Results of the Iowa DNR Animal Feeding Operations Odor Study

Iowa DNR
Ambient Air Monitoring Group
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Project Overview

Background

On April 29, 2002, Iowa Governor Tom Vilsack signed a new statute related to animal agriculture, Senate File 2293. Included in this new law was a section (Appendix A: Iowa Code section 459.207) requiring the Iowa Department of Natural Resources to perform a study of the airborne pollutants emitted by animal feeding operations (AFO's), including hydrogen sulfide, ammonia, and odor. The odor measurements for the study were taken from 2003 through 2005.

Organization

Odor measurements were taken by environmental specialists in the Field Services Bureau of the department. Procedures for the field study were developed by the ambient air monitoring group in the Air Quality Bureau and were signed by the Bureau Chiefs of the Air Quality and Field Services Bureaus [1]. Screening and certification of environmental specialists taking odor study measurements was performed by St. Croix Sensory of Lake Elmo, Minnesota under contract with the department.

Figure 1 Nasal Ranger (left) and Barneby Sutcliffe Scentometers

Measurement Protocol

Odor measurement methods currently used in regulatory applications rely on human odor observers to quantify odor levels [2]. Odor measurements for the field study were taken using scentometers (Figure 1). These simple, portable devices are used to dilute odorous air with odor-free air in known ratios. To quantify the strength of a livestock odor, the odor observer begins the reading with the scentometer set to a high dilution setting. If an odor cannot be detected, the observer works their way down through lower dilution settings, refreshing their nasal cavity with odor free air between dilution settings, until they reach a dilution setting where livestock odor is perceived. If no livestock odor is detected at the lowest dilution setting, the observer then breathes undiluted "full strength" ambient air. The highest dilution setting where the odor can be detected is a measure of the strength of the odor. In the first year of the study, the highest (and only) dilution setting used was 7:1 (Table 1); in the second and third years of the study, a 15:1 dilution setting was added to begin the odor measurement (Table 2).

Table 1 Scentometer Odor Levels used in 2003

Level	Scentometer Result
3	Greater than 7 to 1
2	Detectable, but less than 7 to 1
1	Not detectable
0	No reading taken

Table 2 Scentometer Odor Levels used in 2004-2005

Level	Scentometer Result
4	Greater than 15 to 1
3	Greater than 7 to 1, but less than 15 to 1
2	Detectable, but less than 7 to 1
1	Not detectable
0	No reading taken

For the Iowa field study, environmental specialists were requested to take an initial odor reading with the scentometer, and if the odor intensity exceeded the 7:1 threshold, they were asked to take a second reading at the same location 15 to 60 minutes later. If both readings were over the 7:1 odor threshold, an exceedance was said to occur at the monitoring location.

The definition of an odor exceedance used for the Iowa field study most closely resembles the ambient air standard for odor established by the State of Wyoming. A list of scentometer-based odor standards in other States is provided as an appendix [Appendix B: Scentometer Based Odor Standards].

If the measurement location was downwind of an odor source, such as an animal feeding operation or manure application area, and a suitable upwind monitoring location was accessible, the odor observer was asked to quantify the odor level at the upwind monitoring location. Upwind readings were not included in the exceedance or measurement counts.

Measurement Categories

Measurements were categorized as “facility measurements”, “manure application measurements”, or “PERRC measurements”. Facility measurements were taken near the fence line of animal feeding operations, Manure application measurements include any measurements taken near the fence line of areas where liquid or solid manure application was occurring or had recently occurred. PERRC measurements were taken near **P**ublic use areas, **E**ducational institutions, **R**eligious institutions, **R**esidences, and **C**ommercial enterprises (“PERRC’s”). These particular types of locations have been afforded special protection under Iowa Law (Iowa Code sections 459.202 and 459.204) in the form of separation distance requirements applicable to construction of AFO’s and application of manure. Environmental specialists were requested to perform PERRC measurements in response to complaints, if a PERRC was located downwind of a facility or manure application area where an odor exceedance was measured, or during the course of ordinary field duties.

Results Summary

There were 1708 measurements taken for the odor study, and 118 (7%) measurements resulted in exceedances. Manure application measurements produced the highest exceedance rate (11%), followed by facility measurements (7%), and PERRC measurements (4%) (Table 3). Measurements were taken and exceedances recorded throughout the state (Figure 2).

Table 3 Measurement and Exceedance Summary

Measurement Type	Exceedances	Measurements	Exceedance Rate
Facility	71	1066	7%
Manure Application	36	338	11%
PERRC	11	304	4%
Total	118	1708	7%

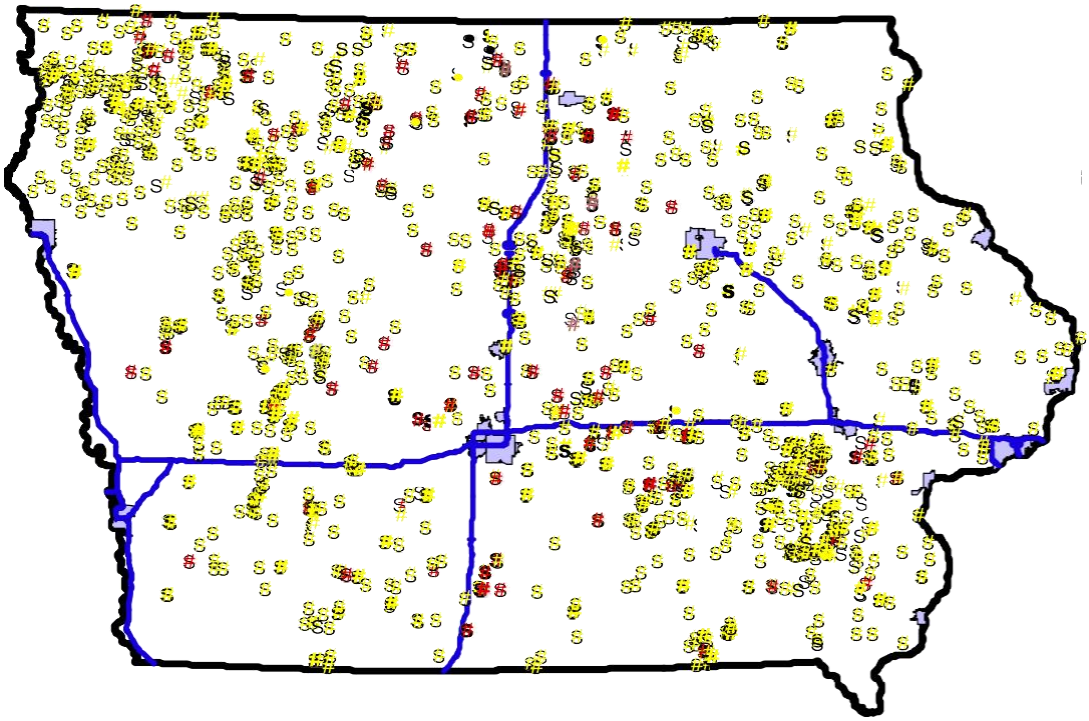


Figure 2 Map of Measurement and Exceedance Locations

The number of measurements taken (Chart 1) and the number of exceedances recorded (Chart 2) were highest in the late summer and fall. Most of the variability in the monthly exceedance count is explained by the monthly variability in the number of measurements (Chart 3).

Chart 1 Measurements by Month

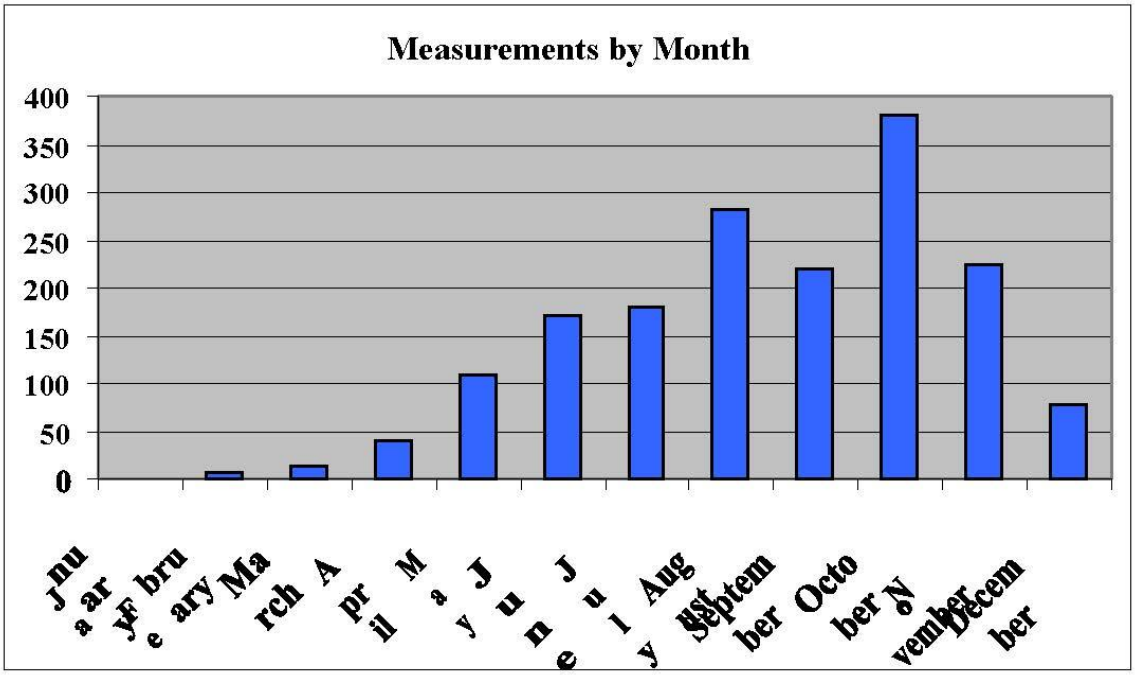


Chart 2 Exceedances by Month

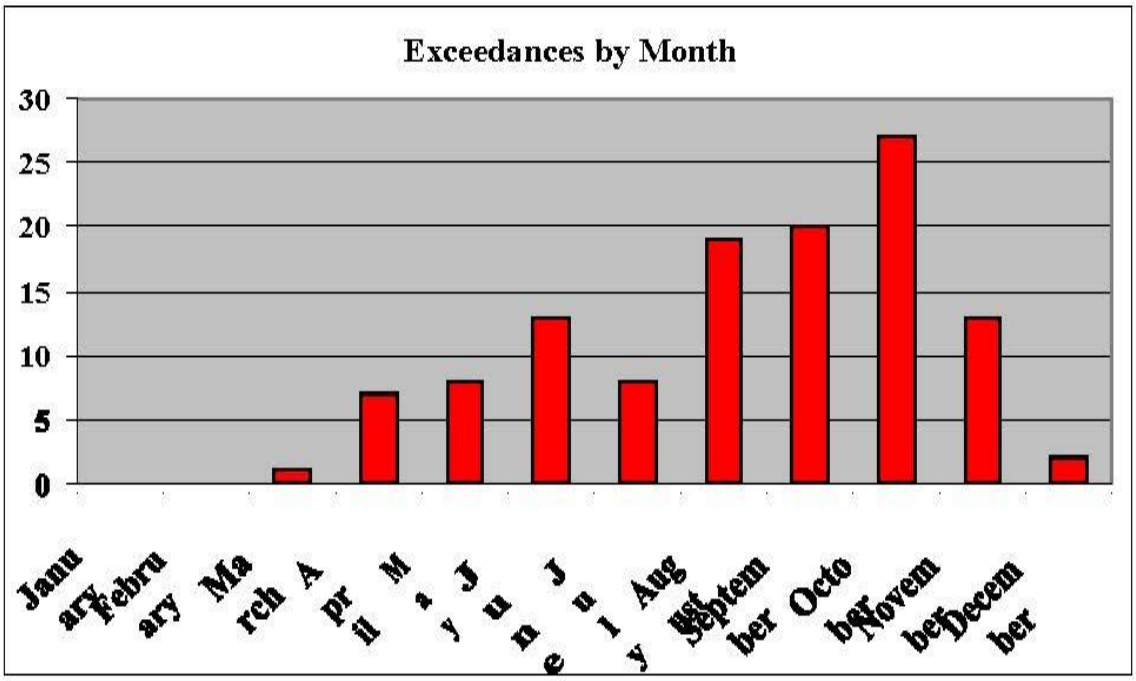
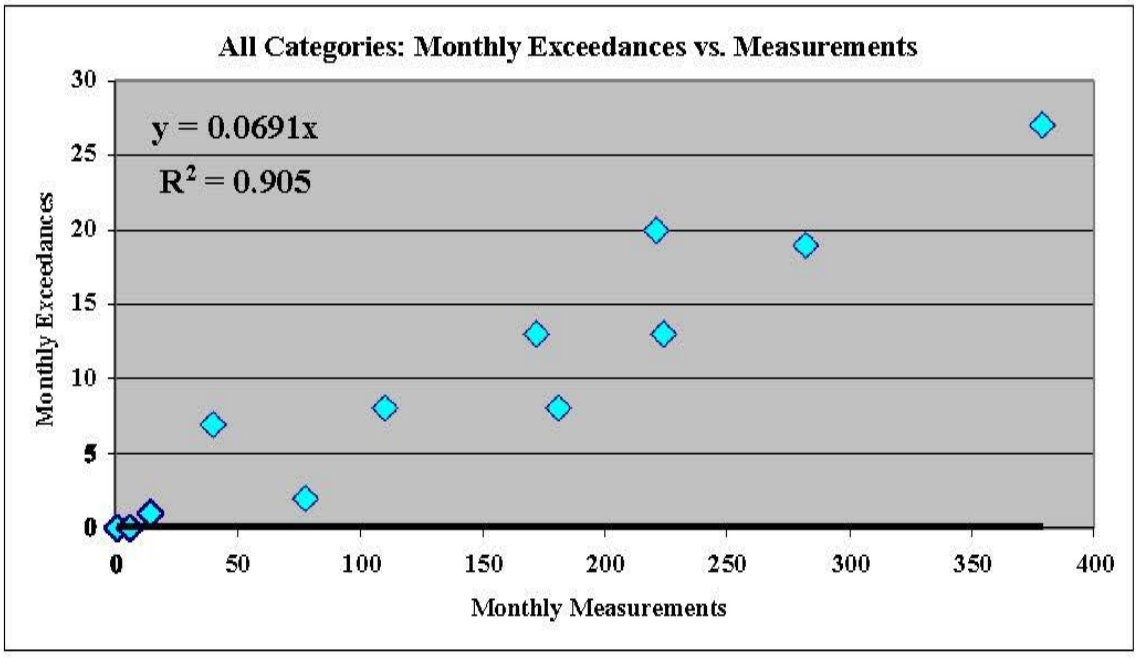


Chart 3 Monthly Exceedances vs. Measurements



Facility Measurements

Sixty two percent of all odor study measurements were taken near animal feeding operation (AFO) facilities. Measurements taken downwind of facilities had a 7% exceedance rate (Table 4).

Table 4 Measurement Summary

Exceedances	Measurements	Exceedance Rate
71	1066	7%

About 10% of facility measurements were taken in response to complaints; the remainder were taken during inspections

of AFO facilities, or as time allowed during the course of routine field office activities.

Map of Measurements and Exceedances

The map below (Figure 3) illustrates the locations of facility measurements taken and exceedances measured during the odor study.

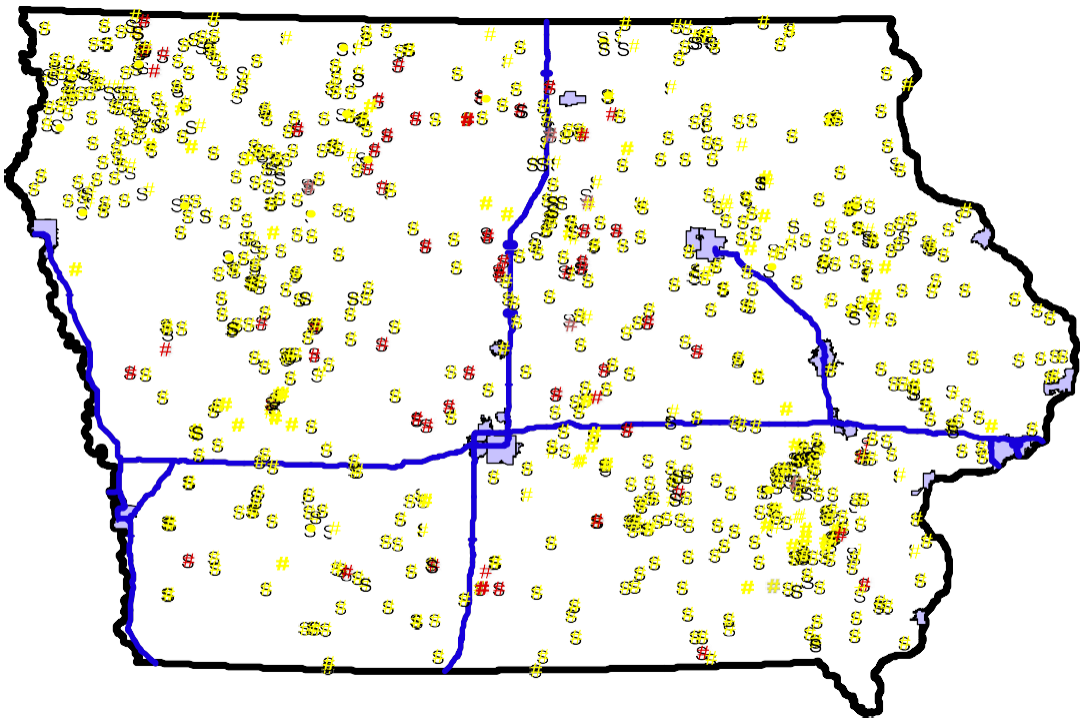


Figure 3 Facility Measurement and Exceedance Locations

Measurement Locations

To measure odors around facilities, the first odor reading is taken on or outside the facility property line downwind of the facility buildings and manure storage structures. If AFO odors are detected at a greater than seven to one dilution with filtered air, and an upwind monitoring location is accessible, a second reading is taken upwind of the AFO facility. Next, a second upwind reading is taken at the same upwind location at least 15 minutes after the first. A second downwind reading is then taken within one hour after the first downwind reading. If both downwind readings show AFO odors are detectable at the seven to one dilution, an exceedance is recorded.

Typical odor reading locations for facility measurements are shown below (Figure 4). “U” represents a typical upwind reading location, and “D” represents a typical downwind reading location.

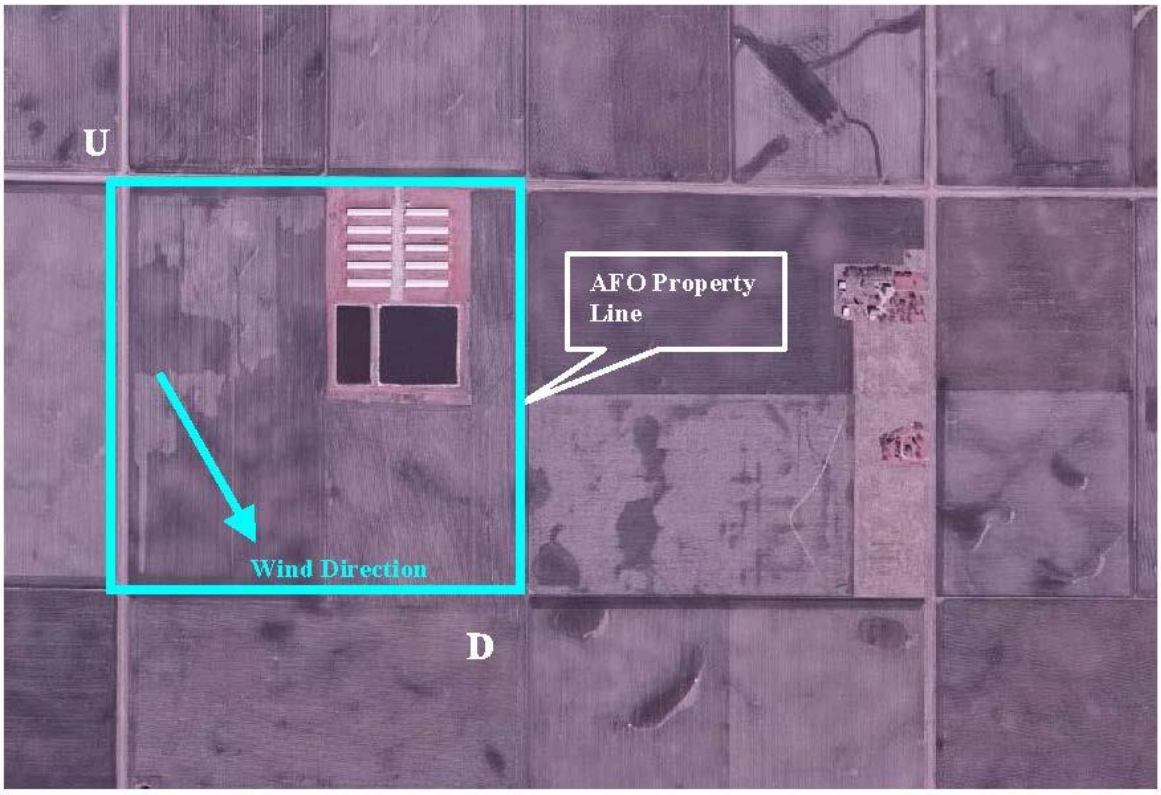


Figure 4 Typical Facility Measurement Locations

Seasonality of Measurements

Most measurements were taken (Chart 4) and most exceedances recorded (Chart 5) during the late summer and early fall. Most of the variability in the monthly exceedance count is explained by the monthly variability in the number of measurements (Chart 6).

Chart 4 Facility Measurements by Month

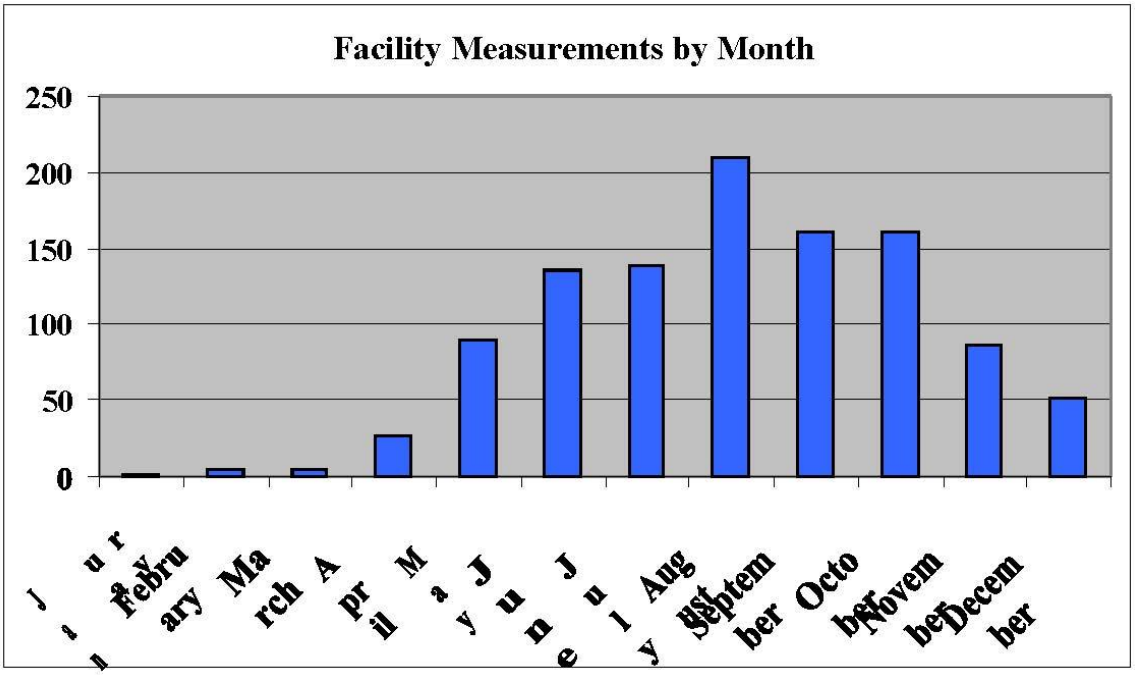


Chart 5 Facility Exceedances by Month

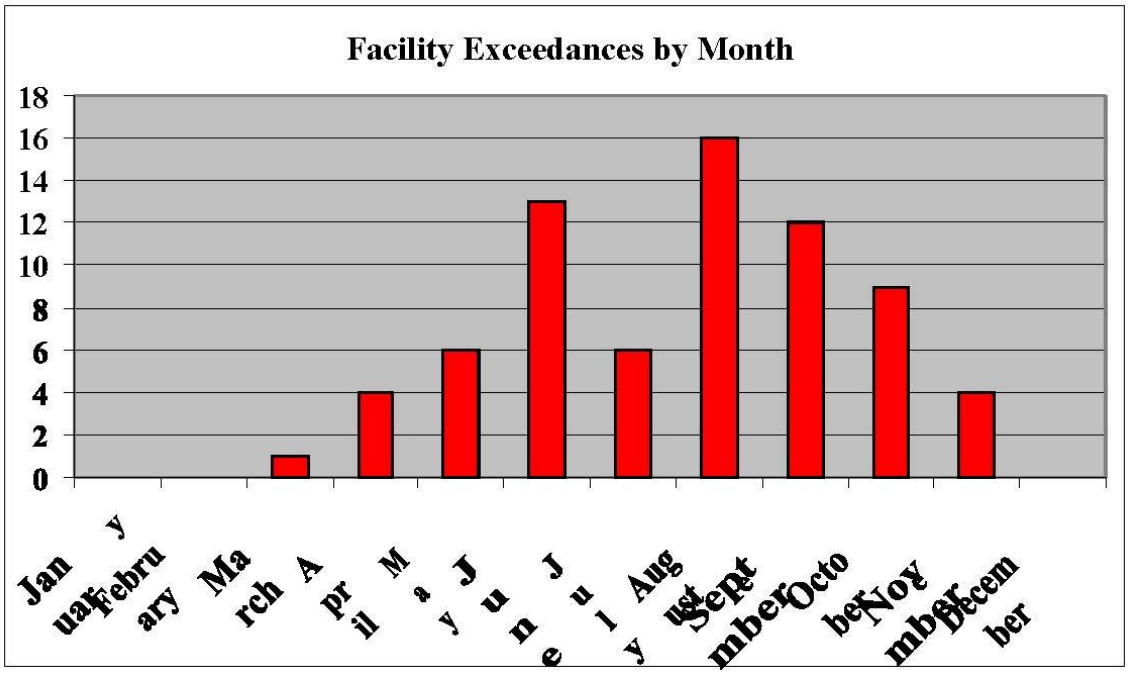
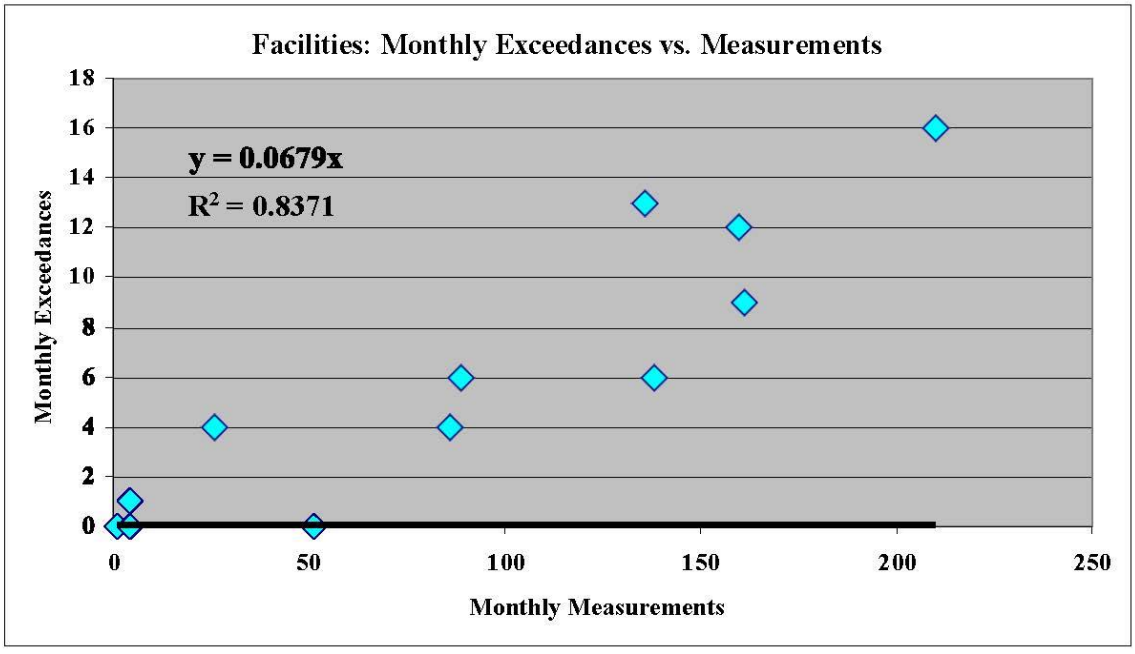


Chart 6 Monthly Facility Exceedances vs. Measurements



Results by Species, Manure Storage, and Facility Size

Dairy cattle had an exceedance rate of 2%, considerably less than the other species measured. Manure tanks and lagoons had exceedance rates that were approximately double those of deep pit or earthen basin manure storage structures. Facilities in the size range from 1001-1500 animal units and from 2501-4000 animal units had higher exceedance rates than other size facilities. The largest and smallest facilities recorded the same exceedance rate (3%). Breakdowns of facility measurements by species, manure storage, and facility size are detailed in the tables and charts (Table 5, Table 6, Table 7, Chart 7, and Chart 8).

Table 5 Facility Measurements and Exceedances by Species

Animal Species	Exceedances	Measurements	Exceedance Rate
Beef Cattle	5	61	8%
Chicken	3	43	7%
Hog	61	896	7%
Turkey	1	18	6%
Dairy Cattle	1	47	2%
Unknown	0	1	0%
Total Facility	71	1066	7%

Table 6 Facility Measurements and Exceedances by Waste Storage

Waste Storage	Exceedances	Measurements	Exceedance Rate
Tank	12	86	14%
Lagoon	10	84	12%
Deep Pit	30	532	6%
Dry Manure Pile	2	36	6%
Earthen Basin	12	230	5%
Runoff Control	2	54	4%
Other	3	44	7%
Total	71	1066	7%

Table 7 Facility Measurements by Facility Size

Size (Animal Units)	Exceedances	Measurements	Exceedance Rate
1 – 500	5	181	3%
501 - 1,000	16	306	5%
1,001 - 1,500	20	186	11%
1,501 - 2,000	13	218	6%
2,001 - 2,500	1	22	5%
2,501 - 3,000	4	26	15%
3,001 - 3,500	1	9	11%
3,501 - 4,000	3	12	25%
> 4,000	1	33	3%
Unknown	7	73	10%
Totals	71	1066	7%

Chart 7 Facility Measurements by Size in Animal Units

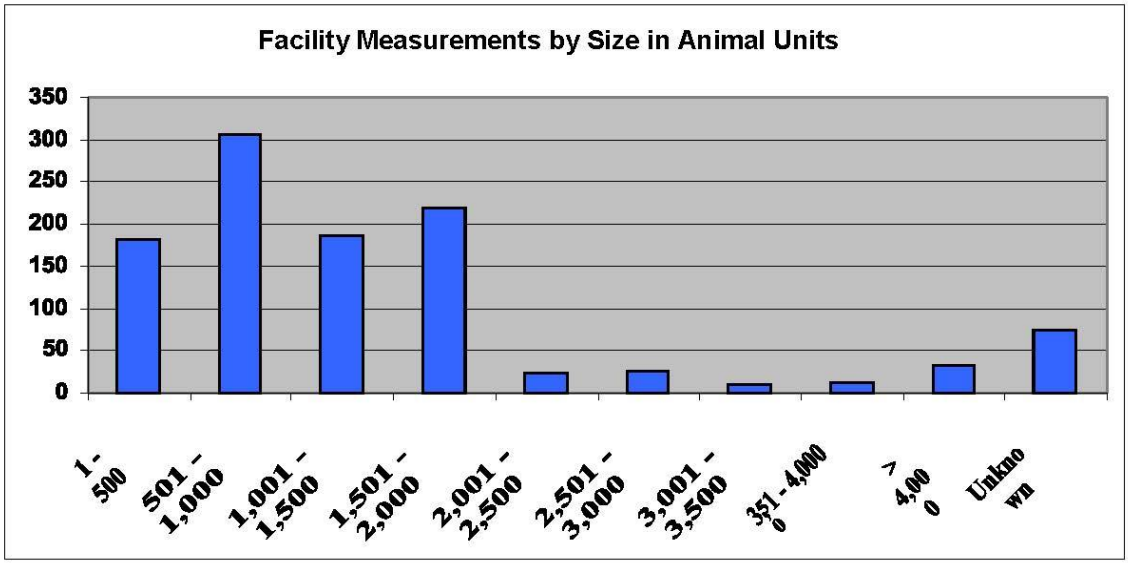
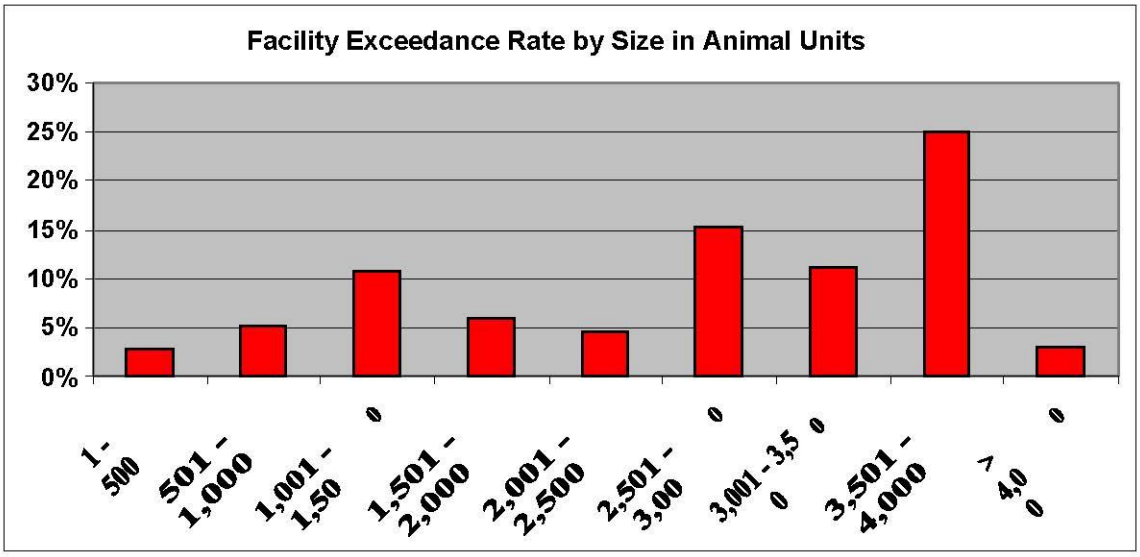


Chart 8 Exceedances by Facility Size



Upwind/Downwind Pairs for Exceedance Measurements

The charts that follow compare the upwind and downwind livestock odors measured in 2003 (Chart 9) and 2004-2005 (Chart 10) during odor exceedances. Much higher odor levels were noted downwind than upwind; downwind levels were typically two or more odor levels higher than the upwind measurements.

Chart 9 Facility Exceedance Levels 2003

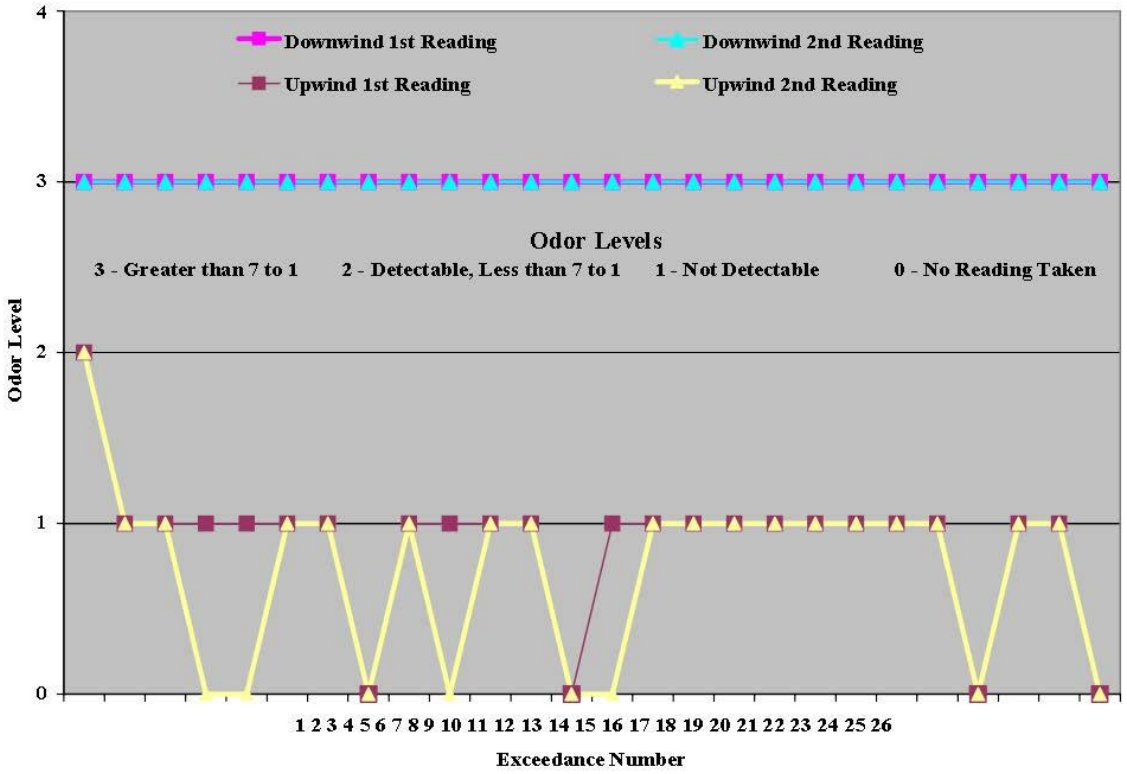
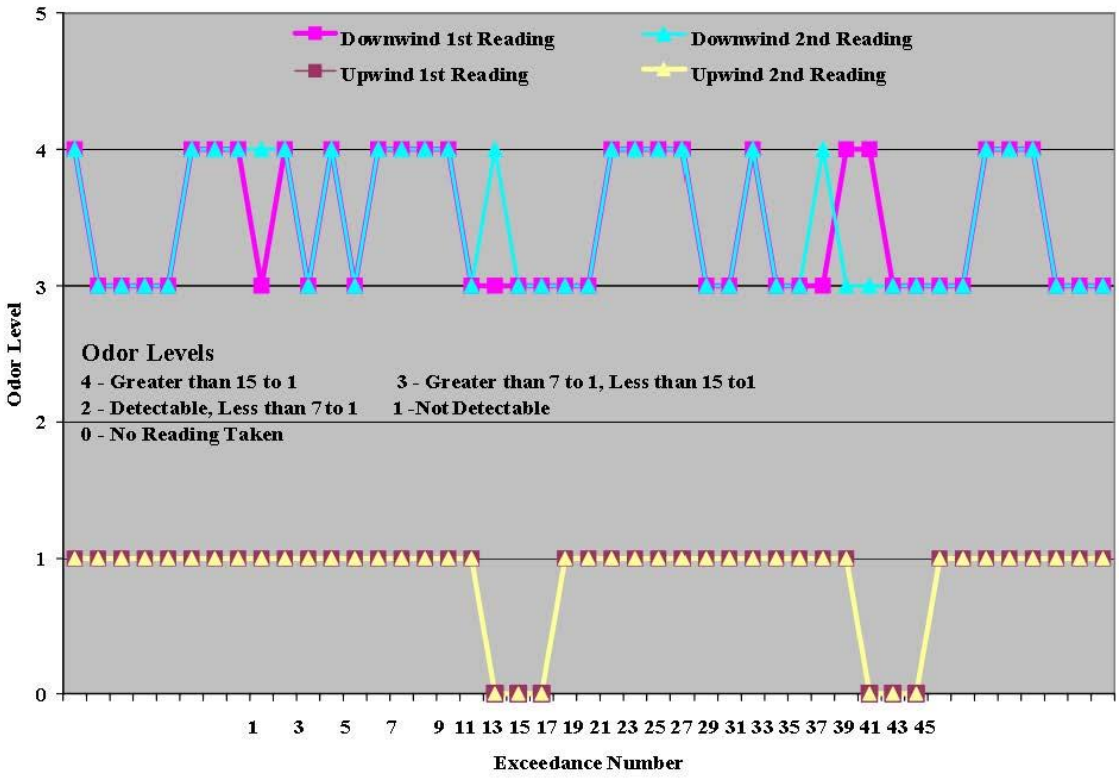


Chart 10 Facility Exceedance Levels 2004-2005



Manure Application Measurements

Overview

About 20% of the measurements (338) for the odor study were taken near manure application areas. Measurements taken downwind of manure application areas had the highest exceedance rate of the three measurement types; about 11% of the downwind measurements were exceedances (Table 8).

Table 8 Manure Application Measurement Results

Exceedances	Measurements	Exceedance Rate
36	338	11%

Map of Measurements and Exceedances

The map below illustrates the manure application measurements and exceedances measured during the odor study.

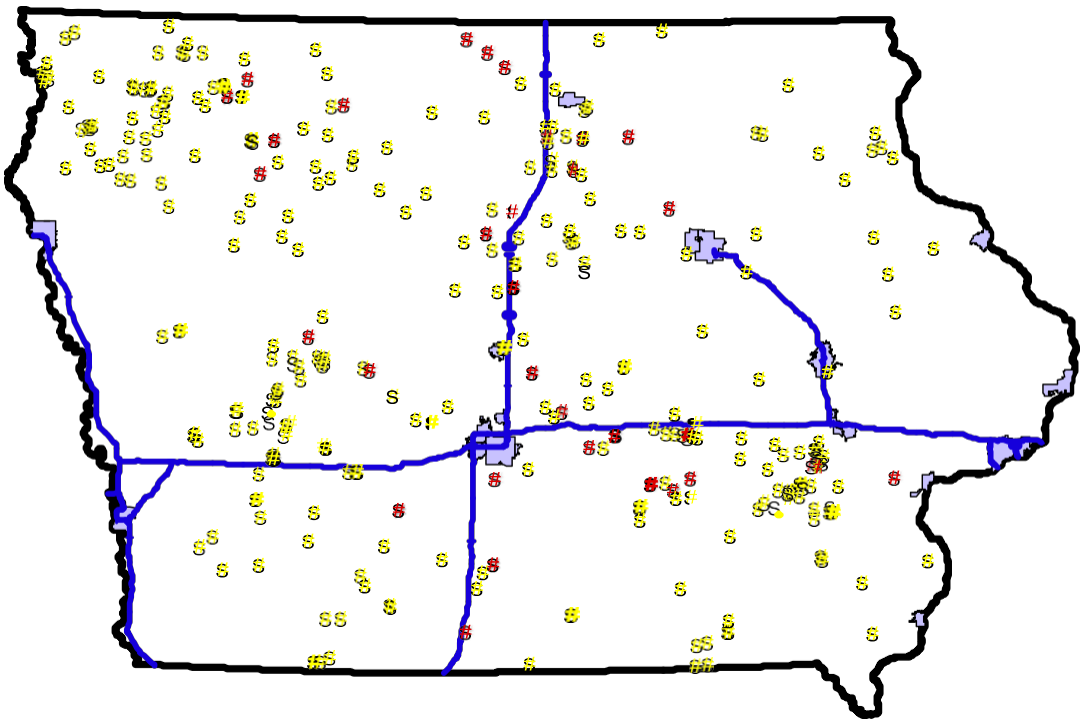


Figure 5 Manure Application Measurements and Exceedances

Measurement Locations

A typical odor measurement near a manure application area is depicted in (Figure 6). The environmental specialist takes a downwind reading near the property line of the manure application area, and an upwind reading to rule out potential upwind sources.

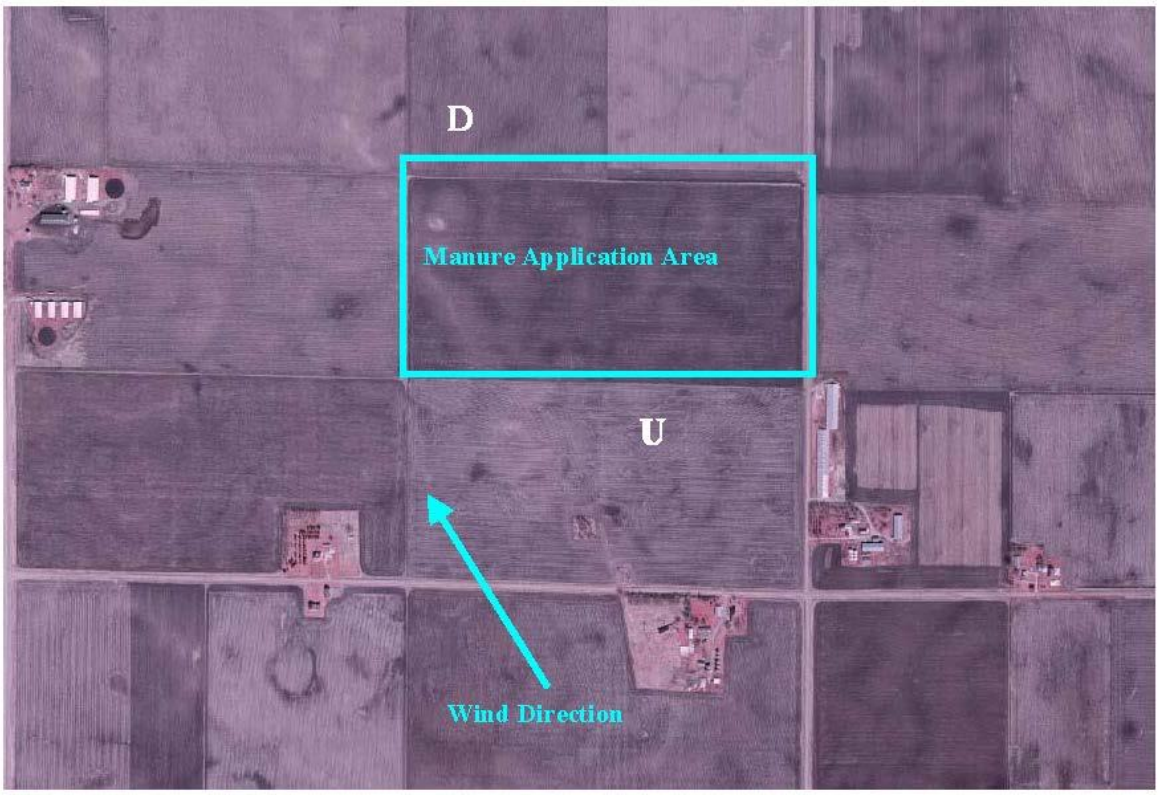


Figure 6 Manure Application Measurement Location

Seasonality of Measurements

Fall manure application takes place after harvest and before the ground freezes. The largest number of manure application measurements and exceedances were recorded in October (Chart 11, Chart 12). About 19% of the manure application measurements were taken in response to complaints. Most of the variability in the monthly number of exceedances is due to the varying number of monthly measurements (Chart 13).

Chart 11 Manure Application Measurements by Month

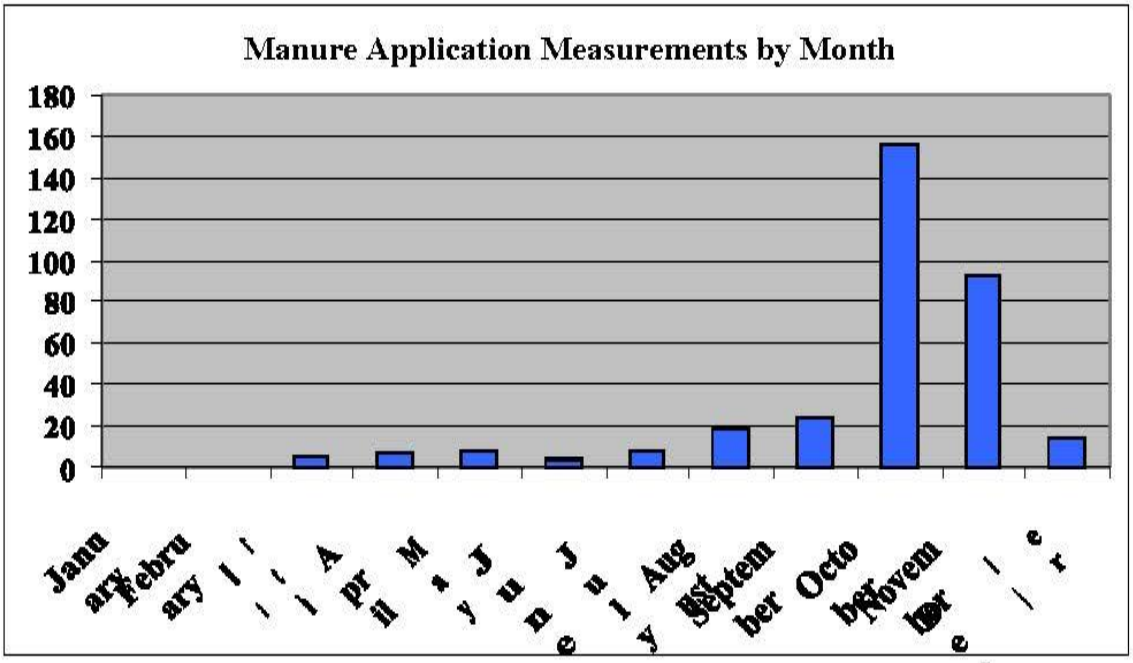


Chart 12 Manure Application Exceedances by Month

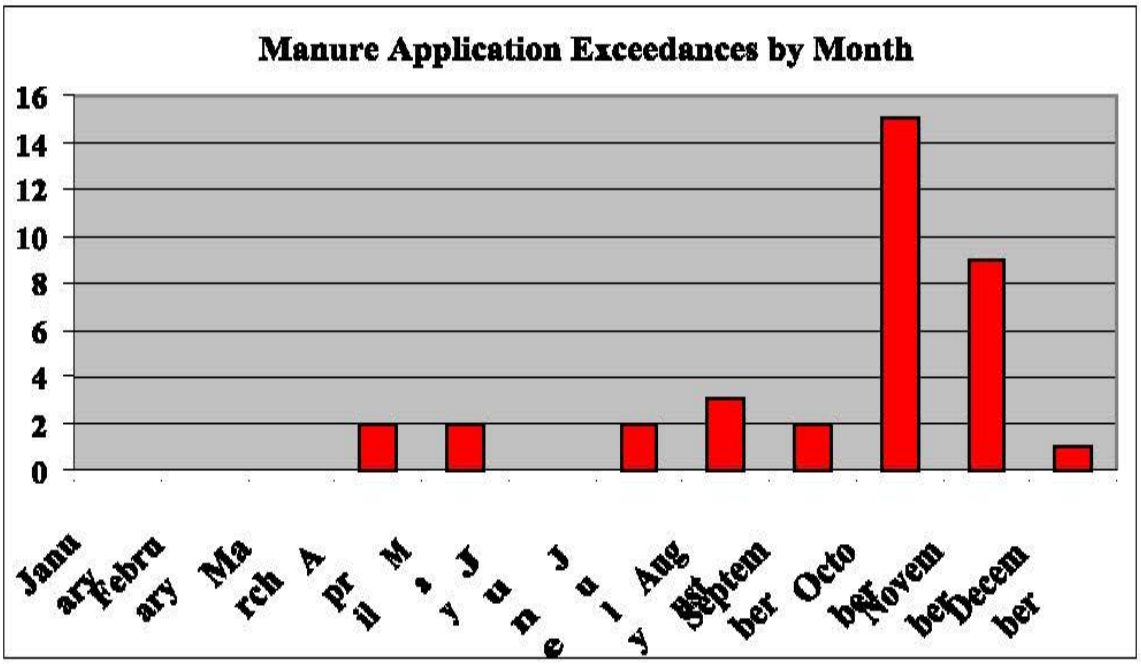
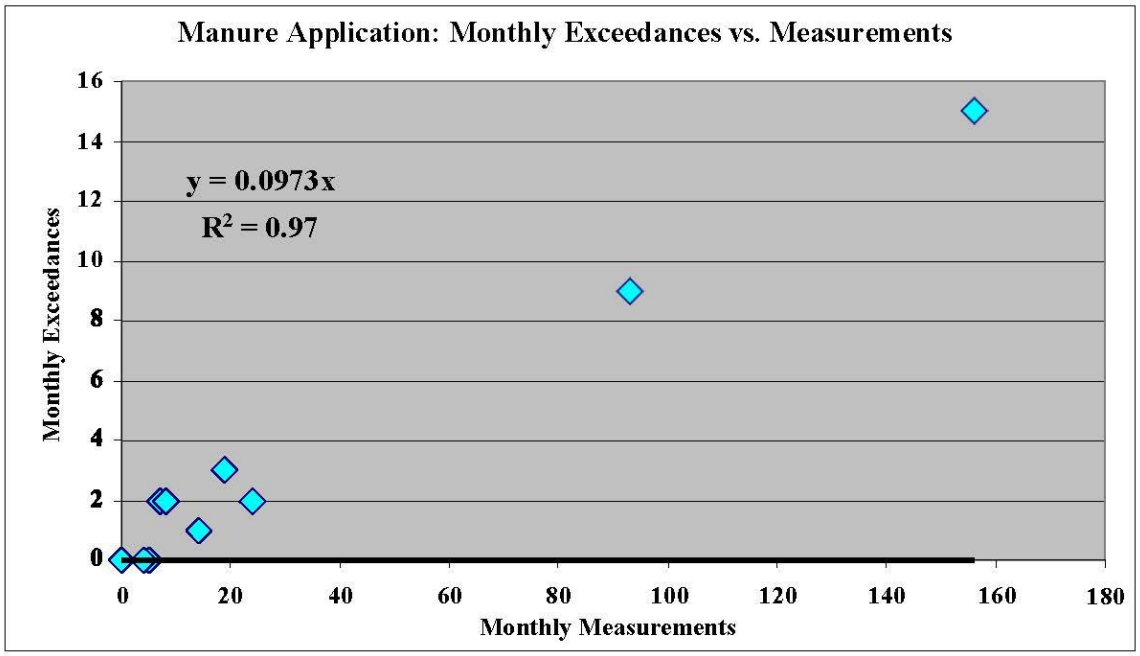


Chart 13 Monthly Manure Application Exceedances vs. Measurements



Results by Species and Application Method

A breakdown of manure application measurements by species is detailed in (Table 9). Most of the measurements (260) were taken near areas where hog manure was being applied. Measurements near areas where chicken manure was being applied had the highest exceedance rate (46%). Most of the measurements taken near manure application areas were associated with liquid manure application (Table 10); injected liquid hog manure resulted in a lower exceedance rate (6%) than surface application of liquid hog manure (11%).

Table 9 Manure Application Measurements and Exceedances by Species

Animal Species	Exceedances	Measurements	Exceedance Rate
Beef Cattle	2	14	14%
Chicken	12	26	46%
Dairy Cattle	0	26	0%
Hog	21	260	8%
Other	1	12	11%
Total	36	338	11%

Table 10 Measurements and Exceedances by Species and Manure Application Method

Animal Species Manure Type Application Method	Exceedances	Measurements	Exceedance Rate
Chicken Solid Manure Surface Application	10	21	48%
Hog Liquid Manure Injection	9	153	6%
Hog Liquid Manure Surface Application	11	96	11%
Other	6	68	10%
Total	36	338	11%

Upwind/Downwind Pairs for Exceedance Measurements

Upwind and downwind odor levels measured at manure application areas that resulted in exceedances in 2003 (Chart 14) and 2004-2005 (Chart 15) are shown below. As expected, higher odor levels were noted downwind than upwind; downwind levels were typically two or more odor levels higher than the upwind measurements.

Chart 14 Manure Application Exceedance Levels, 2003

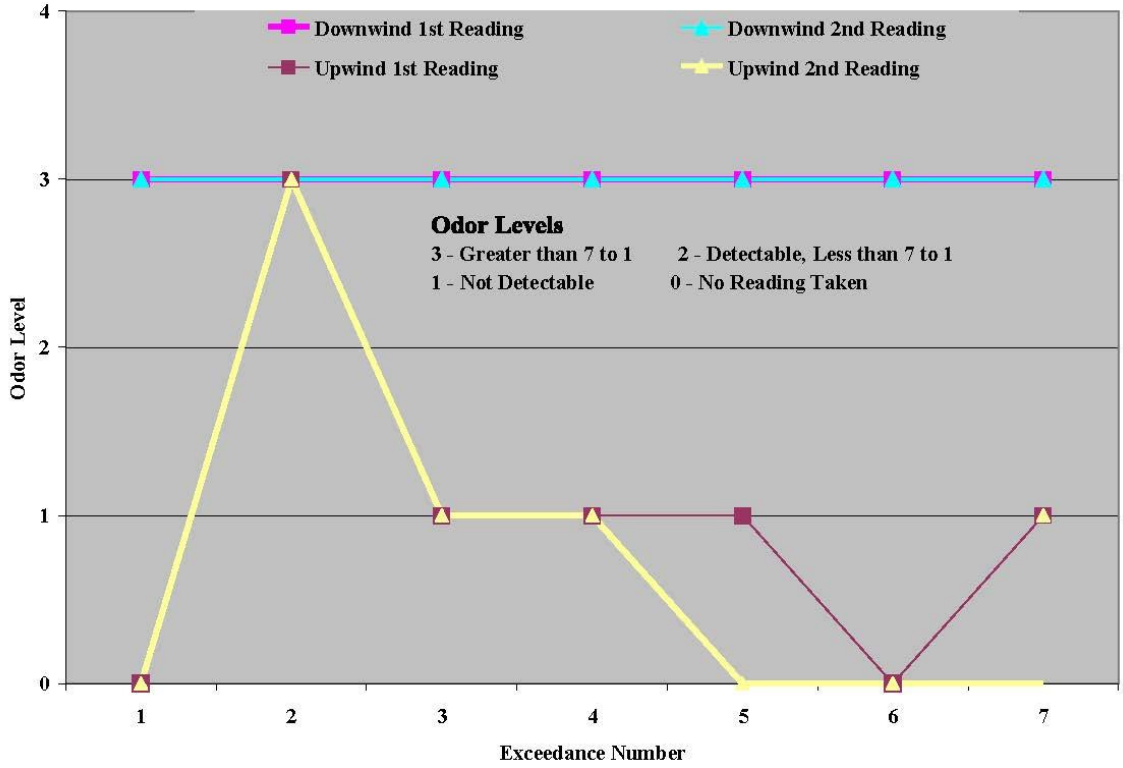
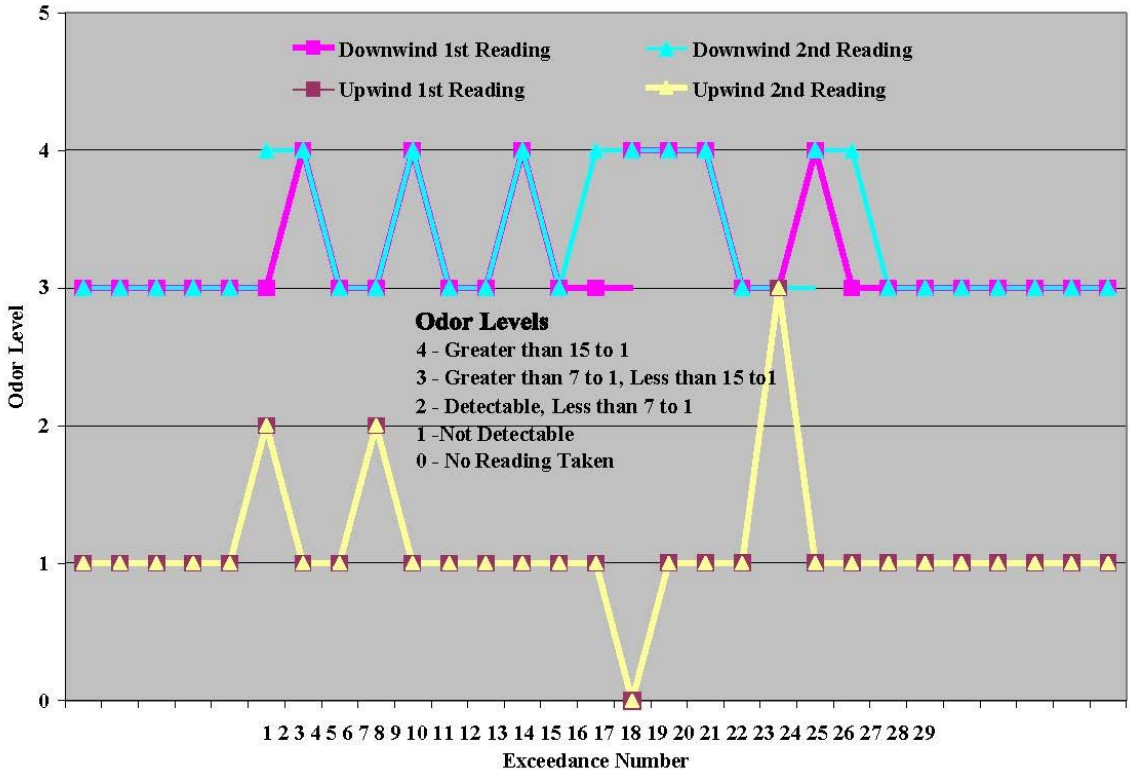


Chart 15 Manure Application Exceedance Levels, 2004-2005



PERRC Measurements

Overview

In addition to measurements near odor sources, scentometer measurements were taken at locations where people live and spend time that were in close proximity to AFO's or manure application areas. For the purposes of the odor study a "PERRC" measurement is a measurement taken near a **P**ublic use area, an **E**ducational institution, a **R**eligious institution, a **R**esidence, or a **C**ommercial enterprise.

In order to establish the maximum odor levels associated with a manure application area or facility at a given time, the environmental specialist's strategy was to take measurements at the downwind fence line of the odor sources. This strategy could not be employed for PERRC measurements, because situations where a PERRC happened to lie directly downwind of an odor source were rare. An important source of PERRC measurements was complaints, with about 39% of all PERRC measurements made in response to complaints. Environmental specialists attempted to respond to complaints before meteorological conditions changed, but there were some limitations to their ability to do this; complaint response was restricted to normal work hours and had to be prioritized along with regular daily tasks. Another difficulty in obtaining PERRC measurements was obtaining permission to access PERRC property. An environmental specialist driving down a road might encounter an odor plume emanating from a AFO toward a nearby house, but the ability to enter the property associated with the house depended on whether or not the house was occupied during the work day.

There were 334 PERRC measurements taken and 11 exceedances measured (Table 11).

Table 11 PERRC Measurement Results

Exceedances	Measurements	Exceedance Rate
11	304	4%

Map of Measurements and Exceedances

The map below illustrates the locations of PERRC measurements and exceedances. Five PERRC exceedances were associated with a single AFO in southwest Iowa in 2003.

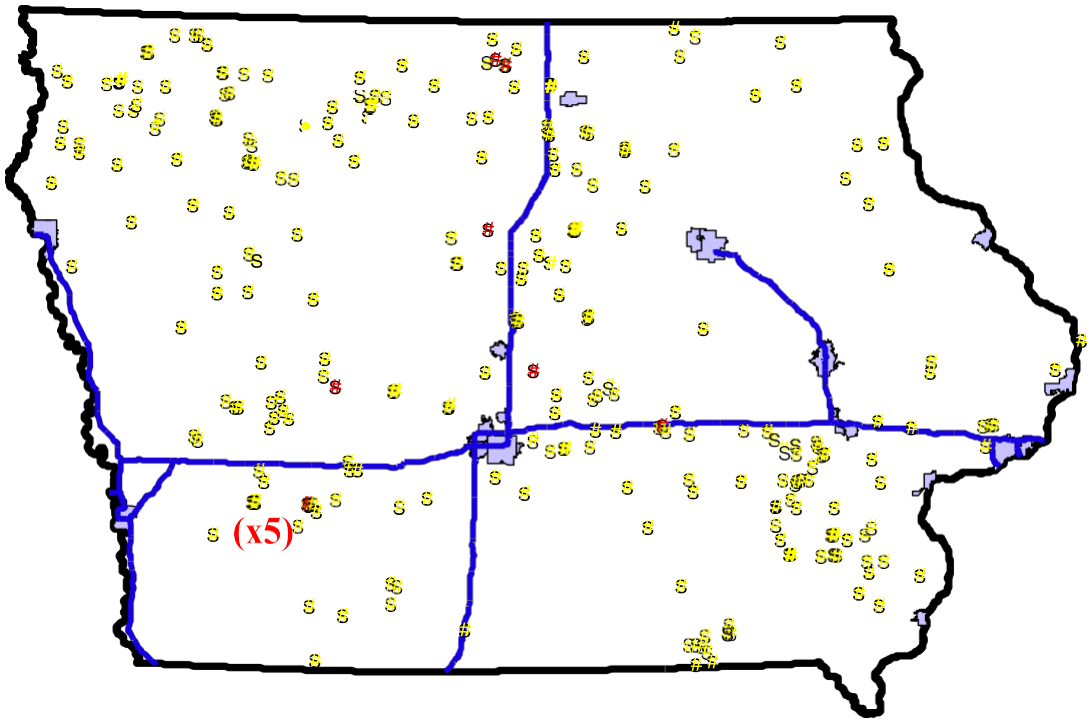


Figure 7 PERRC Measurement and Exceedance Locations

Measurement Locations

In the first year of the odor study, environmental specialists were instructed that PERRC measurements could be taken anywhere on the property associated with the PERRC (Figure 8). During the second year of the study, the department adopted monitor siting rules for the hydrogen sulfide component of the AFO field study that required measurements be taken within 100 meters of the PERRC in order to be considered "at the PERRC". Odor study procedures were subsequently modified to request that environmental specialists take odor readings within 100 meters of the PERRC whenever possible (Figure 9). The two figures below represent the different emphasis regarding PERRC measurements during the first and subsequent years of the odor study. About (63%) of PERRC measurements were taken within 100 meters of the PERRC (Table 12).

Figure 8 Typical PERRC Measurement Location, 2003

Figure 9 Typical PERRC Measurement Location, 2004-2005

Table 12 PERRC Measurement Distances

Distance to PERRC (m)	Exceedances	Measurements
0-50	1	131
51-100	4	62
101-150		7
151-200	2	6
201-250	2	4
251-300		4
301-350		2
351-400	1	7
401-450		7
451-500		4
>500		45
not specified	1	25
Total	11	304

Seasonality of Measurements

Most PERRC measurements were taken in the summer and fall (Chart 16). PERRC exceedances were highest in September and October (Chart 17). Unlike manure application and facility measurements, monthly exceedance rates for PERRC's were not well correlated with the number of monthly PERRC measurements (Chart 18).

Chart 16 PERRC Measurements by Month

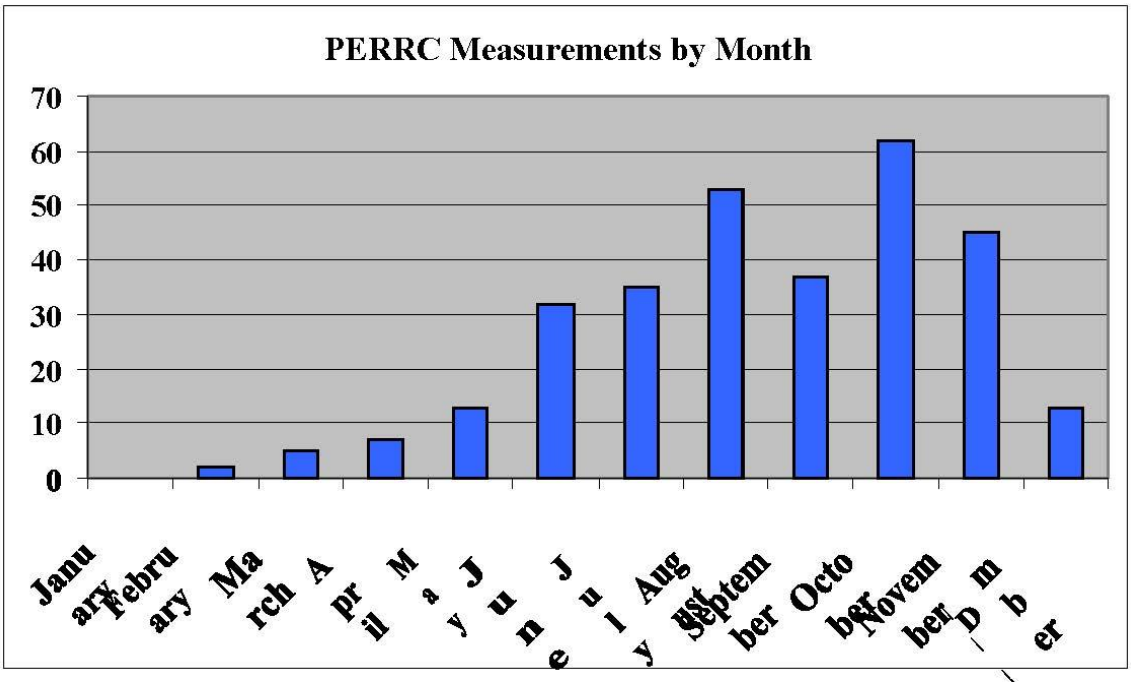


Chart 17 PERRC Exceedances by Month

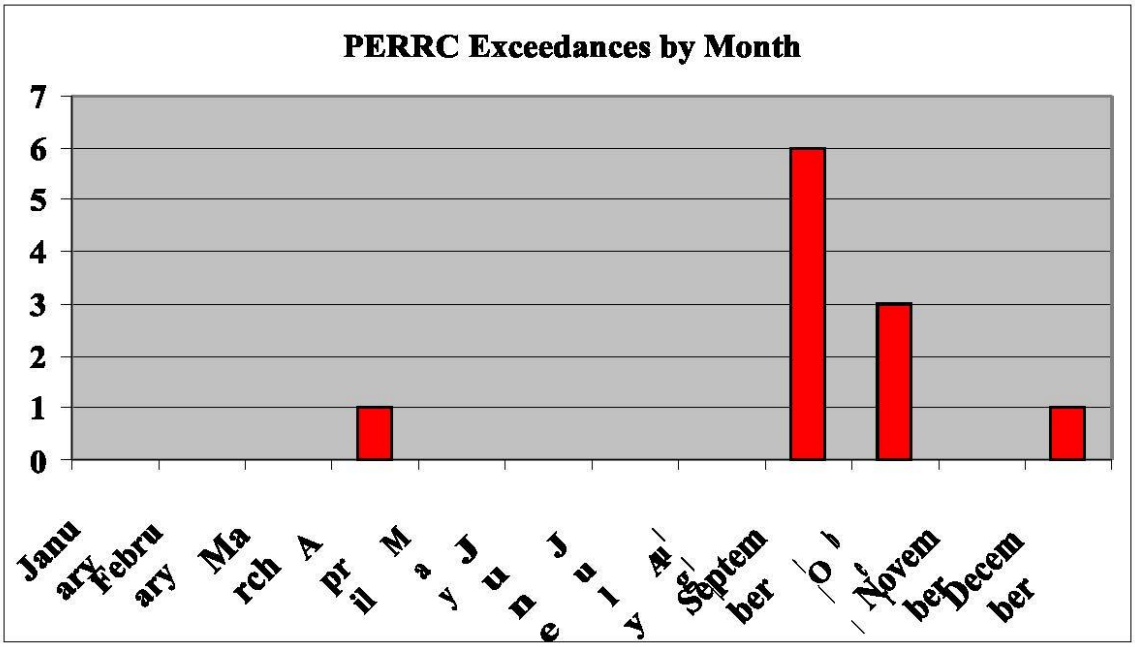
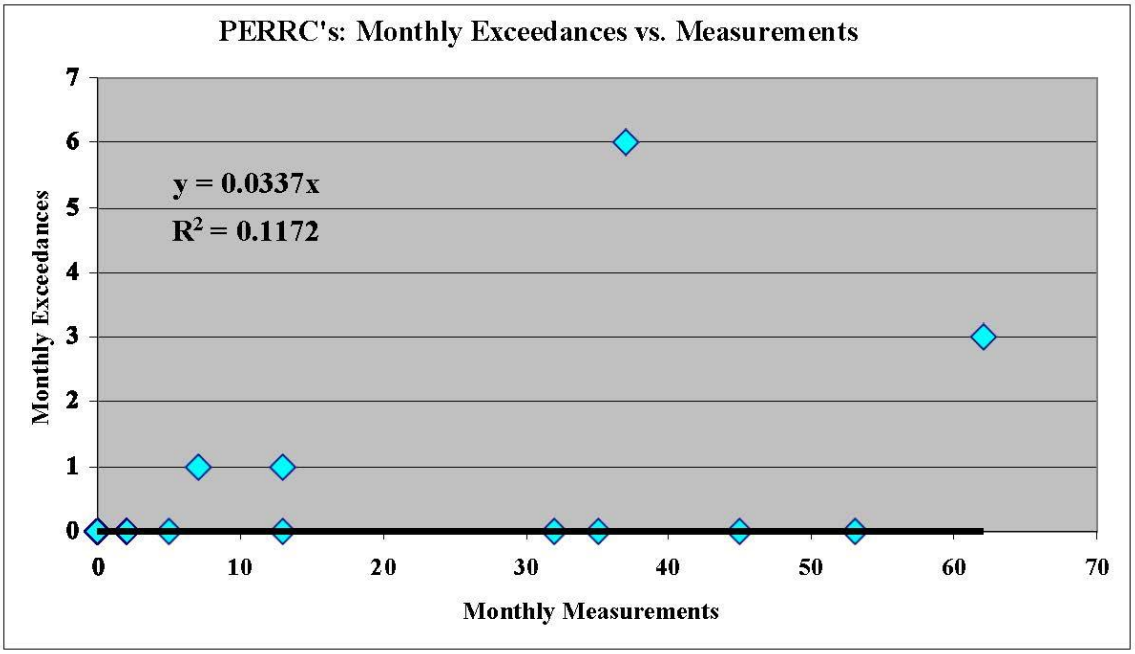


Chart 18 Monthly PERRC Exceedances vs. Measurements



Results by PERRC Type, Species, and Distance from PERRC

The tables below summarize the number of measurements and exceedances recorded at PERRC's by the type of location, animal species, and distance from the PERRC to where the measurement was taken. Most PERRC measurements (79%) were taken near residences (Table 13). Eighty percent of PERRC measurements were associated with hogs (Table 14).

Table 13 PERRC Measurement Breakdown

Type of PERRC	Exceedances	Measurements
Public Use Area	2	44
Educational Institution	0	0
Religious Institution	0	13
Residence	9	239
Commercial Enterprise	0	8
Total	11	304

Table 14 PERRC Measurements by Species

Animal Species	Exceedances	Measurements	Exceedance Rate
Beef Cattle	0	16	0%
Chicken	2	27	7%
Dairy Cattle	0	10	0%
Hog	9	243	4%
Other	0	8	0%
Total PERRC	11	304	4%

An Analysis of the Scentometer Range Used for PERRC Measurements

Ideally, the result of a scentometer odor reading should bracket the odor intensity between dilution ratio settings on the scentometer, rather than providing only an upper or lower bound on the odor intensity.

In the first year of the odor study (2003), there was only one way an exceedance could be recorded; the first and second readings both had to produce a result that odor was detectable at a dilution ratio of 7 to 1 (Table 15). To further

quantify the magnitude of the odors present during an exceedance, a 15 to 1 dilution ratio was added to the measurement protocol. In 2004-2005, three of the five exceedances measured consisted of two readings that were bracketed between the 7 to 1 and 15 to 1 dilution ratio settings (Table 16).

Table 15 Odor Readings for PERRC Exceedances in 2003

1st Odor Reading	2nd Odor Reading	Exceedances
7:1 or Greater	7:1 or Greater	6
	Total	6

Table 16 Odor Readings for PERRC Exceedances in 2004-2005

1st Odor Reading	2nd Odor Reading	Exceedances
Greater than 15:1	Greater than 15:1	1
Greater than 7:1, less than 15:1	Greater than 15:1	0
Greater than 15:1	Greater than 7:1, less than 15:1	1
Greater than 7:1, less than 15:1	Greater than 7:1, less than 15:1	3
	Total	5

In (Table 17) and (Table 18) a breakdown of the scentometer readings for all PERRC measurements are presented. Readings in the "Detectable, but Less than Seven to One" category comprise 57% of all readings. Addition of a 2 to 1 dilution ratio to the scentometer measurement protocol at PERRC's would help to improve the resolution of the low level odor intensity established by the scentometer. This would be consistent with the Colorado odor standard as it applies to PERRC's [Appendix B: Scentometer Based Odor Standards].

Table 17 Odor Levels Detected at PERRC's, 2003

Odor Level	Number of Readings
Seven to One or Greater	12
Detectable, but Less Than Seven to One	30
Not Detectable	33
Total	75

Table 18 Odor Levels Detected at PERRC's, 2004-2005

Odor Level	Number of Readings
15 to 1 or Greater	3
Detectable at 7 to 1, but Less than 15 to 1	9
Detectable, but Less Than Seven to One	156
Not Detectable	81
Total	249

Exceedances at Separated Locations

A separated location is a particular type of PERRC for which a separation distance is required under Iowa Law when building an AFO or applying manure (Iowa Code sections 459.202 and 459.204).

In a typical case, to establish whether or not a particular PERRC represents a separated location with respect to a given AFO requires knowledge of the distance between the AFO (or more precisely, manure storage structures or barns at the AFO) and the PERRC, ownership of the AFO and the PERRC, and the construction dates of the AFO and the PERRC. The PERRC must be constructed before the AFO for separation distance requirements to apply. In addition, the titleholder of the land where the PERRC is located may waive their right to separation from an AFO by filing a letter at the county courthouse.

To establish whether or not a particular manure application event is exempt from manure separation requirements requires information about the manure being applied (manure from small animal feeding operations is exempt from separation requirements), how the manure is applied (liquid manure injected or incorporated within twenty-four hours need not meet the separation requirement) and whether a waiver of the separation distance requirement has been signed by the titleholder of the land where the PERRC is located.

For the odor study, environmental specialists were requested to take measurements at PERRC's without considering whether or not the PERRC was a separated location with respect to the nearest AFO or manure application area. This allowed the odor investigators to be responsive to all odor complaints and to investigate them in a timely manner.

In the event that a PERRC exceedance was measured and the source of the odor appeared to be an AFO, a follow up investigation was performed to determine if the PERRC represented a separated location with respect to the AFO.

Of the eleven PERRC exceedances obtained during the odor study, seven were measured near AFO's and the remaining four near manure application areas.

Of the seven PERRC exceedances caused by AFO's, six were taken in 2003, before the 100 meter recommendation on monitoring locations was introduced into the measurement protocol, and the location of each PERRC exceedance measured near an AFO was greater than 100 meters away from the associated PERRC. Of these six measurements, five were taken in the odor plume of a single AFO on two separate days, September 19th and September 24th of 2003. Two of these five exceedances were measured at the same residence on different days, another two were measured at the same public use area (a cemetery) on different days. The final PERRC exceedance in 2003 was taken at a residence near an AFO on December 1st of 2003. All PERRC exceedances in 2003 were recorded by a single environmental specialist. The last AFO PERRC exceedance in the odor study was recorded on October 6, 2004. The monitoring location was 80 meters from the residence where a complaint had been made, and represents an exceedance at a separated location.

Of the four PERRC exceedances near manure application areas, two were recorded near chicken manure application areas. Since chicken manure is applied in dry form, it does not require a separation distance, and these two PERRC's were not separated locations. The two remaining PERRC exceedances near manure application areas were both associated with the application of liquid hog manure. Both measurements were taken on October 12, 2005, one in Hamilton County and one in Story County. The two environmental specialists both took measurements around 1 pm and reported wind speeds of about 5 mph out of the southeast. The environmental specialist in Story County reported that the distance to the manure application area was 38 meters. This is less than the minimum separation distance of 750 feet, so the Story County PERRC measurement was not a separated location measurement. The environmental specialist in Hamilton County reported that the distance to the application area was 845 meters. Since the liquid hog manure was injected, the Hamilton County PERRC measurement was also not a separated location measurement.

To summarize, of eleven PERRC exceedances, only one was recorded at a separated location.

Precision Results Summary

Precision Results

The basis of a sound scientific study or equitable regulatory program is reproducible measurements. If several different monitors are used to take measurements, and the result of a particular measurement depends on which monitor is used to take the readings, then it can be argued that the decision made with the measurement is arbitrary. Intuitively, one might suspect that two individuals crossing through the odor plume downwind of an AFO or manure application area would agree about whether or not strong livestock odors were present. However, it is well established that there is variability in human sensory response, and the degree of quantitative agreement between odor observers has to be measured directly.

Precision may be defined as the degree to which a measurement is reproducible. Precision for the odor study was estimated by having a second certified odor observer take a measurement at the same location as the first odor

observer. These "co-located" measurements included measurements taken at upwind and downwind monitoring locations near odor sources and near PERRC's. The number of co-located readings taken was approximately 12% of the total number of readings in the study. The simple percent agreement between the two observations has been calculated for all co-located readings taken during the odor study and is illustrated in the following tables. The study design stipulated that unless odor was detected at the exceedance threshold at the first downwind reading, no further readings were required. The co-located data has been separated into 59 pairs of observations collected in 2003 and 204 pairs for the 2004-2005 period. The precision statistic is 97% agreement in 2003 when three odor levels were used and 92% in 2004-2005 when a fourth level was added. There were three instances where the co-located reading differed by more than one odor classification. See Table 19 and Table 20.

Table 19 2003 Precision Results

1st Observer's Reading	2nd Observer's Reading		
	Detectable, but Less Than 7 to 1	7 to 1 or Greater	Not Detectable
Detectable, but Less Than 7 to 1	29	1	
7 to 1 or Greater		6	
Not Detectable	1		22
Pairs in Agreement 57	Total Pairs 59		Agreement 97%

Table 20 2004-2005 Precision Results

1st Observer's Reading	2nd Observer's Reading			
	15 to 1 or Greater	Detectable at 7 to 1, but Less than 15 to 1	Detectable, but Less Than 7 to 1	Not Detectable
15 to 1 or Greater	15	3	2	
Detectable at 7 to 1, but Less than 15 to 1	1	14	3	
Detectable, but Less Than 7 to 1	1	2	88	2
Not Detectable			2	71
Pairs in Agreement 188	Total Pairs 204		Agreement 92%	

References

1. Iowa DNR documents pertaining to the AFO Odor Study (including this document) can be found on the Iowa DNR - Air Quality Bureau Animal Feeding Operations web page. Quality assurance documentation for the AFO Odor Study can be downloaded in .zip format from that page or directly from this link: AFO Odor Study Procedures, 2005.
2. St. Croix Sensory; A Review of the Science and Technology of Odor Measurement is available from the DNR page above or can be downloaded directly here: A Review of the Science and Technology of OdorMeasurement.

Appendix A: Iowa Code section 459.207

459.207 Animal Feeding Operations -- Airborne Pollutants Control.

1. As used in this section, unless the context otherwise requires:
   a. "Airborne pollutant" means hydrogen sulfide, ammonia, or odor.
   b. "Separated location" means a location or object from which a separation distance is required under section 459.202 or 459.204, other than a public thoroughfare.
2. The department shall conduct a comprehensive field study to monitor the level of airborne pollutants emitted from animal feeding operations in this state, including but not limited to each type of confinement feeding operation structure.
3. a. After the completion of the field study, the department may develop comprehensive plans and programs for the abatement, control, and prevention of airborne pollutants originating from animal feeding operations in accordance with this section. The comprehensive plans and programs may be developed if the baseline data from the field study demonstrates to a reasonable degree of scientific certainty that airborne pollutants emitted by an animal feeding operation are present at a separated location at levels commonly known to cause a material and verifiable adverse health effect. The department may adopt any comprehensive plans or programs in accordance with chapter 17A prior to implementation or enforcement of an air quality standard but in no event shall the plans and programs provide for the enforcement of an air quality standard prior to December 1, 2004.
   b. Any air quality standard established by the department for animal feeding operations shall be based on and enforced at distances measured from a confinement feeding operation structure to a separated location. In providing for the enforcement of the standards, the department shall take all initial measurements at the separated location. If the department determines that a violation of the standards exists, the department may conduct an investigation to trace the source of the airborne pollutant. This section does not prohibit the department from entering the premises of an animal feeding operation in compliance with section 455B.103. The department shall comply with standard bio- security requirements customarily required by the animal feeding operation which are necessary in order to control the spread of disease among an animal population.
   c. The department shall establish recommended best management practices, mechanisms, processes, or infrastructure under the comprehensive plans and programs in order to reduce the airborne pollutants emitted from an animal feeding operation.
   d. The department shall provide a procedure for the approval and monitoring of alternative or experimental practices, mechanisms, processes, or infrastructure to reduce the airborne pollutants emitted from an animal feeding operation, which may be incorporated as part of the comprehensive plans and programs developed under this section.

Appendix B: Scentometer Based Odor Standards

Shortly after the development of the scentometer [1] the following categories were associated with scentometer dilution settings.

- Noticeable-odor is detectable at 2 volumes of odor-free air to 1 volume of odorous air (dilution ratio of 2)
- Objectionable-detectable at a dilution ratio of 7
- Nuisance- detectable at a dilution ratio of 15
- Nauseating –detectable at dilution ratio of 31

There are two commercially available scentometer designs, the Barneby Sutcliffe design at the Nasal Ranger design. There are six odorous air inlet holes on one end of the Barneby Sutcliffe box, allowing for dilution ratios of 2, 7, 15, 31, 170, and 350. The Nasal Ranger contains six odorous air inlet orifices for dilution ratios of 2, 4, 7, 15, 30, and 60.

Several states employ the scentometer to implement odor regulations. A typical regulation specifies the types of sources to which the odor standard applies, the dilution ratio, and number of readings required to exceed the standard. A (not necessarily comprehensive) list of states that use a scentometer to implement odor regulation is indicated below.

Wyoming
Citation: Wyoming Dept. of Environmental Quality, Air Quality Division Standards and Regulations, Chapter 2 Ambient Standards, Section 11.*a.*

Available at: http://deq.state.wy.us/aqd/stnd/Chapter2_2-3-05FINAL_CLEAN.pdf

> The ambient air standard for odors from any source shall be limited to: An odor emission at the property line which is undetectable at seven dilutions with odor free air as determined by a scentometer as manufactured by the Barnebey-Cheney Company or any other instrument, device, or technique designated by the Division as producing equivalent results. The occurrence of odors shall be measured so that at least two measurements can be made within a period of one hour, these determinations being separated by at least 15 minutes.

Colorado
Citation: Regulation number 2 (Odor Emission Regulations), Part B on Housed Commercial Swine Feeding Operations, Subpart III.

Available at: http://www.cdphe.state.co.us/op/regs/airregs/100104aqccodoremission.pdf

> A 7 to 1 standard applies at and beyond the property line, except for off-site receptors, where a 2 to 1 standard applies.

A receptor is defined as:

> any occupied dwelling (occupied as a primary dwelling) or curtilage, public or private school, place of business, or the boundaries of any incorporated municipality that has not waived the protection.
>
> For the enforcement of either standard “two (2) odor measurements shall be made within a period of one (1) hour, these measurements being separated by at least fifteen (15) minutes.

North Dakota
Citation: Century Code Chapter 23-25 (Air Pollution Control), Section 23-25- 11(Regulation of odors - Rules)

Available at: http://www.legis.nd.gov/cencode/t23c25.pdf

> In areas located outside a city or outside the area over which a city has exercised extraterritorial zoning as defined in section 40-47-01.1, a person may not discharge into the ambient air any objectionable odorous air contaminant that causes odors that measure seven odor concentration units or higher as measured at any of the

following locations…

An odor measurement may be taken only with a properly maintained scentometer, by an odor panel, or by another instrument or method approved by the state department of health…

If the odor problem persists, the department may proceed with an enforcement action provided at least two certified inspectors at the same time each measure a violation and then confirm the violation by a second odor measurement taken by each certified inspector, at least fifteen minutes, but no more than two hours, after the first measurement.

Kentucky
Citation: 401 KAR 53:010 (Ambient air quality standards)
Available at: http://www.lrc.state.ky.us/kar/401/053/010.htm

At any time when 1 volume unit of ambient air is mixed with 7 volume units of odorless air, the mixture must have no detectable odor.

Missouri
Citation: Rules of Department of Natural Resources, Division 10—Air Conservation Commission, Chapter 3—Air Pollution Control Rules Specific, to the Outstate Missouri Area, 10 CSR 10-3.090, (5)(C)1.
Available at: http://www.sos.mo.gov/adrules/csr/current/10csr/10c10-3.pdf

A scentometer reading of 5.4 to 1 "for two (2) separate trials not less than fifteen (15) minutes apart within the period of one (1) hour" triggers lab olfactometer analysis.

Nevada
Citation: Chapter 445B (Air Controls), section NAC 445B.22087.
Available at: http://ndep.nv.gov/nac/445b-001.pdf

The director shall investigate an odor when 30 percent or more of a sample of the people exposed to it believe it to be objectionable in usual places of occupancy. The sample must be at least 20 people or 75 percent of those exposed if fewer than 20 people are exposed.

3. The director shall deem the odor to be a violation if he is able to make two odor measurements within a period of 1 hour. These measurements must be separated by at least 15 minutes. An odor measurement consists of a detectable odor after the odorous air has been diluted with eight or more volumes of odor- free air.

Illinois
Citation: Title 35: Environmental Protection, Subtitle B: Air Pollution,
Chapter I: Pollution Control Board, Subchapter l: Air Quality Standards and Episodes, Part 245 Odors, Section 245.121, Objectionable Odor Nuisance Determination

Available at: http://www.ipcb.state.il.us/documents/dsweb/Get/Document-11939/

An objectionable odor nuisance exists:

a. On or adjacent to residential, recreational, institutional, retail sales, hotel or educational premises when odor is detectable in the ambient air after it is diluted with eight volumes of odor-free air as measured by the Scentometer;
b. On or adjacent to industrial premises when odor is detectable in the ambient air after it is diluted with twenty-four volumes of odor-free air as measured by the Scentometer;
c. On or adjacent to premises other than those above when odor is detectable in the ambient air after it is diluted with sixteen volumes of odor-free air as measured by the Scentometer;

d. When concurrent determinations made by three trained inspectors as outlined above in any given one hour period and at intervals of not less than fifteen minutes result in two positive determinations in each series of three determinations; and
e. Provided that any quantitative odor level measurements taken to arrive at a determination that an objectionable odor nuisance exists shall be at or beyond the property line or at or near places where people live or work.

1. Huey NA, Broering LC, Jutze GA, and Gruber CW. (1960). Objective Odor Pollution Control Investigations. *J. Air Pollution Control Assoc.,* 10(6), 441-444.