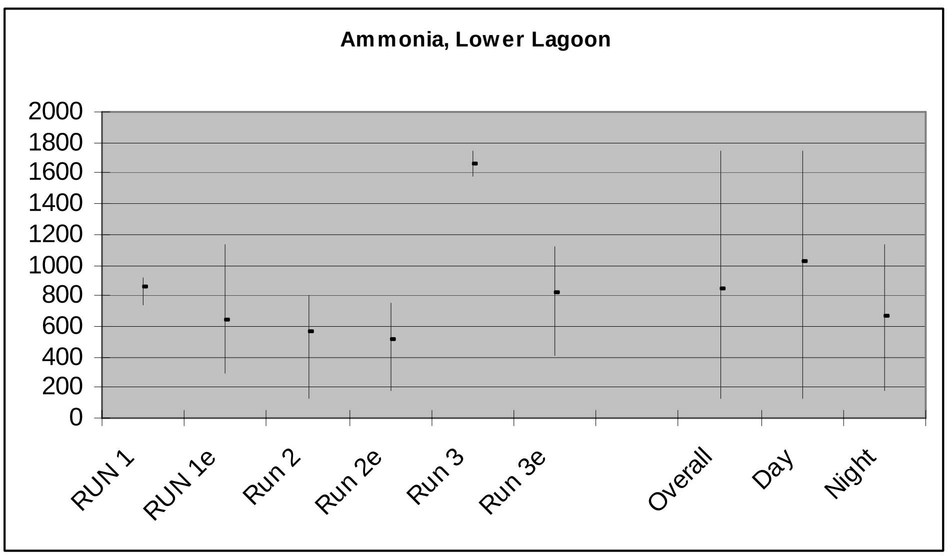

Figure 6.1
Ammonia, Lower Lagoon (Manitowoc County)

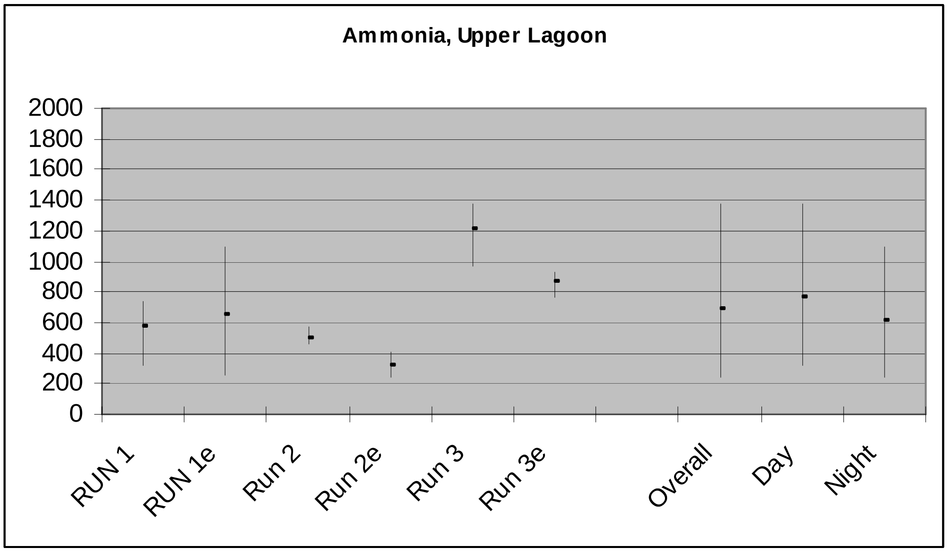

Figure 6.2
Ammonia, Upper Lagoon (Manitowoc County)

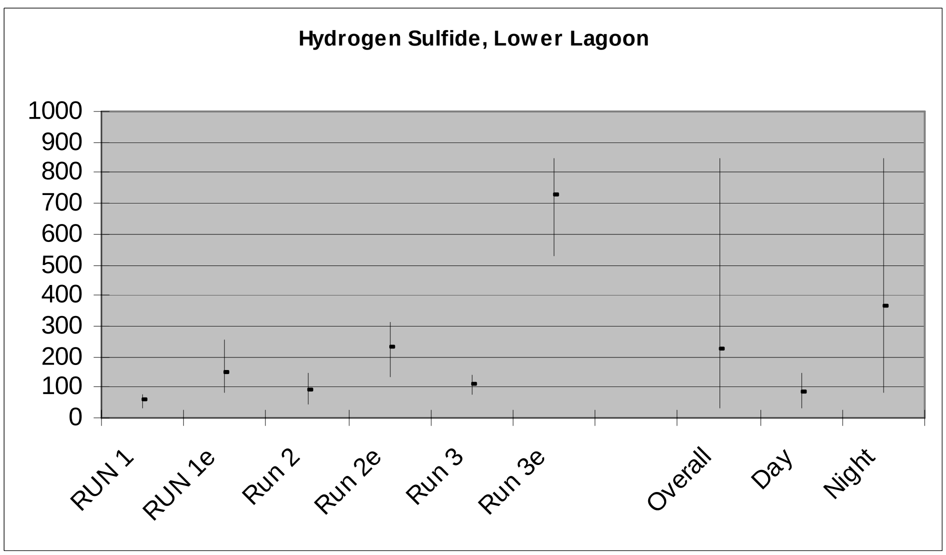

Figure 6.3
Hydrogen Sulfide, Lower Lagoon (Manitowoc County)

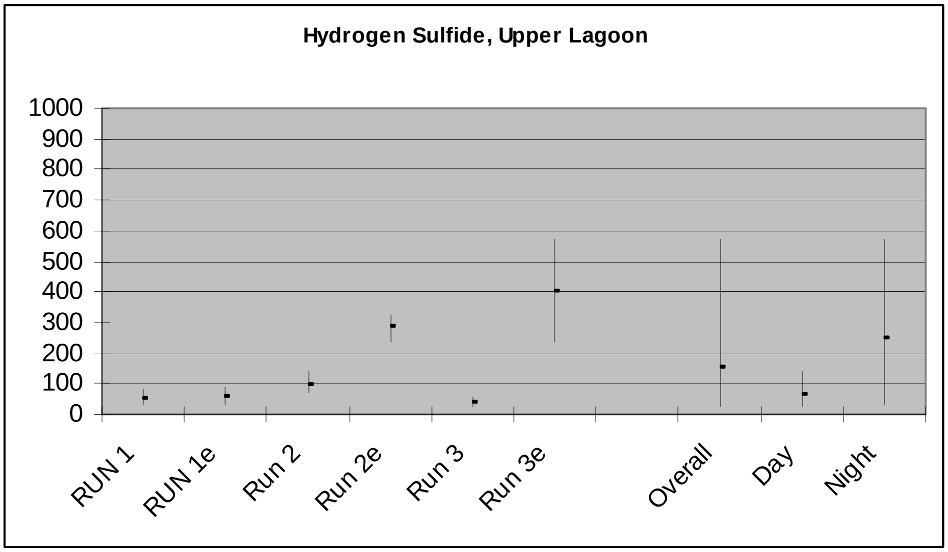

Figure 6.4
Hydrogen Sulfide, Upper Lagoon (Manitowoc County)

Results obtained from the outfall influenced samples on both lagoons are combined and presented in the following graph which compares general results obtained near the upper and lower lagoons with those impacted by the outfalls. Note that this graph presents the overall average plus or minus the 90% confidence interval of the dataset, rather than the max/min/average presented in the graphs above. Hydrogen sulfide results are on the left, while ammonia results are on the right. Note that while the outfall hydrogen sulfide concentrations are obviously and significantly different from the remaining samples, there is no such distinction with the ammonia samples.

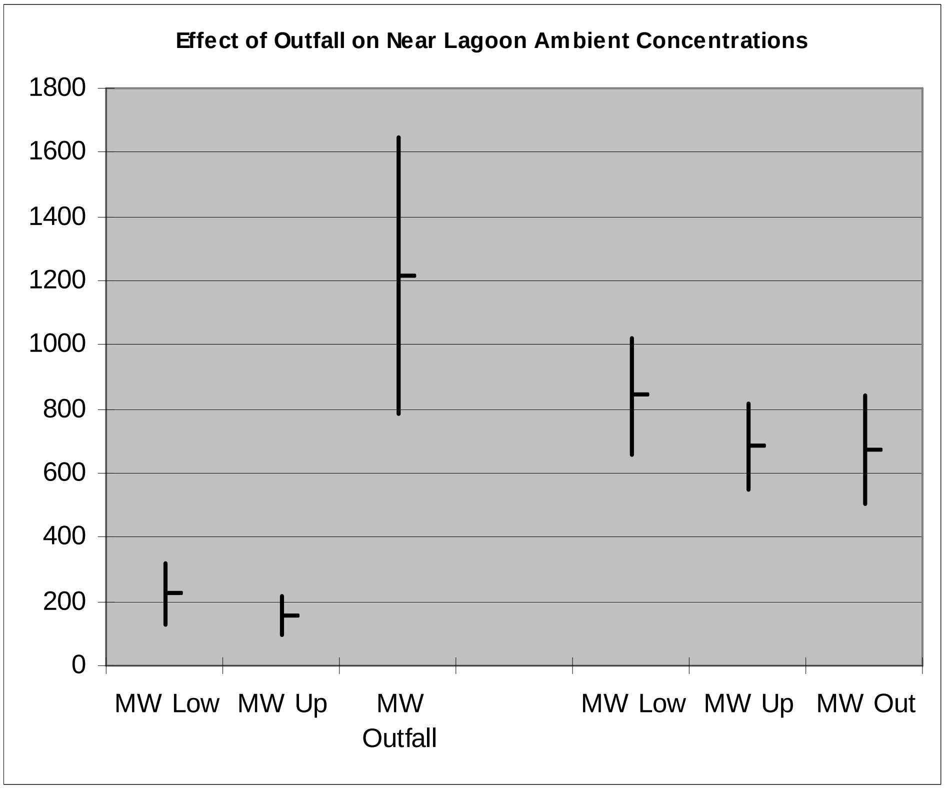

Figure 6.5
Outfall vs. General Results, H_2S (left) and NH_3 (right) (Manitowoc County)

Manure Surface Sampling
Sampling was conducted on the surfaces of both manure lagoons. The figures below display the results obtained from these tests, with the lower lagoon (first to receive the waste) on the left and the upper on the right. Concentration units are micrograms per cubic meter, presented on a logarithmic scale. Note that H_2S results from the different lagoons track well between visits, with the upper lagoon showing consistently higher H_2S concentrations at the surface. NH_3 results are more variable and do not show a specific pattern such as this.

While the data do show this pattern, it should be noted that concentrations on both lagoons vary between site visits by well over an order of magnitude for each parameter. This type of variability impedes our ability to base firm conclusions on our data. A point of interest that will be discussed further in the comparison with other farms is that while the highest H_2S values were observed at this facility, the lowest maximum NH_3 value was recorded here.

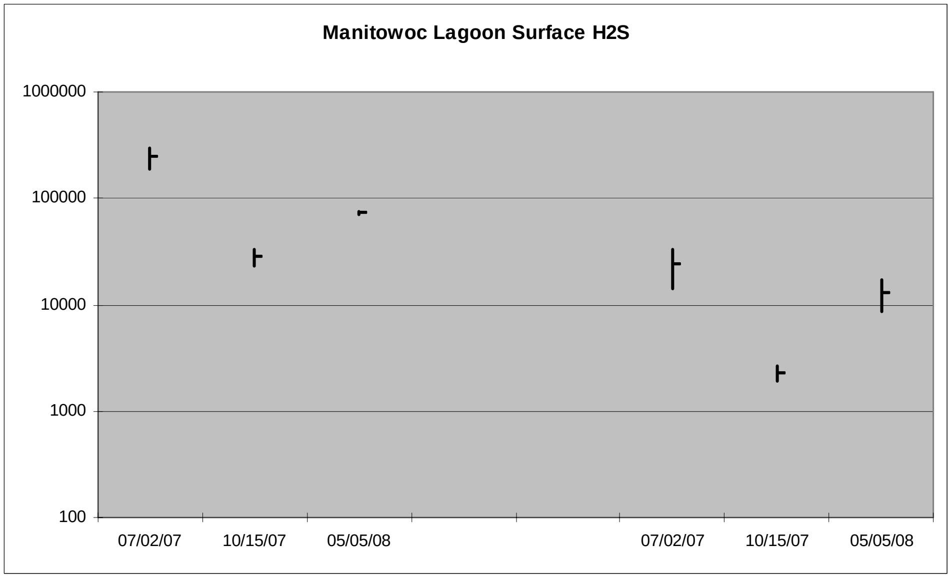

Figure 6.6
Lagoon Surface H_2S (Manitowoc County)

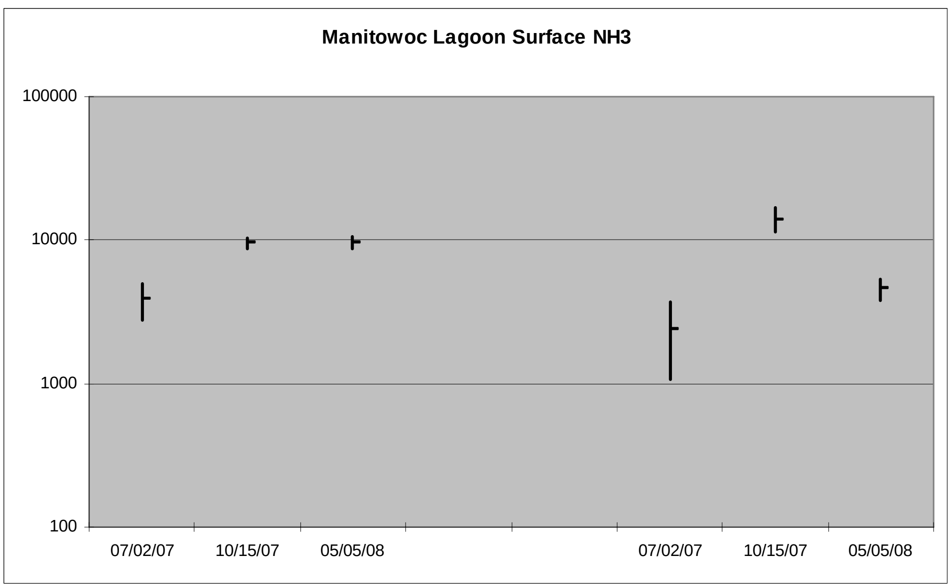

Figure 6.7
Lagoon Surface NH_3 (Manitowoc County)

Case Study 6 Key Findings Summary Statements

Significantly elevated concentrations of both hydrogen sulfide and ammonia were observed around this facility during this study. In general, elevated ammonia concentrations were more widespread than H_2S, but the maximum H_2S concentrations observed exceed the maximum NH_3 significantly.

The highest lagoon oriented hydrogen sulfide concentration observed during this study was collected at this facility. Maximum concentrations were observed either next to or immediately downwind of the outfalls, where manure is being introduced into the lagoons, either from the sand channel (in the case of the lower pit), or pumped up from the lower pit.

In addition to demonstrating the effect surface agitation introduced through an outfall has on hydrogen sulfide concentrations, one sampling event managed to capture an almost calm overnight period, probably representative of an inversion. High concentrations of both H_2S and NH_3 were observed in a majority of the samples collected during this period.

The most concentrated lagoon surface hydrogen sulfide levels were observed at this facility, but concentrations varied widely between sampling trips. An apparent difference between the upper and lower lagoons exists, with the lower lagoon showing higher concentrations than the upper on a consistent basis.

Ammonia results from the surface are significantly lower than the H_2S observations, and do not show the apparent differences between the lagoons. The lowest observed maximum lagoon surface ammonia concentration of the farms in our study was observed at this facility.

Project Focus Key Baseline ~ Case Study 6: Baseline Manure Storage Lagoon (Manitowoc County)

The outcome of the odor transects conducted on the three trips to the Manitowoc County farm are depicted in the data supplement. These represent the odors being generated by a typical large manure storage lagoon. This farm was selected to provide us with baseline data to be used for comparison with the two digester farms. No practices were planned to be installed on this farm. This data is being provided here for baseline purposes only.

Graphing the odor readings from this farm, it can be seen that large manure storage lagoons appear to be a significant source of odors (see Figure 6.8).

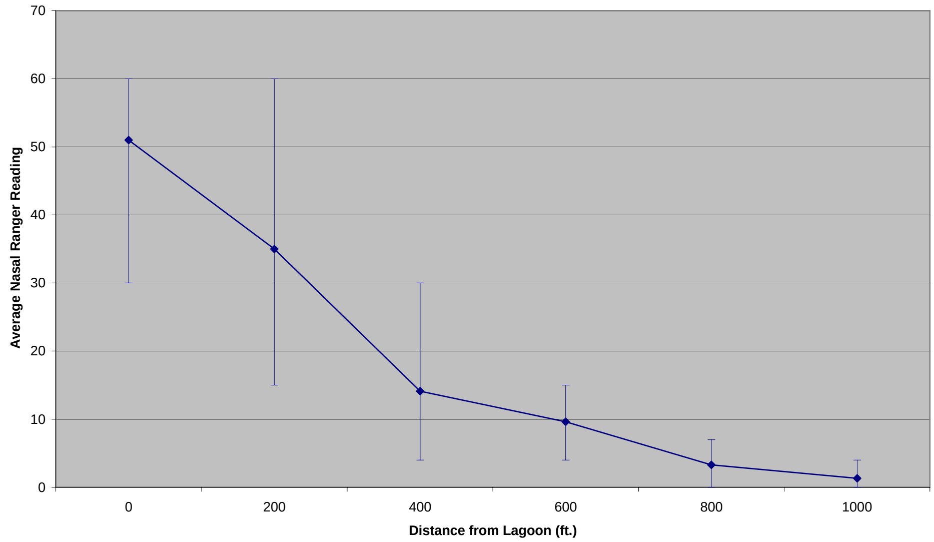

Figure 6.8
Average Nasal Ranger™ Reading at 200 ft Intervals
Baseline Manure Storage Lagoon (Manitowoc County)

Immediately adjacent to the lagoon the average reading was over 50, which would be considered a very strong odor. And, even at a distance of 400 feet downwind of the lagoon average readings are in excess of 10, a noticeable level. It isn't until a separation distance of 900 feet that average readings are 2 or less, which would generally be considered acceptable. Again, this represents a very limited number of samples taken under variable conditions. Caution should be used in applying these results to other manure storage lagoons.

Figure 6.9 below shows the comparison of Nasal Ranger™ readings taken in the field at our Manitowoc County farm to the calculated odor scores for that waste storage lagoon, using the odor standard in ATCP 51. The odor score was calculated for the lagoon assuming the nearest neighbor was located at various distances downwind. These scores were plotted against separation distance to create an odor score curve. The Nasal Ranger™ odor results were then plotted against distance on the same graph. This allowed us to determine the measured average odor level at the distance that corresponds to a passing odor score of 500.

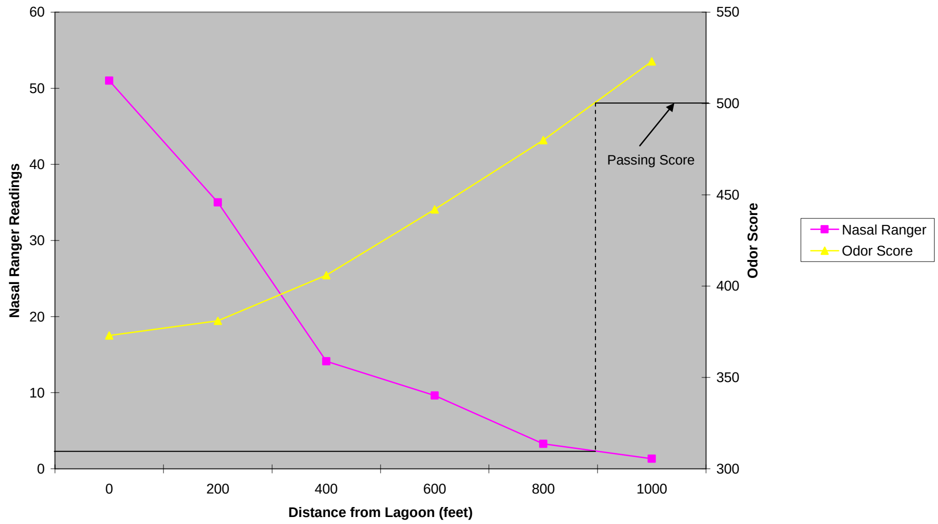

Figure 6.9
Comparison of Nasal RangerTM Field Readings to the Odor Score
Baseline Manure Storage Lagoon (Manitowoc County)

Looking at these results, we see a very good correlation between the field readings and the predicted odor score. The yellow line with triangles is the odor score curve, and the red line with squares is the Nasal Ranger™ field readings curve. Drawing a horizontal line at a passing odor score of 500, and then dropping down from where that line intersects the odor score curve, we see that the point corresponds with a separation distance of just under 900 feet. At this distance the Nasal Ranger™ field readings averaged about 2, the lowest measureable reading. This result indicates that for medium sized waste storage lagoons (4.2 acres) the odor standard was collaborated by our field odor measurements.

PROJECT FOCUS SUPPLEMENT: TWO CASE STUDIES OF SAND SEPARATION CHANNEL IMPACTS ON ODOR CONTROL STUDIES AND MEASURES

Case Study 3.1: Sand Channel (Kewaunee County)

Case Study 3.1 Results Discussion

General Sampling Overview

Key aspects, protocols and results of the testing program conducted on this farm are previously presented in the section titled, "Project Focus: Six Case Studies of Lagoon/Pit Odor Control Measures, Case Study 3.0" The material that follows is focused on sampling around the sand channel, which was conducted on 5 of the 6 sampling visits to this facility. Of the 361 total samples for each of ammonia and hydrogen sulfide collected during all sampling at the Kewaunee farm, 112 of each were collected around the sand channel. Of these, three NH_3 and two H_2S samples were considered void, although not all samples collected during 2009 were submitted to the laboratory.

Ambient Sampling

Figures showing the results described herein are located in the Project Data Supplement in chronological sequence.

The physical layout of the sand channel at this facility allowed for good sampler coverage. Three of the sampling locations (numbers 1 – 3) were located on the edge of the channel itself (location 3 was not available after the August 27-28, 2007 sampling trip because an additional sand drying pad was made in that area), while two of them (4 and 5) were located at either end of the pump area directly to the south of the sand channel.

Of the remaining locations, 6 and 7 were situated on the edge of the sand drying area, while 8 and 9 were located between the sand channel and the road to the south. Under the wind conditions experienced during most of the sampling trips (generally southerly winds), concentrations observed at these locations represent the probable influence of the lagoons, about 100 meters to the south.

Results from around the sand channel at this facility tend to show a greater rate of positive detections than those collected around the pits. There is less generally less upwind/downwind variation, and there these results have been treated somewhat differently than those from the main study.

In the main case studies, the three most concentrated downwind samples were extracted from the entire dataset and evaluated for comparing the different trips. For most of the sampling trips to this facility, the rate of detection is generally so high (2/3rds of the sampling locations returned a detection rate of greater than 75% for ammonia), that somewhat realistic comparisons of overall results are possible.

As such, results obtained from the samplers alongside the sand channel (locations 1 though 5) have been evaluated and are presented below. Results shown are in $\mu g/m^3$, with average, maximum and minimum values for each sampling event, as well as the relative standard deviation (RSD). Note that only a single detect for hydrogen sulfide was obtained from these locations during run 2, and that none of this parameter was detected during runs 4 and 4e.

	Run 2	Run 2e	Run 3	Run 3e	Overall	Day	Night
Average	490	382	325	317	385	417	353
Max	769	644	728	580	769	769	644
Min	317	239	159	141	141	159	141
RSD	34.2%	41.1%	84.0%	59.7%	50.0%	53.4%	46.4%

Table 3.1.1
Ammonia Concentrations Near the Sand Channel, Pre-Cover

	Run 4	Run 4e	Run 5	Run 5e	Run 6	Run 6e	Overall	Day	Night
Average	188	359	274	292	287	180	270	262	277
Max	324	687	589	427	414	270	687	589	687
Min	52	43	86	178	126	108	43	52	43
RSD	102.5%	82.2%	83.3%	40.4%	46.8%	38.1%	64.9%	65.1%	67.4%

Table 3.1.2
Ammonia Concentrations Near the Sand Channel, Post-Cover

	Run 7	Run 7e	Run 8	Run 8e	Overall	Day	Night	All Post
Average	227	134	222	211	205	229	178	288
Max	489	246	349	316	489	489	316	769
Min	97	75	166	100	75	97	75	43
RSD	78.1%	73.2%	34.7%	50.0%	56.7%	56.5%	57.5%	61.9%

Table 3.1.2a
Ammonia Concentrations Near the Sand Channel, 2nd Year Post-Cover

	Run 2	Run 2e	Run 3	Run 3e	Overall	Day	Night
Average	ND	309	106	128	192	127	229
Max	208	607	151	184	607	208	607
Min		20	41	49	20	41	20
RSD		82.4%	48.6%	45.6%	90.4%	50.3%	90.6%

Table 3.1.3
Hydrogen Sulfide Concentrations Near the Sand Channel, Pre-Cover

	Run 4	Run 4e	Run 5	Run 5e	Run 6	Run 6e	Overall	Day	Night
Average			789	8181	411	433	2454	600	4307
Max	ND	ND	2411	16750	1014	809	16750	2411	16750
Min			189	1792	127	95	95	127	95
RSD			137.4%	88.6%	99.4%	72.1%	193.3%	130.8%	146.3%

Table 3.1.4
Hydrogen Sulfide Concentrations Near the Sand Channel, Post-Cover

	Run 7	Run 7e	Run 8	Run 8e	Overall	Day	Night	All Post
Average	75	67	272	168	153	188	119	983
Max	158	109	501	350	501	501	350	16750
Min	28	17	82	62	17	28	17	17
RSD	95.0%	69.4%	64.5%	77.8%	93.0%	89.4%	96.3%	303.6%

Table 3.1.4a
Hydrogen Sulfide Concentrations Near the Sand Channel, 2nd Year Post-Cover

The figures on the following pages represent this data in max/min charts. The value (Y) axis is in micrograms per cubic meter. The scales for the results have been equalized for the pre and post cover sampling; note, however, that the hydrogen sulfide value scales are logarithmic.

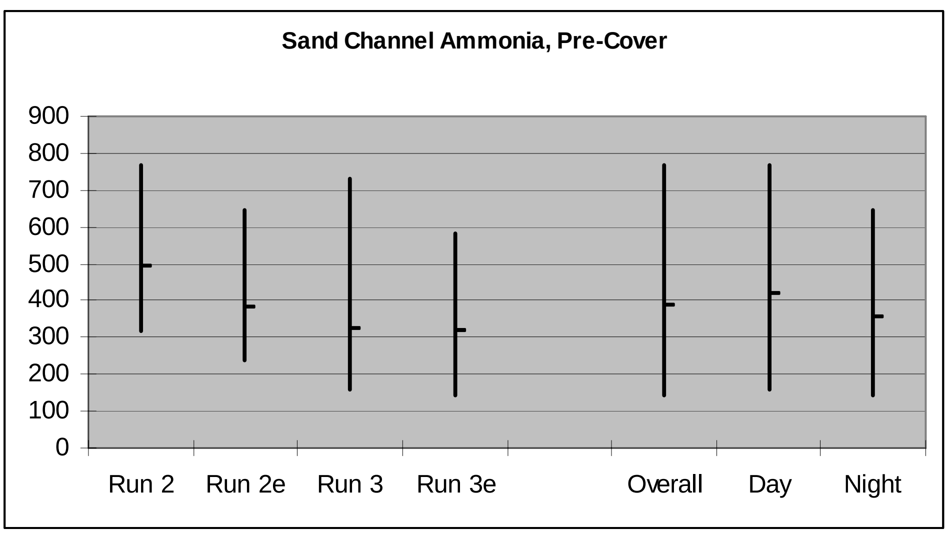

Figure 3.1.1
Sand Channel Ammonia, Pre-Cover (Kewaunee County)

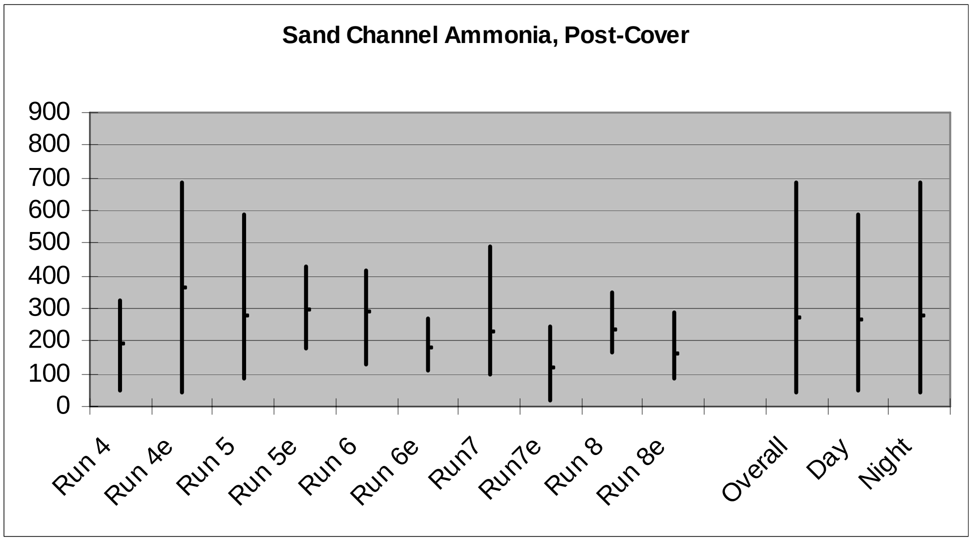

Figure 3.1.2
Sand Channel Ammonia, Post-Cover (Kewaunee County)

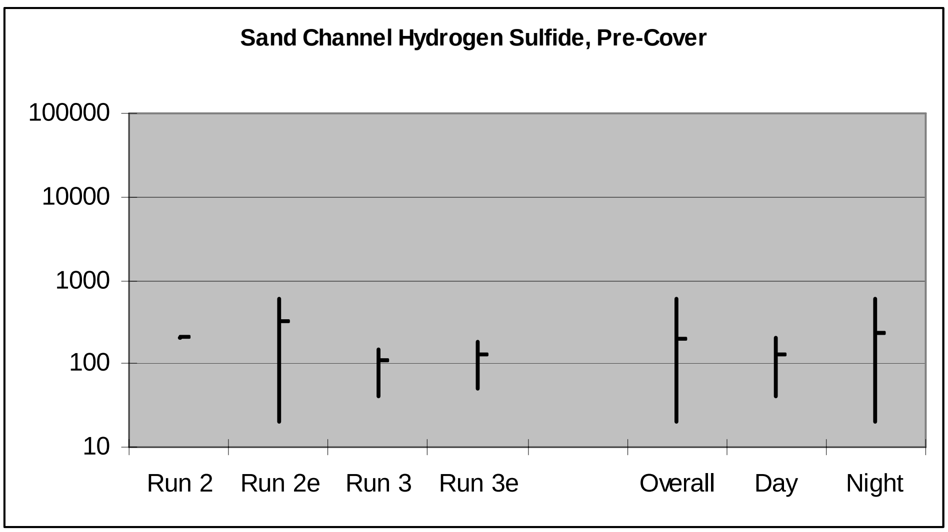

Figure 3.1.3
Sand Channel Hydrogen Sulfide, Pre-Cover (Kewaunee County)

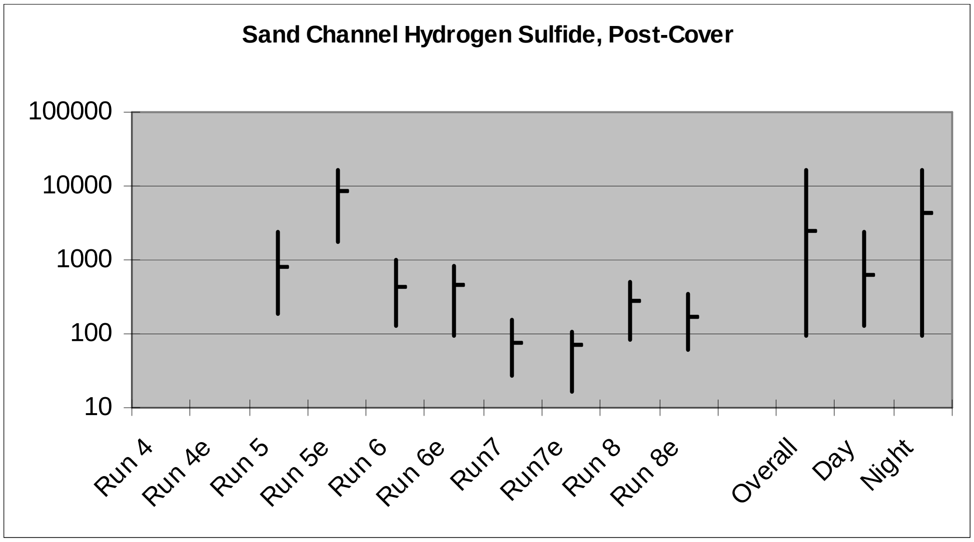

Figure 3.1.3a
Sand Channel Hydrogen Sulfide, Post-Cover (Kewaunee County)

Case Study 3.1 Key Findings Summary Statements

Ammonia concentrations observed around the sand channel at this facility are similar to those observed around the lagoons. Addition of the cover had no significant effect on these concentrations.

Hydrogen sulfide, however, was observed at higher concentrations around the sand channel than next to the lagoon. During the first year following installation of the cover, hydrogen sulfide was an order of magnitude or more concentrated around the sand channel than prior to the cover during most sampling runs. However, during the initial testing period following installation (Run 4 and 4e), no hydrogen sulfide was detected anywhere around the sand channel, and during the second year, results were similar to those obtained prior to installation of the cover. Whether the results of the first year following installation represent a seasonal impact unobserved during the earlier and later testing is unknown.

Odor Sampling

Although not part of the original study plan, we decided to conduct odor transects on the sand separation channel during the follow-up sampling visits to our Kewaunee County farm. This was a result of observations made during our earlier sampling visits, where we noticed that the sand channel produced strong, localized odors.

The proximity of the channel to the animal housing made it difficult to run odor transects under all wind conditions. Transects could only be run when the wind direction was parallel to the freestall barns. A total of three odor transects were run, the results of which can be found in the data supplement to this report.

Looking at the results, it can be seen that the odors were quite strong immediately adjacent to the sand channel, but that they diminished fairly quickly downwind, as compared to odors from the manure storage lagoon. This would indicate that sand channels are a significant source of odor, however their overall impact on neighbors may be less than that of manure storage lagoons due to their smaller footprint.

Case Study 6.1: Sand Channel (Manitowoc County)

Case Study 6.1 Results Discussion

General Sampling Overview

Key aspects, protocols and results of the testing program conducted on this farm are previously presented in the section titled, "Project Focus: Six Case Studies of Lagoon/Pit Odor Control Measures, Case Study 6.0" The material that follows is focused on sampling around the sand channel, which was conducted on 2 of the 3 sampling visits to this facility. Of the 143 total samples for each of ammonia and hydrogen sulfide collected during all sampling at the Manitowoc farm, 9 of each were collected around the sand channel.

Ambient Sampling

Figures showing the results described herein are located in the Project Data Supplement in chronological sequence.

The physical layout of the sand channel at this facility was less conducive for comprehensive sampling than that at the Kewaunee facility. The actual sand channel was surrounded on either side by a significant drying pad for the recovered sand, so that samplers could only be deployed next to the actual channel at the head and foot of the channel (locations 28 and 29). Additional locations were added at about the mid-point of the channel on either side of the drying pad during the final sampling runs (locations 30 and 31).

The very few samples collected at these locations make any numerical summarization somewhat meaningless, so no tables or graphics beyond the results figures have been prepared. It should be noted that the highest hydrogen sulfide concentrations observed throughout the study (> 18,000 $\mu g/m^3$) were collected next to this sand channel, and that the majority of samples observed at concentrations greater than 2,000 $\mu g/m^3$ were obtained in this vicinity.

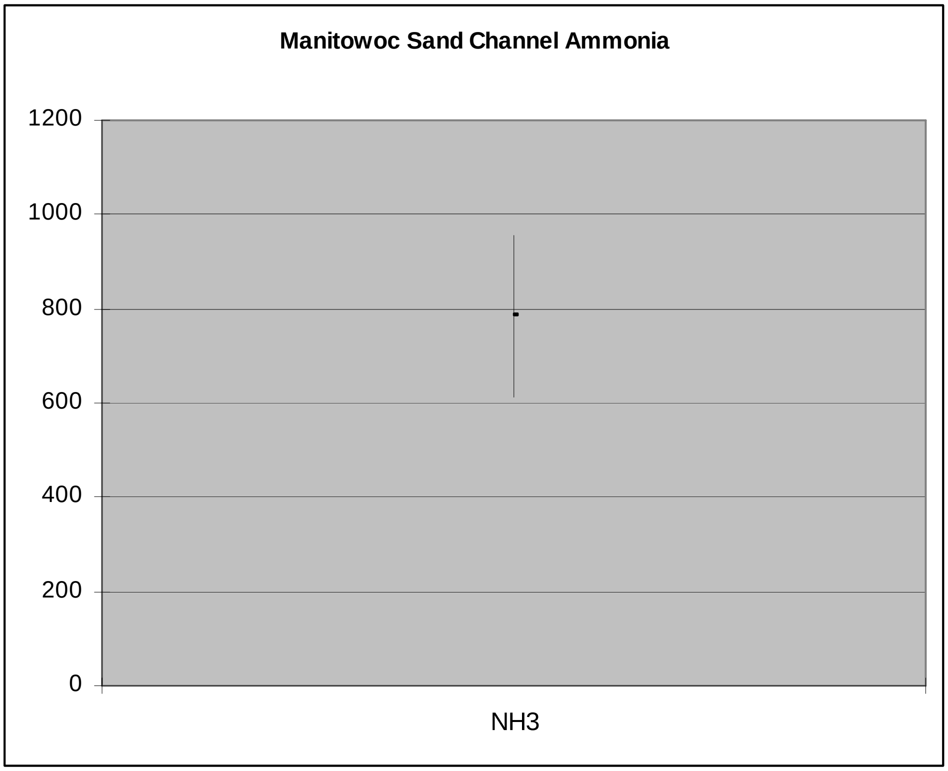

Figure 6.1.1
Sand Channel Ammonia (Manitowoc County)

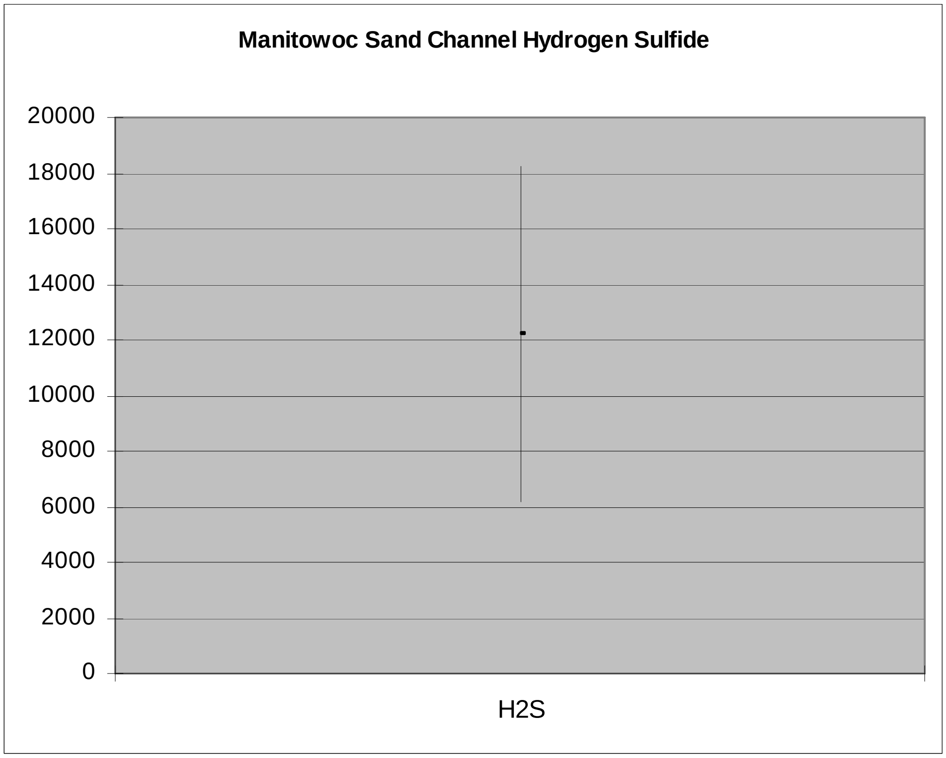

Figure 6.1.2
Sand Channel Hydrogen Sulfide (Manitowoc County)

Case Study 6.1 Key Findings Summary Statements

Ammonia concentrations observed around the sand channel at this facility are similar to those obtained around the lagoons.

Hydrogen sulfide concentrations observed near the sand channel are significantly higher than those observed around the lagoons, and especially higher than concentrations observed away from the outfalls.

SAND CHANNEL OCCUPATIONAL HAZARD IMPLICATIONS

A surprise finding associated with the sand separation channel is the observation of elevated levels of hydrogen sulfide at concentrations at or above recommended occupational exposure levels. Occupational exposure standards, established by OSHA, for hydrogen sulfide are 20 ppm averaged over a typical 8-hour day (also not to exceed 50 ppm over any 10 minute period) which is significantly higher than those established by the Wisconsin Department of Natural Resources for general ambient air (0.24 ppm). Occupational standards are higher because it is assumed that these exposures will be to healthy individuals working typical work days (40 hours per week) in workplaces, while general ambient air concentrations can represent year round exposure levels.

Typically, workers are not near the sand separation channels for significant periods of time. Usually, exposure is limited to the amount of time required to clear the channels of sand for drying and recovery, or to remove the dried sand for re-use as bedding.

In confined spaces associated with manure systems, such as enclosed reception tanks and pits, hydrogen sulfide should always be considered an extreme hazard. Sand separation channels, with open circulation, are not confined spaces and do not warrant confined entry precautions. Nonetheless, this study suggests that the potential exists for hazardous conditions to be present around these structures, and farms with sand separation channels should consider adopting the following safety precautions:

1. Provide fencing, warning signs and other means to exclude unauthorized or accidental entry
2. Avoid worker entry at times when winds are calm (typically early morning and late evening)
3. Avoid prolonged exposure

It should be noted that hydrogen sulfide is an extremely toxic gas. Hydrogen sulfide levels may increase a thousand-fold during the agitation of manure. It is colorless, heavier than air, and may cause death within minutes at high concentrations. At lower concentrations it can irritate and damage the eyes and respiratory tract. While hydrogen sulfide is commonly known for its rotten egg odor, the odor is not detectable by the human sense of smell at higher concentrations. As such, there may be very little warning when a relatively benign situation has changed into a potentially hazardous one.

In addition, several occupational and health agencies are considering changes to the acceptable level of hydrogen sulfide in the air for workers. For example the ACGIH, which is an independent non-governmental organization, is currently proposing to recommend an 8-hour Time Weighted Average (TWA) of 5 ppm (about 7 mg/m^3). By convention, the maximum allowed 30-minute exposure would then be set at 15 ppm, and the maximum allowed peak concentration would be 25 ppm. These guidelines would represent the latest advice of this scientific body as to what levels of exposure would be advisable to protect worker health.

SIGNIFICANT FINDINGS

Several points are important to keep in mind when reviewing the data collected during this project. First and foremost of these is that no matter what the quality of individual measurements and sampling trips may be, we did not make enough trips to any particular facility to determine whether we were sampling during “best-case”, “typical” or “worst-case” conditions with respect to odors or ammonia and hydrogen sulfide.

This reality, combined with the generally large variability observed between trips to the same farm, reduces our overall ability to make firm, general conclusions based on our observations. At the same time, however, for those few cases where our data does suggest an observable difference related to a management practice, the paucity of data strengthens the likelihood that the difference is real.

In general, care must be observed when evaluating our results, and in applying any conclusions drawn from them. The wording used to express the conclusions and evaluations are very specific. The phrase “tended to” or “tendency” means that many of the results observed conformed to whatever point is being made; it does not mean that all results did.

The qualifier “significantly” is used here in the general sense of showing a substantial or considerable difference, as opposed to use of the word in a statistical sense of being quantifiably different. As this project was a demonstration project with limited sampling, instead of a research project wherein a statistically relevant population of samples was collected, statistical tools to evaluate the data beyond simple averages and standard deviations have not been applied.

The descriptor “elevated” is in no way meant to imply magnitude. A downwind concentration of 25 $\mu g/m^3$ is elevated with respect to an upwind observation of 18 $\mu g/m^3$, as is a downwind concentration of 2,500 $\mu g/m^3$.

The descriptor “indistinguishable” indicates that there was considerable overlap in the range of results from the compared observations. Again, statistical tools to quantify the level of overlap between the samples were not applied.

Beyond these qualifiers, it is also important to remember that the BMPs studied here are not the only ones available, nor are they necessarily the most effective. They are merely the ones that were part of this study.

While comparisons between farms are not made on a quantitative basis, the following graphs illustrating the findings are included for reference. Specific conclusions based on these results are listed following.

Figures F and G present a compilation of the lagoon surface sampling, with results presented on a logarithmic scale with units of micrograms per cubic meter. Figure H and I present a comparison of the near lagoon sampling, with results in units of micrograms per cubic meter.

Note that the red line separates the digested manures on the left, from the undigested manures on the right, while the blue lines separate the different practices being studied at each location. The different study locations are abbreviated along the X-axis, with WC for Waupaca County, DC for Dunn County, MW for Manitowoc County, MC for Monroe County and KC for Kewaunee County. Results from Clark County are not presented for comparison in these graphs.

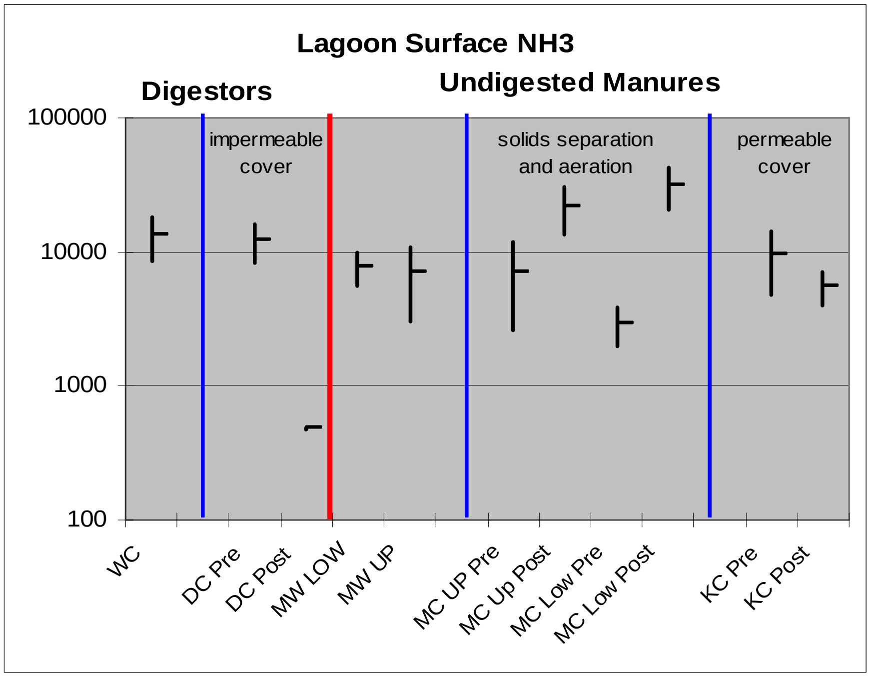

Figure F
Lagoon Surface Ammonia Concentrations

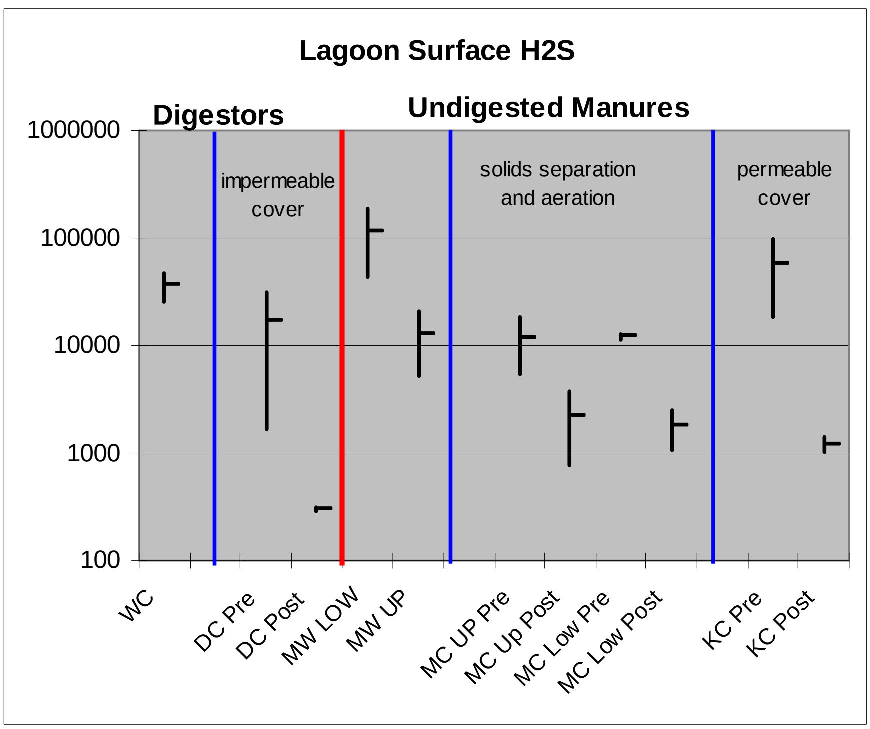

Figure G
Lagoon Surface Hydrogen Sulfide Concentrations

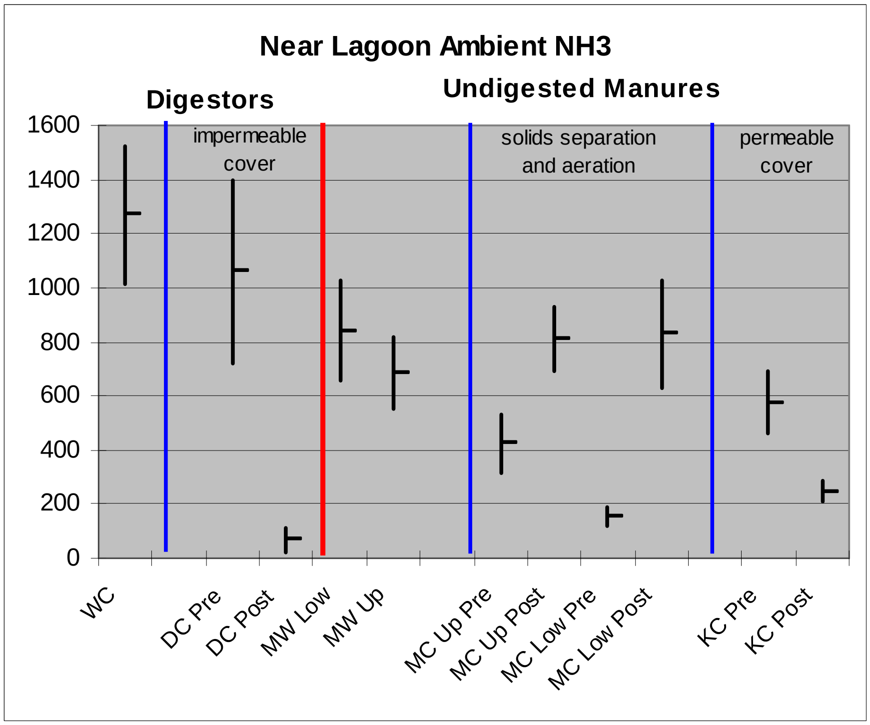

Figure H
Near Lagoon Ammonia Concentrations

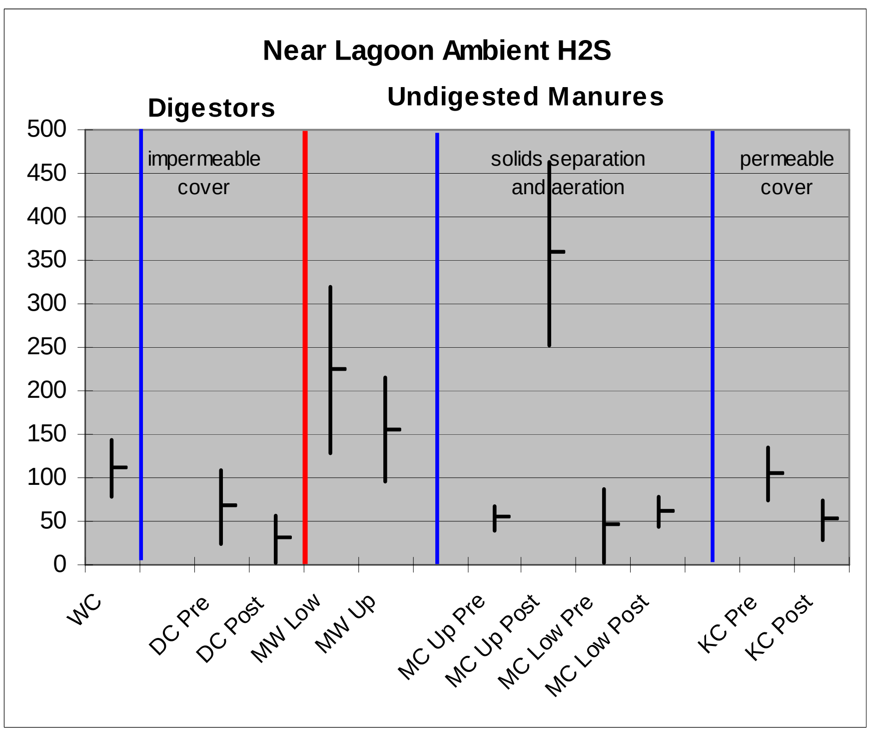

Figure I
Near Lagoon Hydrogen Sulfide Concentrations

The case studies in Waupaca and Dunn counties were intended to collect data on farms where anaerobic digestion is employed, to be compared with the undigested manure farms, especially the Manitowoc and Kewaunee County facilities. Results of these comparisons lead to the following points:

- Lagoon surface concentrations of hydrogen sulfide are indistinguishable between digested and undigested manures.
- Conversely, lagoon surface ammonia concentrations on digested manure tend to be higher than those observed on undigested manure, in the absence of other practices.
- Near lagoon downwind concentrations of hydrogen sulfide tend to be indistinguishable between digested and undigested manures, however, slightly higher rates of detection for this compound are observed around the undigested manures.
- Near lagoon downwind concentrations of ammonia tend to be higher around digested manure lagoons.
- The mesophilic (Waupaca County) and thermophilic (Dunn County) digesters are indistinguishable using our dataset.
- Lagoons that receive digested wastes do not predictably produce less odor than do lagoons receiving undigested wastes. Mesophilic digestion resulted in slightly lower odors, however thermophilic digestion resulted in slightly higher odors.

In addition to employing a digester, the Dunn County facility elected to install an impermeable cover for further odor and gaseous emission control as part of this study. Our results indicate:

- Installation of an impermeable cover significantly reduced surface concentrations of both ammonia and hydrogen sulfide. All lagoon surface samples collected off the surface of the lagoon cover collected undetectable quantities of both analytes. Note that sampling limitations render lagoon surface sample detection limits far higher than those possible around the lagoons.
- An impermeable cover will likewise significantly reduce nearby concentrations of both gases, although not necessarily to below detectable limits.
- Impermeable covers are highly effective at controlling odors from waste storage lagoons.
- No data in this study was collected around land spreading, so no statements can be made regarding effects of the cover on this stage of manure management.

The Kewaunee facility installed a permeable cover during the course of this study. In addition to employing this practice, the farm went through a significant expansion, including the construction of an additional manure storage lagoon adjacent to the lagoon sampled for the project. A cover was installed on new lagoon as well, and there was no noticeable impact from its installation during our sampling.

- Installation of a permeable cover significantly reduced concentrations of hydrogen sulfide observed on the surface. None of this compound was detected in surface samples following installation.

- The permeable cover did not likewise reduce the on-surface ammonia concentrations. Post-installation results were indistinguishable from pre-installation samples.
- Downwind near lagoon hydrogen sulfide results from samples collected following installation appear to be somewhat lower, however there was a significant increase in concentrations observed near areas of turbulence (the sand channel and lagoon outfall).
- Downwind near lagoon ammonia results from samples collected following installation are significantly lower, while those around the sand channel and outfall are indistinguishable than those collected beforehand.
- Permeable covers are very effective at controlling odors from waste storage lagoons, however, not as effective as impermeable covers.

The Monroe County facility installed solids separation and aeration as their best management practice. This installation was planned as part of the original farm construction, and solids separation was employed throughout the project. There were limited opportunities for sampling before aeration was begun. As such, our before and after sampling are less comparable from this facility than from the others.

- Aeration appears to reduce lagoon surface hydrogen sulfide concentrations, however, the surface ammonia concentrations appear to be increased.
- Downwind near lagoon ammonia concentrations appear to be increase following aeration of the lagoon, however this may be an artifact of insufficient pre-installation sampling.
- Downwind near lagoon hydrogen sulfide concentrations show locally significant increases following installation of the aeration units, however the plumes associated with the equipment appear to be quite discrete.
- Solids separation and aeration appears to reduce odors from waste storage lagoons, however further sampling is needed to determine the full potential of this technology to control odors.

ADDITIONAL LESSONS LEARNED

In addition to observations relating directly to the practices being studied, there were a handful of characteristics observed almost universally among our study sites, which may have manure management implications.

Lessons Related to Ammonia and Hydrogen Sulfide:

- On most farms, on-lagoon concentrations of hydrogen sulfide tended to be significantly higher than ammonia concentrations observed at the same time
- Conversely, near-lagoon concentrations of ammonia tended to be significantly higher than the hydrogen sulfide concentrations collected at the same locations
- Elevated near lagoon ammonia concentrations tended to be somewhat evenly distributed across the downwind edge, implying a general surface/air exchange

- Near lagoon hydrogen sulfide concentrations were strongly driven by areas of turbulence (such as outfalls) which would behave somewhat like point sources. While some general elevation in hydrogen sulfide concentrations was usually observed downwind of the lagoon, very discrete plumes associated with turbulence were frequently captured.
- Near lagoon ammonia concentrations tended to be of generally the same magnitude during the day and night time sampling periods during individual sampling trips, with perhaps a slightly higher daytime concentration. This was true whether wind conditions remained consistent between the sampling periods, or if there were nighttime inversions.
- Near lagoon hydrogen sulfide concentrations, on the other hand, were frequently elevated during the night time sampling with respect to the daytime samples collected on the same trip, especially around undigested manures when the wind dropped during the night.
- The highest ambient hydrogen sulfide concentrations observed during this study were in samples collected around the sand channels and outfalls.
- The highest ambient ammonia concentrations observed were in samples obtained around manure lagoons containing digested manures.

Lessons Related to Odor:

- Agitation of wastes greatly increases the odors generated from waste storage lagoons. Whenever possible, submerged inlets should be used to help minimize surface disturbances, and thus reduce odors.
- Although digesters reduce the organic content of the wastes passing through them, some organics remain undigested. The longer the retention time, the more thorough the digestion, however, the larger the digester also needs to be. Most digesters are sized to optimize pay-back, which means they are smaller than what would be needed for complete digestion. If odor control is a goal, retention time should be maintained at 29 days or longer. Future farm expansions should be considered when sizing a digester. A 20% expansion in herd size will result in a 20% reduction in retention time (i.e. 23 days versus 29 days) and a probable increase in odors.
- Most digesters employ a flare to burn off excess gas not used in the generator set. If the flare malfunctions, unburned gasses are released directly to the atmosphere. To avoid this, it is important that the flare has a reliable igniter that is maintained in good working condition. Also, an oversized baffle can help to avoid the flare from being extinguished in high winds. The Waupaca farm actually replaced its original flare with one having these design features to improve reliability.
- The discharge point from anaerobic digesters can be a significant source of odors. The owner of the Waupaca county farm devised and installed an innovative system to control these odors. This system consists of a blower, air ducting, and a gas-entrapment tank.

  The 2 HP regenerative blower is connected to 3” PVC piping such that it pulls air from around three separate odor sources. These three areas are the digester extraction tank, the solids separator room, and a 4,500 gallon separated liquids holding tank. The emissions from these three sources are then sent by the blower through additional piping to a 600 gallon air sparging tank. In this tank the gasses are bubbled up through 20" of water via small holes drilled in the piping. As the gasses pass through the water, hydrogen sulfide is converted to sulfuric acid. This acid then flows from the tank to the waste storage lagoon. A trickle of fresh water into tank constantly replenishes the supply.

Since the installation of this system, the owner has noticed significantly lower odor levels, and has not noticed any detrimental effects to his waste storage lagoon. The concentration of sulfuric acid is so low that it is easily buffered by the large volume of waste in the lagoon. The system continues to perform well, and has required very little maintenance.

- Permeable covers are very effective at controlling odors from manure storage lagoons, however they can interfere with traditional methods of agitation and pumping. With a cover in place, an above-surface gun can not be used to break up floating solids. Also, the added friction caused by a cover can reduce the effective distance of a below-surface mixer. A number of openings should be designed into the cover to allow for complete agitation of the wastes. A manure pump should be stationed at each opening to circulate the entire contents of the lagoon at once. This will re-suspend settled solids and break up floating solids prior to emptying and land application. The availability of pumps, or the cost to rent additional pumps, should be factored into the decision to install a permeable cover.

- The Kewaunee farm experienced difficulties with removing solids from one of their covered lagoons in the fall. This was from the second of three lagoons, all connected in series. This lagoon receives overflow from a small primary lagoon. The third lagoon, which in turn receives overflow from the second lagoon, experienced no difficulties. The solution to their problem was to use multiple pumps as described above, however they plan to make modifications to avoid that in the future. Their plan is to connect lagoons one and two using a submerged pipe rather than a surface channel. This should retain floating solids in lagoon one, which is not covered, where they can be more easily removed. The contents of lagoon two should then be mostly liquid, as it currently is in lagoon three, thus aiding agitation and pumping. Lagoon one is also where residual sand bedding accumulates if it escapes the sand separation channel. Any farmer who uses sand bedding, and wishes to install a cover on their waste storage lagoon, would be well advised to have a small uncovered primary lagoon preceding their larger covered lagoon.

  Impermeable covers do not provide for agitation of the wastes in a lagoon. For that reason, they should be used only on lagoons that are preceded by a solids separation system. Also, if the farm uses sand bedding, an effective sand separation system must precede the lagoon.

  Experience with a covered lagoon at another Wisconsin farm indicates that solids accumulation may not be a concern. Even after a number of years, few solids remain after the liquids are pumped out twice each year. The theory is that the anaerobic conditions which exist in the sealed lagoon serve to liquefy the solids over time, much as what happens in a home septic tank. The plan at this farm is to wait until the cover needs replacing before completely emptying the lagoon of any accumulated solids.

- During the course of this study, it was noted that feed storage often generated significant odors. At times, depending on wind direction and other factors, it became difficult to determine which was more noticeable, the odors from the waste storage lagoon or the ones from the feed bunker. These conditions seemed to occur at farms where feed was stored at higher moisture content. Feed that was put up dry, and kept well protected from precipitation, did not generate as much odor as did feed that was leaching due to wet conditions. A farmer wishing to control odors should maintain stored feed in as dry a condition as possible.
- The sampling on our baseline animal feedlot indicated that this type of facility is not a concern for odors or concentrations of ammonia and hydrogen sulfide. However, this must be qualified with the fact that the stocking rate at this facility was fairly low (999 animals on 80 acres of land). The sampling also indicated that areas where the animals were concentrated, such as around feed bunks, tended to have higher levels than did other areas, as would be expected. Open feedlots with very high stocking rates, such as is common in the western U.S., would logically produce more odors, and higher concentrations of ammonia and hydrogen sulfide, than our study farm.

  If control of odors and emissions from open feedlots is a concern, it stands to reason that stocking rates should be kept low. Lower animal densities will also help to maintain vegetation and reduce erosion. A good land base will bring nutrients into balance, reducing inputs as well as the need to haul manure.

ADDITIONAL RESEARCH NEEDS IDENTIFIED BY THIS PROJECT

It became apparent quite early in the study that our study design was stretched too thin to accomplish our goals to a statistically relevant and significant extent. As such, more sampling in general would be desirable around most of these facilities. Beyond this, the following specific recommendations for facilities involved in this study are included below.

Case Study 1, Anaerobic Digester (Waupaca County): Although no additional practices were installed at this farm, further sampling would be of use because of the existence of separate digested and undigested manure lagoons. If we had realized early enough in the study that this was the case at this facility, sampling on and around both lagoons would have been conducted as a matter of course. Although not the highest priority at this point, re-sampling this facility for a series of three sampling runs encompassing both lagoons would be of interest.

Case Study 2, Impermeable Cover (Dunn County): Addition of the impermeable cover renders this facility somewhat less interesting for further sampling. Although it would be of use to check on the condition of the cover and general odors around the facility on a perhaps annual basis, no further sampling is recommended.

Case Study 3, Permeable Cover (Kewaunee County): Further sampling at this facility is something of a priority. Initial post-cover results obtained in May 2008 showed no hydrogen sulfide, while follow up visits revealed significant concentrations, especially around the sand channels and outfall. Determining whether this was a random occurrence, or whether there truly is a reduction in local hydrogen sulfide to almost zero on a seasonal basis is of importance in evaluating the impact of this practice. Follow up visits in Spring, 2009 did not capture both hydrogen sulfide conditions. An on-going program of periodic long term sampling would be of interest to observe the behavior of the cover over time.

Case Study 4, Solids Separation and Aeration (Monroe County): in the ideal world, more pre-practice sampling would be conducted around this facility, to make our pre- and post- practice results more comparable. However, this is not possible, so the best we can do is conduct more sampling runs with the system in operation, to see if there are reductions as the system reaches a more complete equilibrium. An on-going program of periodic long-term sampling would be of interest to observe the aeration system over time..

Case Study 5, Animal Feed Lot: Further sampling at this facility is not of significant interest.

Case Study 6, Manure Storage Lagoon (Manitowoc County): although no practices were installed at this facility, its significant concentrations render it an interesting site for further background studies. However, with limited resources, no immediate further sampling is recommended.

In addition to the recommendations above, significant further research would be useful. It must be recognized that the practices studied here are by no means the only possible BMPs related to odor and air emissions control. Finding examples of different practices and conducting before and after studies on them would be of great value in determining which of the practices accomplish goals of reducing air impacts in a cost effective manner.

Of special interest would be investigating practices surrounding the use of sand channels, which our study identified as significant areas of elevated concentrations. In addition, the little sampling we did around barns have identified that they are sources of ammonia, and thus could be the subject of altered management practices intended to reduce air impacts.

TECHNICAL COST BENEFITS REALIZED

Operating Costs	Dunn County Site *		Waupaca County Site *	
	Cash (Out of Pocket Costs)	In-kind	Cash (Out of Pocket Costs)	In-kind
Digester Maintenance	$27,300		0	
Substrate Transportation	$255,970		NA	
Separator Repair/Maintenance	$32,200		$17,500	
Pumps Repair/Maintenance	$38,951		$3,000	
Other Costs (Repairs, Maintenance, Labor, Fuel, Insurance, etc.)	$84,108		$70,100	$9,500
Total Operating Costs for Reporting Period	$538,529		$90,600	$9,500

Benefits/Income	Dunn County Site *	Waupaca County Site *
Income from Energy Produced	$359,134	$248,756
Selling Compost	$6,000	$27,300
Savings on Bedding Materials	$42,000	$117,250
Other Benefits/Income	(Substrate Income) $125,017	$35,000
Other Benefits/Income	(Offset Credits) $80,948	
Total Benefits/Income for Reporting Period	$613,099	$428,306

* Costs and Income from both sites are for the 3rd and 4th quarter of 2006, all of 2007, and the 1st quarter of 2008

Table E
Costs and Income for Participating Manure Digester Systems

APPENDIX A: SAMPLE NASAL RANGER™ ODOR SENSITIVITY TEST DATA SHEET SAMPLE

St. Croix Sensory, Inc.

Odor Sensitivity Test Data Sheet B

Name : Steve Struss Date : 5/19/08 Time : 11:00 Am

The Red Pen presention order is designated by the shaded box.
Record Responses as G for guess and D for detect.

Level	Warm Up 1	Warm Up 2	Warm Up 3	Round 1: 1	Round 1: 2	Round 1: 3	Round 2: 1	Round 2: 2	Round 2: 3
15			G						
14									
13	G								
12									
11	G								
10					G				
9	G			G				G	
8						G		D	
7		D		D			D		
6					D				
5			D						
4									
3									
2									

Warm Up presentations alternate every-other dilution

Round 1 Starting Point is 3 levels back from the first of two consecutive correct Warm Up Detects

Round 2 Starting Point is 2 levels back from the first of two consecutive correct Round 1 Detects

The Score is the first level of two consecutive correct D responses.

SCORE: 7 SCORE: 8

Individual's Odor Sensitivity (average of the SCORES): 7.5

Test Administrator : Mike Murray

Odor Pen Kit Serial Number : S/N 50361

St. Croix Sensory, Inc. 3549 Lake Elmo Ave. N. P.O. Box 313 Lake Elmo, MN 55042 U.S.A. Tel:800-879-9231 Fax:651-439-1065
Email:stcroix@fivesenses.com Web:www.fivesenses.com and www.nasalranger.com

APPENDIX B: PRE- AND POST-BMP SURVEY RESULTS

<Farm Name> Survey Results					**Comments**
1. Length of residency in Kewaunee Co.					
1-5 yrs	5-10 yrs	10-25 yrs	25+ yrs	NR	2/3 over 10 yrs
1	3	3	7	1	
6.66%	20%	20%	46.60%	6.66%	
2. Odor impact outdoor plans					about
Never	Almost never	Occasionally	Frequently	NR	1/2 no impact
5	2	4	3- 1 windows open 1- 57 days identified	1	and 1/2 impact
33.30%	13.30%	26.60%	20%	6.66%	
3. Season of odor issues					
Never	Spring fall	Summer	Pit emptying and agitating	NR	Summer and pit
1	5	8	4	1	agitation
5.20%	26.30%	42.10%	21%	5.20%	19 responses- multiple months
					Multiple responses on some surveys
4. Increase of odor nuisance					
Yes	No	No response			over 1/2 had not
5	9	1			reported increase
33.30%	60%	6.66%			
5. Are you satisfied with <Farm Name> efforts to control odors					
Very satisfied	Somewhat satisfied	Somewhat dissatisfied	Very dissatisfied	NR	
4	6	2	2	1	2/3 satisfied
26.60%	40%	13.30%	13.30%	6.66%	1/3 not
6. Move to another home in area-location of <Farm Name> impact decision					
Yes	No				Overwhelming response
13	2				on location
86.60%	13.30%				
					normal farm odors
7. Farm odors make you move from rural area					do not appear to force
yes	no	NR			people to move
3	9	3			
1 if CAFO					
8. Air emissions/odors impact human health					
not concerned at all	somewhat concerned	very concerned	NR		40% is either somewhat
8	3	3	1		or very concerned about
53.30%	20%	20%	6.60%		health impacts
9.Live on a farm					
yes	no				
10	5				
66.60%	33.30%				

Additional comments- concerned about lagoon seepage, small farm odors do not bother respondent but CAFO's do, more concern about hog than dairy cattle odors; type of odor, hauling and spreading was also mentioned.

NR- no response

<Farm Name> SURVEY 2 RESPONSES

1. How long have you lived in the Town of <>, Kewaunee Co? Average 30.1 years
Range from 0 to 74 years

1-5 years	5-10 years	10-25 yrs	25+ yrs	NA
0	3	2	4	1

2.Have you noticed reduced odor instances or intensity since the cover was installed in late 2007?

Yes	No	No difference
4	4	2

3. How frequently have odors from <Farm Name> affected your outdoor plans, such as eating outdoors, taking a walk, gardening, etc. since the manure storage cover was installed in late 2007?

Never	Almost Never	Occasionally	Frequently
4	1	3	2

4. Are you satisfied with the efforts <Farm Name> to control its odor?

Very Satisfied	Somewhat satisfied	Somewhat dissatisfied	Very dissatisfied	NR
4	2	1	2	1

5. Has the efforts of <Farm Name> made it more likely that you want to continue to live in the neighborhood?

Yes	No	NR
5	3	2

6. Are you still concerned about the effect of air emission/odors from livestock to your health?

Not concerned at all	Somewhat concerned	Very concerned
2	4	4

7. Do you currently live on a farm?

Yes	No
5	5