Final Report of Air Testing Swine Lagoons in Southeast Colorado

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About the Author

Brad is a soil scientist who has worked as an agricultural consultant for 16 years. Prior to that, he was a Research Associate involved in nitrogen transformation studies with USDA-ARS in Fort Collins, Colorado. Brad is the founder and president of AgSkill, Inc., an environmental and agricultural consulting firm based in Lamar, Colorado. Brad advises area farmers in crop production. He also works with livestock producers throughout the State of Colorado addressing their environmental needs. Brad has been involved in many agronomic and environmental studies over the years. He has authored over 300 papers.

Introduction

In November 1998, Colorado voters passed Amendment 14 with the intent of minimizing the environmental impacts of the emerging swine industry on the State (Regulation No. 61). One goal of this Amendment was to reduce the odor emitted from swine effluent storage lagoons. The Amendment states that a swine waste lagoon must have a cover over it or must be an aerobic body of water (Regulation 2, 1999). The Colorado Department of Public Health & Environment (CDPH&E) is charged with overseeing that Colorado swine producers adhere to the regulations presented in Amendment 14. When the Amendment became law, it was modified to include technologies that reduce odors being emitted from the lagoons. The CDPH&E is making an allowance for these technologies provided they meet the standards established for air quality. Best Achievable Control Technology(BACT) was adopted by the Air Quality Division. The permit review process accounts for site-specific variables on a case-by-case basis taking into account energy, environmental, and economic impacts and other costs. This process ensures that as new and better technology is developed, it will be incorporated into Colorado's program for minimizing, to the greatest degree practicable, odorous emissions from such facilities (Bundy, et.al. 2000). This report evaluates and provides a comparison of several of these technologies.

A total of six lagoons and one digester in five locations were included in this study. The lagoons examined in this study are described as follows:

Digester: This micro-digester, operated by Colorado Pork LLC, is overlaid with a plastic cover. The air gases are captured and the resulting methane gas is used to fuel a micro-turbine. The micro-turbine then produces electricity that is used by Colorado Pork in their swine operations.

Evaporative: After the raw effluent from the swine houses has been in the digester, it gravity flows into an evaporative lagoon. This is a shallow, uncovered lagoon which has a large enough surface area that much of the liquid evaporates off the lagoon. The advantage of this is that Colorado Pork does not have to be concerned with applying the effluent to growing crops at agronomic rates. During most years the amount of liquid produced is small enough, especially when coupled with evaporation, that the lagoon would not overflow and thereby require pumping. The level of the surface area increases during the winter months when evaporation rates decrease. However, it appears that the lagoon is more than adequate sized to ensure it will not have to be pumped. At some point, however, enough solids will accumulate in the evaporative lagoon to require removal. When removed, these solids will be applied to crop land at agronomic rates.

Aerators: Each lagoon at OutWest Nurseries A and B has two aerators floating on the surface. These electric-powered aerators are Model 600 Vacuum Bubble Aerators manufactured by Aerob-a-Jet. Each aerator produces 475 lbs of oxygen per day. The purpose of using these aerators is to create an aerobic "cover" that reduces odor emitted from the lagoon. The oxygen produced is the driving component that reduces the odors. Aeration treatments have proven to be an effective method of reducing lagoon odors by encouraging oxidative metabolism (William et.al. 1989; Evans et.al,

1986). Aeration studies have shown a resulting decline of Total Volatile Solids (TVS) and smaller decreases in total ammonia concentrations.

Algae: The primary and secondary lagoons at the OutWest Holly Barrow Site are treated with algae. The green algae is grown in two stock tanks in a greenhouse and one tank located outside the greenhouse. The algae is provided with nutrients from the lagoon water which is supplemented with fresh water. The algae flourish in the tanks. The algae is introduced into the lagoon when the tanks are pumped, 2 to 3 times per day. The algae produces oxygen and thereby produces an aerobic "cover" over the lagoon. The oxygen produced by the algae is as effective at reducing odors as the aerators.

Untreated: The lagoon at OutWest Nursery Site C does not have a cover, aerators, or algae. However, a product called 'Pit Remedy' has been used in the barns since June 2001. Pit Remedy is a bacteria which acts as a manure liquefier which helps reduce the Total Volatile Solids (TVS).

This study measured odor and various air gases produced by different swine effluent lagoons. The air testing included measurements of the following parameters:
Hydrogen Sulfide (H_2S), Ammonia (NH_3), Volatile Organic Compounds (VOC), and Odor (using Scentometer). The lagoon water was also evaluated to determine Biological Oxygen Demand (BOD) - [mg/l for 5 days]. The protocol used to collect the samples is included in this report.

Methods

A summary of the sites included in the study is as follows:

Site	**Treatment**
OutWest	
Holly Barrow (2 lagoons)	Algae
Nursery A	Aerators
Nursery B	Aerators
Nursery C	Untreated - Baseline levels
Colorado Pork	
Digester	Cover
Evaporative	Untreated

The testing includes the following parameters:

I. Air Testing
   1. Hydrogen Sulfide (H_2S)
   2. Ammonia (NH_3)
   3. Volatile Organic Compounds (VOC)
   4. Odor (using Scentometer)

II. Lagoon Water
   1. Biological Oxygen Demand (BOD) -[mg/l for 5 days]

Air Testing

Air samples from the lagoons were collected and analyzed on the following dates: May 22 and 23, 2000; July 10, 2000; September 12 and 13, 2000; January 22 and 23, 2001; April 2 and 4, 2001; May 7 and 9, 2001; June 4 and 6, 2001; and June 28, 2001 at Outwest Farm sites Holly Barrow, Nurseries A, B, C , and the Colorado Pork site.

The air sampling protocol was developed by Dr. Alan Sutton of Purdue University, Dr. Dwaine Bundy of Iowa State University, and Bill Cote, P.E. with TetraTech EM, Inc. AgSkill worked with Southeastern Land and Environment and the Colorado Department of Public Health & Environment (CDPH&E) on the air sampling. Once air samples were collected, they were sent to Iowa State University Olfactometer Laboratory for analysis.

Method of Sampling

The odorous gas samples were collected in ten-liter tedlar bags using an equilibrium chamber floated on the surface of the lagoon. The odor threshold and odorous gas samples were also evaluated from the tedlar bag sample.

The only measurement for compliance was the odor threshold; however, if the lagoon did not come in compliance further evaluation was performed. In addition to the odor threshold, the samples measured ammonia and hydrogen sulfide levels.

Collection of Sample

The sample was collected on the lagoon surface at a distance of approximately 5 feet from the bank on the side opposite of the lagoon inlets coming from the buildings. The wind speed had to be below 25 mph during sampling.

The samples were collected under an equilibrium chamber. The chamber is made of stainless steel equipped with a flotation collar to allow it to float on the surface of the lagoon. The equilibrium chamber sits in the liquid (penetrating the liquid surface) of the lagoon. When the samples were collected from a covered lagoon, the chamber was placed on top of the cover.

To avoid the drawing of a vacuum on the chamber during sampling, a source of make-up air was provided. The make-up air consisted of an opening in the chamber 1/8 inch that is connected to a tedlar tubing that extends to within 3 inches of the liquid in the chamber. After "equilibrium" conditions were achieved, a sample was drawn from the enclosure. The chamber was allowed to rest in the liquid for at least 2 minutes prior to collecting the sample. The first sample was drawn into the tedlar bag. The pump was stopped and the air sample deflated from the bag (first sample was taken only after the tank was placed onto the lagoon). Then the sample bag was refilled. The chamber is 0.4 meters in diameter, with a volume capacity of 0.03 cubic meters.

A vacuum pump was used to fill the sample bags. A rigid air sample box that allows the direct filling of an air sample bag using negative pressure was required. (Typical Vac-U-Chamber, Cat. No. 231-939 by SKC, Inc.). The filling rate was approximately 0.004 m^3/min (4 l/min).

If used, the ten-liter tedlar bags were flushed twice with filtered air prior to using. However, no bags were reused.

Collection and Preparation of Sample

The samples collected in a 10-liter tedlar bag were evaluated within 24 hours of sampling by an approved olfactometer laboratory. These samples were evaluated by the Iowa State University Olfactometer Laboratory. The samples that were shipped by air were filled to not more than 80 percent capacity, i. e., samples did not exceed more than 8 liters of total air sampled.

Odor threshold evaluation

The odor evaluation was completed by using a triangular-forced-choice olfactometer. The odorous sample was evaluated by a dilution-to-threshold determination by a group of trained panelists. The purpose of the evaluation was to determine the intensity of the odor. The olfactometer was manufactured by St. Croix Sensory in Stillwater, MN and followed the ASTM standard. It used a binary (2-fold) dilution series and has a range of 2^3 to 2^{16} on 14 levels of presentation.

Each panelist was given three stimulus presentations in random order. One of the three presentations contained the diluted test sample from the lagoon, the other two presentations were fresh air. The panelist was required to identify or guess which stimulus presentation contains the odorous air. If the panelist was unable to discriminate between the presentations, he/she responded with a guess and the panel leader increased the dilution by one increment. If the odor was sensed, the panelist selected the presentation containing the odor and indicated detection. Following a correct detection, the panelist was required to have an additional correct detection at the next highest dilution level of the olfactometer.

Each panelist was screened prior to hiring. Smokers and individuals living with smokers were not used. Workers were not allowed to eat spicy foods on the day of sniffing odors or wear perfume in the laboratory. Panelist was retrospectively screened on each sample.

VOC's evaluation

VOC measurements were not analyzed on all samples. Phyllis Woodford with the CDPH&E Air Pollution Control Division explained the cost to analyze the VOC's was greater than the information we would receive. She decided we did not have to have the VOC's analyzed. However, the following methods were used when VOC's were evaluated. The samples were taken from the ten-liter tedlar bags in the laboratory. Air samples were adsorbed onto 75 um Polydimethylsiloxane/carboxen Solid Phase MicroExtraction fibers using the portable field samplers (Supelco, Bellefonte, PA). For purposes of uniformity between samples, a 30-minute adsorption time was recommended. In the laboratory, the SPME fibers were desorbed directly in the injection port of a gas chromatograph equipped with a mass selective detector. Standard solutions containing the below odorants were used to derive standard curves and quantify the occurrence of the below analytes in collected test samples. Additional compounds were identified by the GC-Ms system but not quantified. The following table lists the standard compounds that were be placed on the GS/MS to determine if and at what concentrations they existed in the test sample. A total VOC concentration was also be calculated.

Odorant	
Acetic acid	ethanethiol (ethyl mercaptan)
Propanoic acid	propanethiol
iso-Butyric	butanethiol
Butanoic	methylamine (40%)
3-methylbutanoic	dimethylamine (40%)
Pentanoic	Diethylamine
Phenol	Triethylamine
3-methylphenol	Carbon disulfide
4-methylphenol	Dimethyl disulfide
2-ethylphenol	
3-ethylphenol	
4-ethylphenol	
Indole	
2-methylindole	
3-methylindole	
4-methylindole	
2,6-*bis*(1,1-	

Hydrogen sulfide evaluation

A Jerome meter (manufactured by Arizona Instrument) was used at the lagoon berm to measure hydrogen sulfide in ppm. In addition, the hydrogen sulfide was measured from the ten-liter tedlar bags from the surface of the lagoon. The lab also used a Jerome meter to measure hydrogen sulfide from the tedlar bags.

Ammonia measurement

Ammonia was measured using a Sensidyne Gastec pump equipped with detector tubes. The specific volume employed were required by the pump system and tube used. The Ammonia samples were taken from the 10-liter tedlar bags in the laboratory.

Scentometer

Brad Walker, Tom Zehnder, and Chris Henderson, all certified by the CDPH&E to use the Scentometer, conducted the test. The odor observation protocol is as follows:

Odor Observation Procedures using the Scentometer

3. The testers were positioned downwind from the lagoon, on the edge of the lagoon.
4. The testers inserted the scentometer into nostrils, making sure the fit was leaktight.
5. A "Leak-check" was performed by the testers by attempting to inhale with all (both odor and odor-free) inlets closed.
6. The testers then opened odor free ports (while leaving the odor inlets closed) until no odor sensation is noted. This refreshed the nasal cavity.
7. The testers began the odor observation by opening the smallest (largest dilution) odor inlet and determining if any odor sensation was noted at that dilution. The scentometer was held at a ninety-degree angle to the wind. If no odor sensation was noted, the testers opened the scentometer to the next larger odor inlet.
8. The testers recorded the D/L (Dilution to Threshold ratio) of that odor inlet where an odor response was first detected (highest dilution). The time and wind direction were also recorded.
9. The testers closed the odor inlets and breathed through the scentometer for a long enough period of time that no odor sensation was observed.
10. The testers closed all ports and again documented a leak-tight fit.
11. The testers then moved to a location upwind from the lagoon, on the edge of the lagoon, and documented time and wind direction and whether any odor was observed.
12. The testers then returned to the downwind location and repeated steps 1-8. This supplied two readings per site.

Lagoon Water Testing

Biological Oxygen Demand (BOD) - mg/l for 5 day.

BOD's were collected in the following manner:

2. A two-person crew, using a small boat, worked from the surface of the lagoon to collect the sample.
3. The location of the sample site on the lagoon was near the opposite side of the inlets to the lagoon.
4. A column of water that represents the vertical distribution of the lagoon was removed using a water column sampler. Samples were collected from 0-1 ft., 1-2 ft., and 2-3 ft. depths using the following protocol
    A. The water column sampler was inserted into the lagoon to a 3-ft. depth with the top valve open.
    B. The top valve was closed.
    C. The plug at the bottom of the column was inserted.
    D. The water column sampler containing the lagoon water was removed from the lagoon and placed in the boat.

E. The 0-1 ft. sample was removed from the column by opening the top valve on the side of the column. The lagoon water was drained into a one liter, wide-mouth polyethylene container. The one liter container was then mixed by inverting the container. A subsample was then collected into a 250-ml polyethylene container.

F. The 1-2 ft sample was removed from the column by opening the middle valve on the side of the column. The lagoon water was drained into a one liter wide-mouth polyethylene container. The one liter container was then mixed by inverting the container. A subsample was then collected into a 250-ml polyethylene container.

G. The 2-3 ft sample was removed from the column by opening the bottom valve on the side of the column. The lagoon water was drained into a one liter wide-mouth polyethylene container. The one liter container was then mixed by inverting the container. A subsample was then collected in a 250-ml polyethylene container.

The samples were then refrigerated and shipped to Olsen's Agricultural Laboratory in McCook, Nebraska the same day. The samples were received by Olsen's Lab within 48 hours of sampling.

5. Olsen's Lab then analyzed the lagoon water for BOD - 5 day.
6. The analytical methods used were as follows:
   A. Standard Methods for the Examination of Water and Wastewaters. 18th Edition, 1992. APHA.
   B. Methods for Chemical Analysis of Water and Wastes. March 1983. EPA
   C. AOAC Official Methods and Analysis (1990). 15th Edition.
   D. AOCS Official Methods and Recommended Practices (1989).
   E. EPA 821-B-94-004 October 1994.
   F. AOAC Official Methods of Analysis (1995) 16th Edition.
   G. Standard Methods for the Examination of Water and Wastewaters. 19th Edition. APHA.

Sampling Frequency

The air was tested as specified by Monty Torres with Southeastern Land and Environment. Monty collaborated with Phyllis Woodford of the CDPH&E to ensure testing efficiency. Air samples from the lagoons were collected and analyzed on the following dates: May 22 and 23, 2000; July 10, 2000; September 12 and 13, 2000; January 22 and 23, 2001; April 2 and 4, 2001; May 7 and 9, 2001; June 4 and 6, 2001; and June 27, 2001.

The BOD's were collected and analyzed from all of the lagoons in the past, prior to this study, as required by CDPH&E. They were not collected at the January 2nd and 4th, 2001 sampling because the lagoons were frozen.

Environmental Conditions

The following environmental conditions were recorded whenever samples were collected:

Sample Time
Ambient Temperature
Wind Speed
Wind Direction
Relative Humidity

The environmental conditions can be found in the results. The samples collected in January 2001 were from lagoons, that for the most part, were frozen. All samples were collected in the tedlar bags from the frozen lagoons. The exceptions were at Nursery sites A and B. At these sites, a portion of the lagoon was not frozen where the Aerators were operating. The results denote if the sample was collected on a frozen lagoon.

Results

A summary of the results of tests which included odor thresholds, hydrogen sulfide, ammonia, and VOC's collected from the surface of the lagoons with the equilibrium chamber are presented by site in Tables 1 through 7. These Tables also include the results of the portable Jerome Meter measurements of hydrogen sulfide taken at the berm of the lagoons. The wind direction, determined at the time of sampling is also included in Tables 1 through 7. According to Colorado State regulations, the primary performance standard for odor evaluations is the odor threshold as measured through olfactometry. A secondary evaluation would include measurements of ammonia, hydrogen sulfide, and VOC's.

Table 1 is the summary from Colorado Pork's Digester Unit during 2000 and 2001. The maximum odor threshold of 6000, was never exceeded at this site at the time samples were taken. This was predicted as the Digester Unit has a plastic cover which minimizes the odor released by the lagoon.

Table 2 is the summary from Colorado Pork's Evaporative Lagoon during 2000 and 2001. Two replications were collected from this site during each sample. The raw data from this site can be found in Table 2A of the Appendix. Table 2 represents the average of the two replications. At this site, the maximum odor threshold was exceeded three of the eight times sampled. This site has no cover, consequently odors are easily released from the lagoon. The maximum odor threshold was exceeded once in 2000 (May 22nd) and twice in 2001 (April 4th and June 6th). It should be noted that, although the odor threshold was exceeded at the June 6th sample date, the threshold was well below the maximum level by the next sampling on June 28th.

Table 1 . Summary of Air Testing at Colorado Pork L.L.C. Digester Unit in 2000 & 2001.

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S (ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/22/00	WNW	3880	2.30	8	2.865	-	
7/10/00	NNW	4991	0.36	13	-	0.004	0.009
9/12/00	S	954	0.31	0	-	-	
1/23/01	N	658	0.004	0	-	0.003	0.028
4/4/01	E	5662	0.42	<1	-	0.007	0.004
5/9/01	SW	997	0.31	8	-	0.005	0.016
6/6/01	SW	2751	0.26	5	-	-	
Average		**2841.9**	**0.57**	**5**	**2.865**	**0.005**	**0.014**

***Average of three readings**

Table 2. Summary of Air Testing at Colorado Pork L.L.C. Evaportative Lagoon Year 2000 & 2001.

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S (ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/22/00	WNW	7976	8.85	55	9.35		
7/10/00	NNW	5448.5	3.35	190	-	0.006	0.015
9/12/00	S	1917	0.335	53	-		
1/23/01**	N	515.5	0.009	0		0.005	0.084
4/4/01	E	8814	26	75.5	-	0.003	0.007
5/9/01	WSW	2665	13.5	101	-	0.007	0.001
6/6/01	SW	15222	100	373	-	0.003	0.001
6/28/01	NNE	2151	11.7	n/a	-	0.005	0.005
Average		**5588.6**	**20.47**	**121.07**	**9.35**	**0.005**	**0.019**

***Average of three readings**

**samples were collected on frozen lagoon

Table 3 is a summary of the air testing at OutWest's Holly Barrow Primary Lagoon during 2000 and 2001. Two replicates were collected from this site for each sample period except on July 10th, 2000 and June 28th, 2001. Table 3 represents the average of the two replicates. The raw data from this site can be found in Table 3A of the Appendix. At this site, the maximum odor threshold was exceeded two of the eight times sampled. The first time the site exceeded the maximum odor threshold was on April 2nd, 2001. By the next sampling date (May 7th), the odor threshold had been reduced to below the maximum threshold. The next time the site exceeded the maximum odor threshold was on June 4th, 2001. By the next sampling date (June 28th), the odor threshold had once again been reduced to below the maximum threshold.

Table 3. Summary of Air Testing at OutWest Holly Barrow Site - 1st Lagoon Year 2000 & 2001

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S (ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/23/00	WNW	411	0.29	1.13	45.81		0.101
7/10/00	NNW	4991	6.4	25	-		0.043
9/13/00	W	3581	9.5	18	-	-	
1/22/01**	W	1224	0.018	0	-	0.004	0.008
4/2/01	WSW	13945.5	21.5	51	-	0.002	0.005
5/7/01	SE	4644.5	16	35	-	0.005	0.050
6/4/01	ESE	11916	24.5	74.5	-	0.002	0.065
6/28/01	NW	2069	2.5	n/a	-	0.003	0.032
Average		**5347.8**	**10.09**	**29.23**	**45.81**	**0.003**	**0.043**

***Average of three readings**

** samples were collected on frozen lagoon

Table 4 is a summary of the air testing at OutWest's Holly Barrow Secondary lagoon during 2000 and 2001. Two replicates were collected from this site for each sample period except on May 23rd , 2000 and June 28th, 2001. Table 4 represents the average of the two replicates. The raw data from this site can be found in Table 4A of the Appendix. At this site, the maximum odor threshold was exceeded only once of the eight times sampled. The only time the site exceeded the maximum odor threshold was on June 4th, 2001. By the next sampling date (June 28th), the odor threshold had been reduced to below the maximum threshold.

Table 4. Summary of Air Testing at OutWest Holly Barrow Site - 2nd Lagoon Year 2000 & 2001.

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S (ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/23/00	WNW	298	0.070	2	56.74		0.016
7/10/00	NNW	819	0.315	13	-		0.060
9/13/00	W	1438.5	0.17	14	-	-	
1/22/01**	W	1118	0.0305	0	-	0.008	0.010
4/2/01	WSW	711	0.60	6	-	0.002	0.008
5/7/01	SE	438	0.0225	7	-	0.005	0.005
6/4/01	ESE	6784.5	1.85	22.5	-	0.003	0.004
6/28/01	NW	1108	0.033	n/a	-	0.004	0.008
Average		**1589.38**	**0.39**	**9.21**	**56.74**	**0.004**	**0.016**

***Average of three readings**

* *samples were collected on frozen lagoon

Table 5 is a summary of the air testing at OutWest's Nursery A lagoon during 2000 and 2001. Two replicates were collected from this site for each sample period except on January 22nd , 2001. Table 5 represents the average of the two replicates. The raw data from this site can be found in Table 5A of the Appendix. At this site, the maximum odor threshold was never exceeded.

Table 5. Summary of Air Testing at OutWest Site Nursery A Year 2000 & 2001.

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S (ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/22/00	W	186	0.0495	1	12.63	0.006	0.032
9/12/00	SE	4414	3.05	16.5	-	-	
1/22/01**	NW	658	0.003	0	-	0.008	0.007
4/4/01	SSW	5291.5	1.5	2.75	-	0.003	0.007
5/9/01	SW	3434	13.5	36.5	-	0.004	0.123
6/6/01	E	4160.5	0.18	16.5	-	0.003	0.003
Average		**3024.00**	**3.05**	**12.21**	**12.63**	**0.005**	**0.034**

***Average of three readings**

** samples were collected on frozen lagoon

Table 6 is a summary of the air testing at OutWest's Nursery B lagoon during 2000 and 2001. Two replicates were collected from this site for each sample period except on April 4th , 2001. Table 6 represents the average of the two replicates. The raw data from this site can be found in Table 6A of the Appendix. At this site, the maximum odor threshold was never exceeded**.**

Table 6. Summary of Air Testing at OutWest Nursery B Year 2000 & 2001

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S(ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/22/00	W	357	0.1475	2	32.305	0.007	0.039
9/12/00	SE	5032.5	3.2	6	-	-	
1/22/01**	WSW	627.5	0.030	0	-	0.005	0.006
4/401	S	3676	0.52	<1	-	0.002	0.002
5/9/01	SW	3434	25.5	66.5	-	0.009	0.096
6/6/01	NE	5150	16	60	-	0.010	0.131
Average		**3046.17**	**7.57**	**22.58**	**32.31**	**0.007**	**0.055**

***Average of three readings**

* *samples were collected on frozen lagoon

Table 7 is a summary of the air testing at OutWest's Nursery C during 2000 and 2001. Two replicates were collected from this site for each sample period except on January 22nd, 2001, April 2nd, 2001, and June 28th, 2001. Table 7 represents the average of the two replicates. The raw data from this site can be found in Table 7A of the Appendix. At this site, the maximum odor threshold was exceeded two of the eight times sampled. The first time the site exceeded the maximum odor threshold was on April 2nd, 2001. By the next sampling date (May 9th), the odor threshold had been reduced to below the maximum threshold. The next time the site exceeded the maximum odor threshold was on June 4th, 2001. By the next sampling date (June 28th), the odor threshold had once again been reduced to below the maximum threshold.

Table 7. Summary of Air Testing at OutWest Nursery C Year 2000 & 2001

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S(ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
9/12/00	SE	731	0.125	35	-	-	
1/22/01**	SSW	1188	0.027	0	-	0.006	0.005
4/2/01	E	10500	5	22	-	0.007	0.056
5/9/01	S	1942.5	1.8	16.5	-	0.006	0.01
6/4/01	SE	10324	13	48.5	-	0.006	0.002
6/28/01	NNE	3062	7.8	n/a	-	0.004	0.018
Average		**4624.58**	**4.63**	**24.40**	**0.000**	**0.006**	**0.018**

***Average of three readings**

** samples were collected on frozen lagoon

Figure 1 is a graphical representation of the odor threshold by site over the sampling period 2000-2001. This representation indicates that the site with the lowest odor threshold is OutWest Holly Barrow - 2. The sites with the highest odor thresholds are OutWest (OW) Holly Barrow - Primary and Colorado Pork's Evaporative lagoon. It is also evident that several of the sites exhibited the same odor flucuation over time.

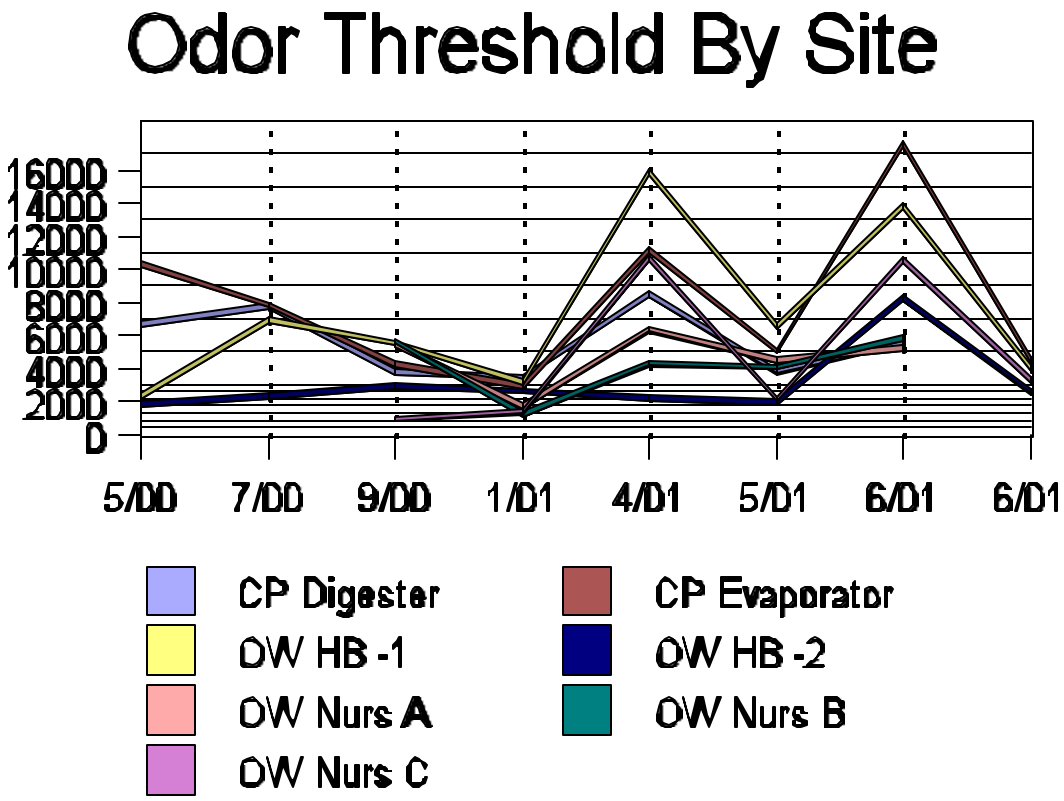

Figure 1. Odor Threshold by Site for 2000-2001

Table 8 is a summary of the Average Air Testing Result for each site. The odor threshold for Colorado Pork's Digester, OutWest's Holly Barrow Secondary lagoon, OW Nursery A and OW Nursery B are all below the average calculated over all sites. The sites can be ranked from lowest average odor threshold to highest odor threshold in the following order: OW Holly Barrow - Secondary, CP Digester lagoon, OW Nursery B, OW Nursery A, OW Nursery C, OW Holly Barrow - Primary, and CP Evaporative. When the individual sites are averaged across the sampling date for each site, none of the sites exceeded the maximum odor threshold.

All sites, except Colorado Pork's Evaporative and Holly Barrow's Primary Lagoon were below the average calculated for hydrogen sulfide across all sites. The sites can be ranked from lowest to highest average hydrogen sulfide levels in the following order: OW Holly Barrow - Secondary, CP Digester lagoon, OW Nursery A, OW Nursery C, OW Nursery B, OW Holly Barrow - Primary, and CP Evaporative.

All sites, except Colorado Pork's Evaporative lagoon, were below the average calculated for ammonia. The sites can be ranked from lowest to highest average level of ammonia in the following order: CP Digester lagoon, OW Holly Barrow - Secondary, OW Nursery A, OW Nursery B, OW Nursery C, OW Holly Barrow - Primary, and CP Evaporative.

Table 8. Summary of the Average Air Testing Results by Site

Site	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S (ppm)	
	Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
CP Digester	2841.8	0.6	5	2.865	0.005	0.0143
CP Evaporative	5588.6	20.5	126.3	9.35		0.019
OW Holly Barrow Primary	5251.3	10.9	29.6	45.8		0.04
OW Holly Barrow Secondary	1716.0	0.4	9.8	56.7		0.02
OutWest Nursery A	3239.0	3.3	13.4	12.6		0.03
OutWest Nursery B	2988.9	8.2	27	32.3		0.05
OutWest Nursery C	4527.2	4.7	27.87		0.01	0.018
Average	**3736.11**	**6.94**	**34.14**	**26.60**	**0.008**	**0.027**

Tables 9 through 15 represent summaries of the Scentometer Results for all the sites included in the study. Additionally, environmental parameters measured during the sampling periods of this study are also included. These parameters include wind speed, temperature (ºF), and percent relative humidity. Wind directions during sampling are included in Tables 1 through 7. All scentometer readings were taken at the lagoon's berm. The Scentometer, previosly described, is a device which measures the odor concentration at a specific location. According to Colorado Standards, a swine facility must have a scentometer reading of less than 7:1 at the property line or it is considered to be in violation of the law. This measurement indicates that odorous air can be detected when the air is diluted with 7 volumes of odor-free air. In Colorado, facilities other than swine, are considered "out of compliance" if a reading of 15:1 is observed.

Table 9 is the summary of the Scentometer reading at Colorado Pork's Digester. No odors were detected during most of the sampling periods. This was expected as the digester is covered with plastic. Odors were detected on April 4th and May 9th, 2001. On April 4th, the odor threshold for the digester was 5662 while it was 997 on May 9th, 2001 (Table 1). The digester never exceeded the odor threshold during the study.

Table 9. Summary of Scentometer Results at Colorado Pork's Digester Lagoon (2000-2001).

Date	Wind Speed	Temp. (F)	R.H. %	Up-Wind	Down-Wind
9/12/00	1-3	62	8	N/D	N/D
1/23/01	1-3	30	58	N/D	N/D
4/4/01	8-10	58	65	N/D	2:1
5/9/01	6-8	82	26	N/D	11:1
6/6/01	2-3	80	33	N/D	N/D
6/28/01	4-6	91	30	N/D	N/D
Average		**67.2**	**36.7**	**N/D**	**2.2:1**

R.H. = Relative Humidity
N/D = None Detected
All scentometer readings are taken at the berm of the lagoon.

Table 10 is a summary of Scentometer readings at Colorado Pork's Evaporative Lagoon. The highest Scentometer reading occurred on April 4, 2001. At that time, the odor threshold was measured at 8814 (Table 2). This level exceeded the maximum odor threshold for the State of Colorado. However, when the odor threshold at this site measured 15222 on June 6th, 2001, no odors were detected at the berm. High Scentometer readings were expected from this site due to the fact that the lagoon is untreated and there is no cover. However, the digester does remove some of the gases.

Table 10. Summary of Scentometer Results at Colorado Pork's Evaporative Lagoon (2000-2001).

Date	**Wind Speed**	**Temp. (F)**	**R.H. %**	**Up-Wind**	**Down-Wind**
9/12/00	1-3	62	8	N/D	7:1
1/23/01	1-3	30	58	N/D	2:1
4/4/01	8-10	58	65	N/D	15:1
5/9/01	8-15	77	30	N/D	2:1
6/6/01	2-3	80	33	N/D	N/D
6/28/01	4-6	91	30	N/D	7:1
Average		**66.3**	**37.3**	**N/D**	**5.5:1**

R.H. = Relative Humidity
N/D = None Detected
All scentometer readings are taken at the berm of the lagoon.

Table 11 is a summary of Scentometer readings at OutWest's Holly Barrow Primary Lagoon. The highest Scentometer reading occurred on July 10, 2000. The odor threshold at this time was measured as 4991. This did not exceed the maximum odor threshold. When the maximum odor threshold was exceeded at this site, April 2nd and June 4th, 2001 (Table 3), the Scentometer readings were only 7:1 and 4.5:1.

Table 11. Summary of Scentometer Results at OutWest's Holly Barrow Primary Lagoon (2000-2001).

Date	Wind Speed	Temp. (F)	R.H. %	Up-Wind	Down-Wind
7/10/00	1-5	88		N/D	15:1
9/13/00	2-4	86	21	2:1	2:1
1/22/01	4-6	35	53	N/D	2:1
4/2/01	3-4	54	76	N/D	7:1
5/7/01	5-8	59	50	2:1	7:1
6/4/01	2	57	79	N/D	4.5:1
6/28/01	0-2	82	37	4.5:1**	2:1
Average		**65.9**	**52.7**	**1.2:1**	**5.6:1**

R.H. = Relative Humidity
N/D = None Detected
All scentometer readings are taken at the berm of the lagoon.
**Odor coming from the barns

Table 12 is a summary of Scentometer readings at OutWest's Holly Barrow Secondary Lagoon. The highest Scentometer reading occurred on May 7, 2001 The odor threshold at this time was measured as 438. When the maximum odor threshold was exceeded at this site on June 4th, 2001 (Table 4), no odor was detected using the Scentometer. At this particular lagoon, the effluent level was 50 feet below the berm of the lagoon. This is much lower than the other lagoons.

Table 12. Summary of Scentometer Results at OutWest's Holly Barrow Secondary Lagoon (2000-2001).

Date	Wind Speed	Temp. (F)	R.H. %	Up-Wind	Down-Wind
7/10/00	1-5	88		N/D	2:1
9/13/00	2-4	86	21	N/D	N/D
1/22/01	4-6	35	53	N/D	2:1
4/2/01	3-4	54	76	N/D	2:1
5/7/01	5-8	59	50	N/D	7:1
6/4/01	2	57	79	N/D	N/D
6/28/01	0-2	82	37	N/D	2:1
Average		**65.9**	**65.9**	**N/D**	**2.1:1**

R.H. = Relative Humidity
N/D = None Detected
All scentometer readings are taken at the berm of the lagoon.

Table 13 is a summary of Scentometer readings at OutWest's Nursery A Lagoon. The highest Scentometer reading occurred on April 4th, 2001 The odor threshold at this time was measured as 5291.5. This did not exceed the maximum odor threshold, although it was the highest odor threshold reading throughout the study for this site. The odor threshold was never exceeded at this site during the study (Table 5).

Table 13. Summary of Scentometer Results at OutWest's Nursery A Lagoon (2000-2001).

Date	Wind Speed	Temp. (F)	R.H. %	Up-Wind	Down-Wind
9/12/00	3-5	71	32	N/D	2:1
1/22/01	1	60	17	N/D	N/D
4/4/01	8-10	55	71	N/D	11:1
5/9/01	9-11	70	61	N/D	2:1
6/6/01	1	69	74	N/D	N/D
Average		**65**	**51**	**N/D**	**3:1**

R.H. = Relative Humidity
N/D = None Detected
All scentometer readings are taken at the berm of the lagoon.

Table 14 is a summary of Scentometer readings at OutWest's Nursery B Lagoon. The highest Scentometer readings occurred on April 4th and June 6th, 2001 The odor thresholds at these times were measured at 3676 and 5150, respectively (Table 6). This site did not exceed the maximum odor threshold during this study.

Table 14. Summary of Scentometer Results at OutWest's Nursery B Lagoon (2000-2001).

Date	Wind Speed	Temp. (F)	R.H. %	Up-Wind	Down-Wind
9/12/00	4-5	75	26	N/D	2:1
1/22/01	2-4	44	44	N/D	N/D
4/4/01	5-7	56	69	N/D	4.5:1
5/9/01	9-11	75	48	N/D	2:1
6/6/01	2-4	62	85	N/D	4.5:1
Average		**62.4**	**54.4**	**N/D**	**2.6:1**

R.H. = Relative Humidity
N/D = None Detected
All scentometer readings are taken at the berm of the lagoon.

Table 15 is a summary of Scentometer readings at OutWest's Nursery C lagoon. The highest Scentometer readings occurred on May 7th and June 4th, 2001. The odor threshold at these times were measured at 1942.5 and 10324, respectively. The the maximum odor threshold was exceeded on April 4th and June 4th, 2001 at this site (Table 7).

Table 15. Summary of Scentometer Results at OutWest's Nursery C Lagoon (2000-2001).

Date	Wind Speed	Temp. (F)	R.H. %	Up-Wind	Down-Wind
9/12/00	5-9	81	26	N/D	2:1
1/22/01	1-2	51	25	N/D	N/D
4/2/01	8-10	60	66	N/D	2:1
5/7/01	5-6	60	51	N/D	4.5:1
6/4/01	2-4	68	58	2:1	4.5:1
6/28/01	5-7	85	33	N/D	2:1
Average		**67.5**	**43.2**	**0.3:1**	**2.5:1**

R.H. = Relative Humidity
N/D = None Detected
All scentometer readings are taken at the berm of the lagoon.

Tables 17 through 21 represent summaries of the Biological Oxygen Demand (BOD) from the lagoons included in this study. The Colorado Pork Digester was not sampled for BOD's due to the cover. BOD (5 day) is the amount of oxygen required to digest the organic matter in the sample through biochemical action in 5 days at 20EC (±0.1EC). Wastewater with high BOD levels creates an oxygen demand in the receiving stream. This leads to low levels of oxygen. The amount of waste each lagoon receives is different. The Nurseries receive less waste than the Multiplier units at Holly Barrow and Colorado Pork. A summary of the number of animals at each site is located in Table 16.

Table 16. The number of animals and pounds of animals per site.

Site	# of Animals / Site	Lbs of Animals / Site
OW Holly Barrow	5,500 Sows (ave. wt. 450 lbs)	2,475,000
OW Nursery A	6,000 Weaning swine (wt. range 10-50 lbs)	180,000
OW Nursery B	6,000 Weaning swine (wt. range 10-50 lbs)	180,000
OW Nursery C	6,000 Weaning swine (wt. range 10-50 lbs)	180,000
Colorado Pork	5,200 Sows (ave. wt. 400 lbs)	2,138,000
Colorado Pork	1,200 Gilts (wt. range 10-220 lbs)	138,000

Table 17 is a summary of the BOD's from Colorado Pork's Evaporative Lagoon. BOD values were higher during the fall of 2000 than in the spring and summer of 2001. This indicates that the lagoon was in better aerobic condition during the spring and summer. With the exception of the sample collected May 9th, 2001, the 1-2 foot sample had the highest BOD's.

Table 17. Summary of Biochemical Oxygen Demand (5 Day) Results from Colorado Pork L.L.C. Evaporative Lagoon

Date	BOD,s (5 Day) - Depth (mg/l)			Average
	0-1 (ft.)	1-2 (ft.)	2-3 (ft.)	
9/13/00	32100.0	29700.0	42000.0	34600.0
10/18/00	15415.0	12480.0	14920.0	14271.7
4/4/01	6864.0	5760.0	6900.0	6508.0
5/9/01	6645.0	7013.0	7403.0	7020.3
6/6/01	8060.0	240.0	513.0	2937.7
Average	**13816.8**	**11038.6**	**14347.2**	**13067.5**

Table 18 is a summary of the BOD results from OutWest's Holly Barrow Primary Lagoon. The BOD values from this site are all relatively low, indicating good aerobic conditions at this site. The lowest BOD's were found in the top layer of the lagoon. This is where the greatest concentration of algae can be found.

Table 18. Summary of Biochemical Oxygen Demand (5 Day) Results fromOutWest's Holly Barrow Primary Lagoon .

Date	**BOD,s (5 Day) - Depth (mg/l)**			**Average**
	0-1 (ft.)	**1-2 (ft.)**	**2-3 (ft.)**	
11/29/00	515.0			515.0
3/1/00	1196.0			1196.0
4/5/00	1359.0	1481.0	1006.0	1282.0
4/19/00	1443.0	2478.0	3966.0	2629.0
9/11/00	533.0	856.0	704.0	697.7
4/2/01	618.0	567.0	674.0	619.7
5/7/01	869.0	731.0	705.0	768.3
6/4/01	879.0	1239.0	927.0	1015.0
Average	**926.5**	**1225.3**	**1330.3**	**1160.7**

Table 19 is a summary of the BOD results from OutWest's Holly Barrow Secondary lagoon. This site had the lowest BOD's of all sites in this study. BOD's were very low at this site, indicating good aerobic conditions in this lagoon. BOD's were lowest in spring and summer of 2001 compared with fall of 2000.

Table 19. Summary of Biochemical Oxygen Demand (5 Day) Results fromOutWest's Holly Barrow Secondary Lagoon .

Date	BOD,s (5 Day) - Depth (mg/l)			Average
	0-1 (ft.)	1-2 (ft.)	2-3 (ft.)	
9/11/00	657.3	584.0		620.7
4/2/01	440.3	268.5	418.2	375.7
5/7/01	380.5	410.0	426.0	405.5
6/4/01	675.0	792.0	558.5	675.2
Average	**538.3**	**513.6**	**467.6**	**506.5**

Table 20 is a summary of the BOD results from OutWest's Nursery A lagoon. BOD's were low at this site, indicating good aerobic conditions in this lagoon.

Table 20. Summary of Biochemical Oxygen Demand (5 Day) Results fromOutWest's Nursery A Lagoon .

Date	BOD,s (5 Day) - Depth (mg/l)			Average
	0-1 (ft.)	1-2 (ft.)	2-3 (ft.)	
11/29/00	341.0			341.0
3/1/00	600.1			600.1
4/5/00	1692.0	1225.0	1166.0	1361.0
4/19/00	1328.0	707.0	694.0	909.7
9/12/00	522.0	572.0	536.0	543.3
4/4/01	855.0	841.0	861.0	852.3
5/9/01	795.0	870.0	795.0	820.0
6/6/01	936.0	720.0	456.0	704.0
Average	**883.6**	**822.5**	**751.3**	**766.4**

Table 21 is a summary of the BOD results from OutWest's Nursery B lagoon. BOD's were low at this site, indicating good aerobic conditions in this lagoon. BOD's values were very low in the top one foot of the lagoon at both the Nursery A and Nursery B lagoons (883.6 mg/l and 880.8 mg/l, respectively). This indicates that the aerators are producing oxygen and the aerobic microorganisms have broken down some of the organic compounds, resulting in low BOD values.

Table 21. Summary of Biochemical Oxygen Demand (5 Day) Results fromOutWest's Nursery B Lagoon .

Date	BOD,s (5 Day) - Depth (mg/l)			Average
	0-1 (ft.)	1-2 (ft.)	2-3 (ft.)	
11/29/99	675.0			675.0
3/1/00	1670.0			1670.0
4/5/00	1679.0	916.0	931.0	1175.3
4/19/00	1027.0	1098.0	1267.0	1130.7
9/12/00	415.0	552.0	468.0	478.3
4/4/01	297.0	291.0	300.0	296.0
5/9/01	413.0	430.0	465.0	436.0
6/6/01	870.0	600.0	432.0	634.0
Average	**880.8**	**647.8**	**643.8**	**724.1**

Table 22 is a summary of the BOD results from OutWest's Nursery C lagoon. BOD's in the top foot at this site were the second highest in the study. This is a lagoon which has a low loading rate because of the low total pounds of animals at this site. The loading rate is similar to Nursery sites A and B. The difference is that the use of aerators at sites A and B have resulted in lower BOD's.

Table 22. Summary of Biochemical Oxygen Demand (5 Day) Results fromOutWest's Nursery C Lagoon .

Date	BOD,s (5 Day) - Depth (mg/l)			Average
	0-1 (ft.)	1-2 (ft.)	2-3 (ft.)	
11/29/99	789.0			789.0
3/1/00	1441.0			1441.0
4/5/00	1130.0	1282.0	1349.0	1253.7
4/19/00	1358.0	1227.0	1092.0	1225.7
9/11/00	834.0	983.0	1065.0	960.7
4/2/01	953.5	888.5	904.0	915.3
5/7/01	1650.0	1830.0	960.0	1480.0
6/4/01	1227.0	1305.0	1257.0	1263.0
Average	**1172.8**	**1252.6**	**1104.5**	**1166.0**

A summary of the average BOD by site is presented in Table 23. When the top one foot of the lagoon is compared across all sites, the CP Evaporative lagoon has, by far, the highest BOD levels. This is a result of high loading rates coupled with no treatment to the lagoon. The next highest BOD level is at OW Nursery C which is also untreated, but has an low loading rate. The third highest BOD values are found from the OW Holly Barrow Primary lagoon. It has a high loading rate but uses algae as a lagoon treatment. OW Nursery sites A and B have similar BOD values. They have a low loading rate and use aerators on the lagoon. The lagoon with the lowest BOD values is the Secondary lagoon at OW Holly Barrow. It also uses algae as a treatment.

Table 23. Summary of the average BOD's by Site

Site	BOD,s (5 Day) - Depth (mg/l)			Average
	0-1 (ft.)	**1-2 (ft.)**	**2-3 (ft.)**	
CP Evaporative	13816.8	11038.6	14347.2	**13067.5**
OW Holly Barrow Primary	926.5	1225.3	1330.3	**1160.7**
OW Holly Barrow Secondary	538.3	513.6	467.6	**506.5**
OutWest Nursery A	883.6	822.5	751.3	**819.1**
OutWest Nursery B	880.8	647.8	643.8	**724.1**
OutWest Nursery C	1172.8	1252.6	1104.5	**1176.6**
Average	**3036.5**	**2583.4**	**3107.5**	**2909.1**

Conclusions

Table 24 is a summary of the averages for the parameters measured during this study. These parameters are what the Colorado Department of Public Health & Environment will use to evaluate effectiveness of management of lagoons to minimize odor problems in the swine industry. These parameters include odor threshold, scentometer, and BOD.

Odor threshold is the first parameter examined by the CDPH&E when it evaluates swine lagoons. Therefore, the sites are sorted in ascending order in Table 24 according to the average odor threshold. The results indicate that OW Holly Barrow's Secondary lagoon had the lowest average odor threshold during the course of this study. The remaining lagoons can be ranked in order from lowest to highest odor threshold as follows: Colorado Pork Digester, OW Nursery B, OW Nursery A, OW Nursery C, OW Holly Barrow Primary, and Colorado Pork Evaporative lagoon. This is also the approximate order when ranking by average hydrogen sulfide, average ammonia, average Scentometer Reading, and average BOD as well.

Table 24. Summary of the Average Odor Threshold, Scentometer Reading, and BOD for all sites.

Site	Average Odor Threshold	Average Hydrogen Sulfide	Average Ammonia	Average Scentometer	Average BOD
OW HB -Secondary	1716.0	0.4	9.8	2.1:1	519.2
CP Digester	2841.8	0.6	5.0	2.2:1	-
OW Nurs B	2988.9	4.7	27.0	2.6:1	811.9
OW Nurs A	3239.0	3.3	134	3:1	766.4
OW Nurs C	4527.2	8.2	27.9	2.5:1	1166.0
OW HB - Primary	5251.3	10.9	29.6	5.6:1	1090.3
CP Evaporative	5588.6	20.5	126.3	5.5:1	13067.5

Graphical representation of the average odor thresholds,, hydrogen sulfide, ammonia, Scentometer readings and average BOD's in the top one foot of the lagoon are presented graphically in Figures 2 through 6.

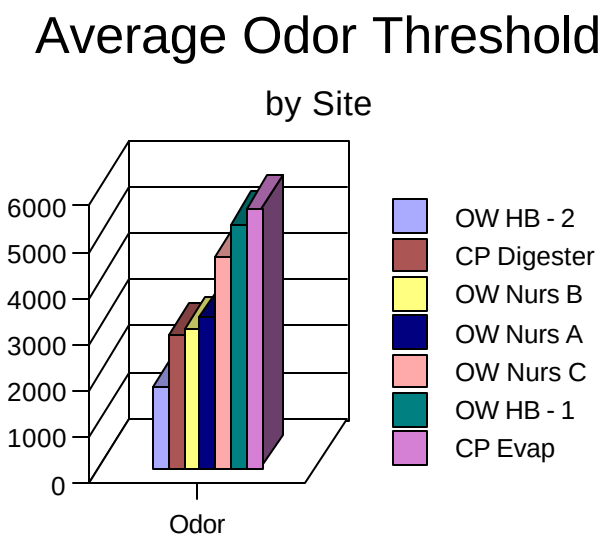

Figure 3. Odor Threshold by Site

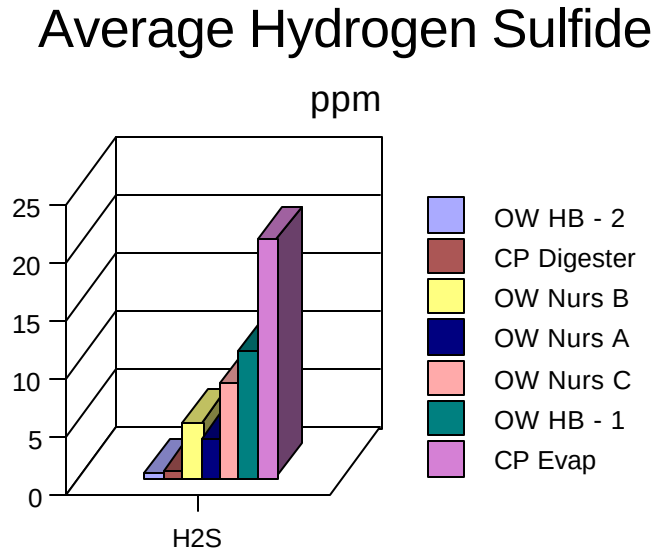

Figure 2. Hydrogen Sulfide Levels by Site

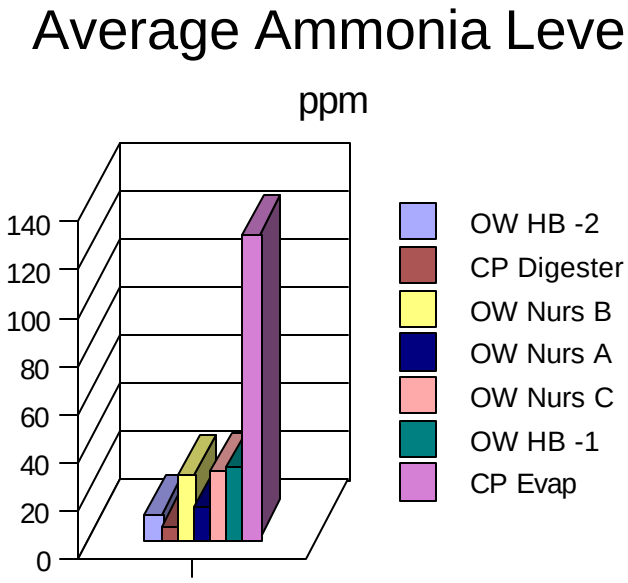

Figure 4. Average Ammonia Levels by site

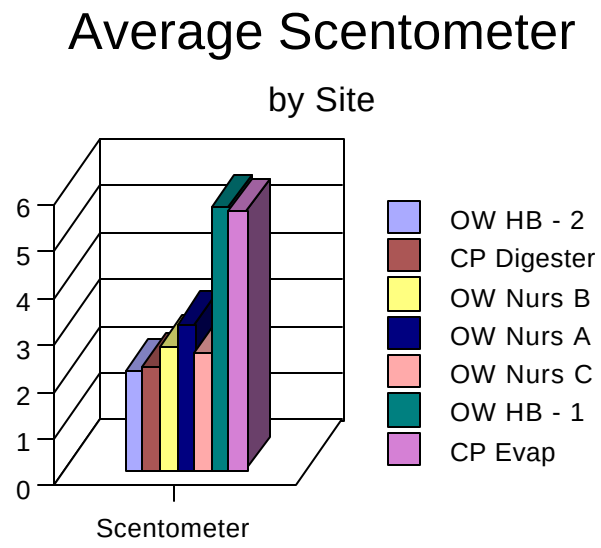

Figure 5. Average Scentometer Reading by Site

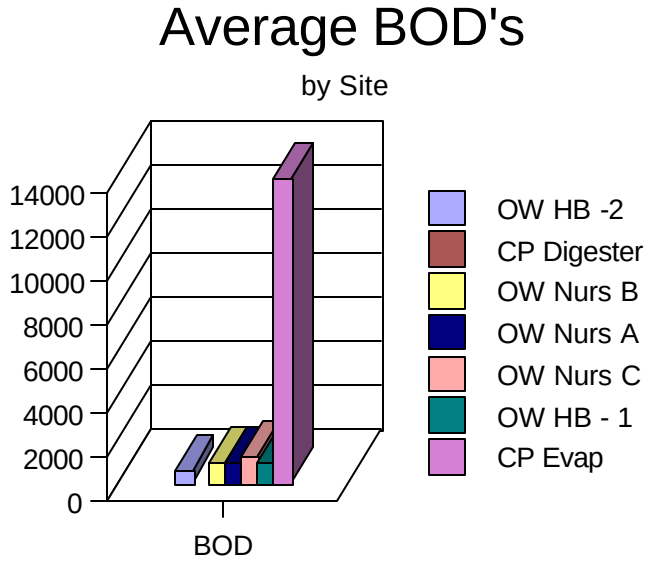

Figure 6. Average BOD's in top one foot of the lagoon by site

The Primary and Secondary lagoons at OW Holly Barrow are both treated with algae. However, the concentration of effluent in the Secondary lagoon is less than in the Primary. Effluent is pumped directly into the Primary lagoon. The contents of the Primary lagoon are pumped into the Secondary lagoon when a maximum level has been reached for the Primary lagoon. Both lagoons receive algae. The manner in which the two lagoons are treated results in the Secondary lagoon having little odor and low BOD's. It is possible that the material in the Primary lagoon is more concentrated than a typical lagoon because the excess lagoon content is pumped from the lagoon when it reaches a maximum level. This material, fluid in nature, is pumped into the Secondary lagoon, leaving more solids behind in the Primary lagoon. This may explain why the results measured from Primary lagoon fall between the results from the untreated OW Nursery C lagoon and the untreated Colorado Pork lagoon.

The next lagoon which had the least smell was Colorado Pork's Digester lagoon. This was expected since the equilibrium chamber used to collect samples is placed on top of the plastic cover over the lagoon. This lagoon never exceeded the odor threshold during the duration of this study.

OW Nursery lagoons A and B had relatively good results in this study as the odor thresholds were never exceeded at these two lagoons during the study. They also had good BOD measurements as well. These two lagoons have aerators which sit on top of the lagoon. The aerators provide circulation and add oxygen to the lagoon, creating an aerobic condition.

Once again, Colorado Pork's Evaporative lagoon received no treatment at all. This provides a good comparison for all the other lagoon treatments. Although OW Nursery C lagoon is considered an untreated lagoon, it does receive a product called 'Pit Remedy'. Pit Remedy acts as a manure liquefier. However, the evidence indicates the product provides little or no solution to the odor problem as this lagoon exceeded the odor threshold on the same sampling dates as the untreated Evaporative lagoon. The results from the OW Nursery C lagoon are better than the Colorado Pork Evaporative Lagoon because the loading rate is lower in Nursery C. In addition to the higher loading rate, the Evaporative lagoon, by design, allows for the water to evaporate with the solids and salts remaining in the lagoon. This increases the concentration of the waste in the Colorado Pork Evaporative lagoon.

As with most studies, this study has generated more questions that should be researched. Further sampling should be undertaken to evaluate odors from the different lagoons 1) when effluent is added to the lagoon; 2) one week after the effluent has been added; and 3) two weeks to one month after the effluent has been added. Studies should also consider the apparent cyclic flucuations of odor and BOD with an attempt to correlate that to lagoon management or environmental conditions. Environmental conditions, such as spring turnover observed in bodies of water, appear to increase the odor. Further studies should also include a comparison of the cost to establish and maintain the various treatments used in the lagoons.

Finally, Phyllis Woodford with CDPH&E has reviewed the Air Quality Semi-Annual Reports (July 2001) for Colorado Pork and OutWest Farms. These reports include odor thresholds, BOD's, Scentometer readings, and Total Volatile Solid (TVS) data used to evaluate the air quality of all lagoons in this study. Ms. Woodford has approved the data submitted by the swine operations meaning they have passed the minimum standards set by the Air Quality Commission and do not have to be retested for odor threshold, ammonia, hydrogen sulfide, VOC's and BOD's for three years. The swine operation must still collect Scentometer readings once in January or February, and again in July or August. TVS sampling is still needed if effluent is land applied. The data is still reported to CDPH&E in the semi-annual reports as well as in an Annual Self-Certification.

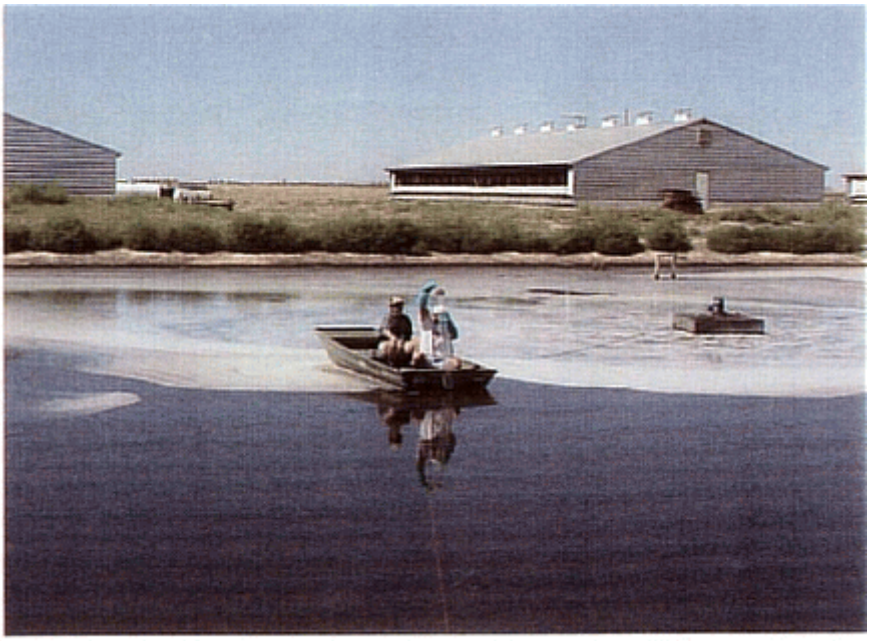

Photo 1. Phyllis Woodford & Brad Walker collecting BOD samples from Nursery B. Note aerators in background.

Photo 2. A frozen, untreated lagoon at Nursery C.

Photo 3. Phyllis Woodford at Nursery A with equilibrium chamber and vacuum box. Note bubbles in background from aerators.

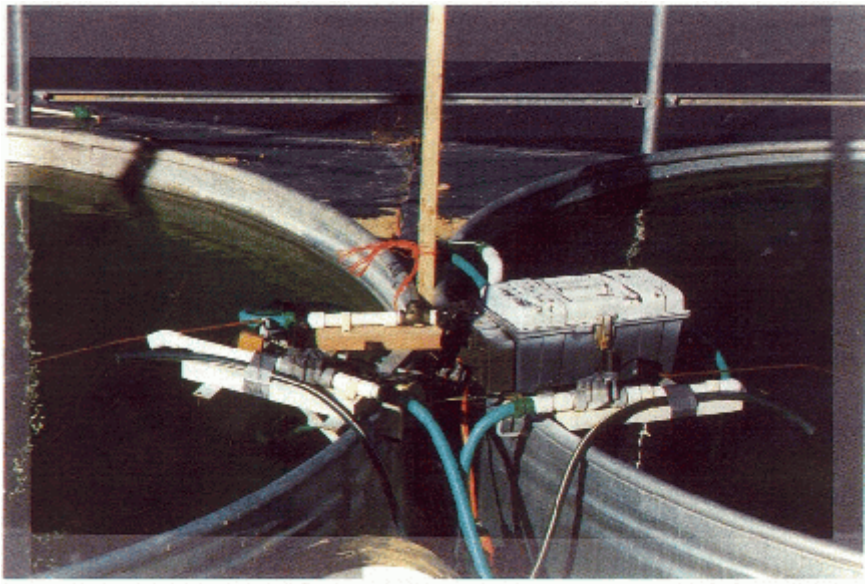

Photo 4. Algae tanks and controller box at Holly Barrow lagoons.

Photo 5. Brad Walker & Tom Zehnder with equilibrium chamber at Holly Barrow Secondary lagoon. Irrigation pump in background.

Photo 6. Digester Lagoon and Evaporative Lagoon at Colorado Pork.

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Appendix

Table 2A. Summary of Air Testing at Colorado Pork L.L.C. Evaportative Lagoon Year 2000 & 2001.

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S (ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/22/00	WNW	8365	9.10	50	9.74		
		7587	8.60	60	8.96		
7/10/00	NNW	4991	3.2	199	-	.006	0.015
		5906	3.5	181			
9/12/00	S	2089	0.43	53	-		
		1745	0.24				
1/23/01**	N	541	0.007	0	-	.005	0.084
		490	0.011	0			
4/4/01	E	7137	26	62	-	0.003	0.007
		10491	26	89			
5/9/01	WSW	2197	12	90	-	0.007	0.001
		3133	15	112			
6/6/01	SW	15784	100	364	-	0.003	0.001
		14660	100	382			
6/28/01	NNE	2069	14	n/a	-	0.005	0.005
		2233	9.4	n/a			
Average		5588.6	20.47	126.31	9.35	0.005	0.019

***Average of three readings**

**samples were collected on frozen lagoon

Table 3A. Summary of Air Testing at OutWest Holly Barrow Site - 1st Lagoon Year 2000 & 2001

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S (ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/23/00	WNW	388	0.287	1	45.08		0.101
		434	0.293	1.25	46.53		
7/10/00	NNW	4991	6.4	25	-		0.043
9/13/00	W	2695	8.3	16	-	-	
		4467	10.7	20			
1/22/01**	W	1329	0.015	0	-	0.004	0.008
		1119	0.021	0			
4/2/01	WSW	15173	33	75	-	0.002	0.005
		12718	10	27			
5/7/01	SE	4844	20	53	-	0.005	0.050
		4445	12	17			
6/4/01	ESE	12712	25	77	-	0.002	0.065
		11120	24	72			
6/28/01	NW	2069	2.5	n/a	-	0.003	0.032
Aveage		5607.4	10.89	29.56	45.81	0.003	0.043

***Average of three readings**

** samples were collected on frozen lagoon

Table 4A. Summary of Air Testing at OutWest Holly Barrow Site - 2nd Lagoon Year 2000 & 2001.

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S (ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/23/00	WNW	298	0.070	2	56.74		0.016
7/10/00	NNW	878	0.22	14	-		0.060
		760	0.41	12			
3/13/00	W	1638	0.23	22	-	-	
		1239	0.11	6			
1/22/01	W	1117	0.036	0	-	0.008	0.010
		1119	0.025	0			
4/2/01	WSW	745	0.58	6	-	0.002	0.008
		677	0.62	6			
5/7/01	SE	449	0.026	7	-	0.005	0.005
		427	0.019	7			
6/4/01	ESE	6331	1.8	23	-	0.003	0.004
		7238	1.9	22			
6/28/01	NW	1108	0.033	n/a	-	0.004	0.008
Average		1716.00	0.43	9.77	56.74	0.004	0.016

***Average of three readings**

* *samples were collected on frozen lagoon

Table 5A. Summary of Air Testing at OutWest Site Nursery A Year 2000 & 2001.

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S (ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/22/00	W	178	0.041	0	3.08	0.006	0.032
		194	0.058	2	22.18		
9/12/00	SE	4414	2.3	15	-	-	
		4414	3.8	18			
1/22/01**	NW	658	0.003	0	-	0.008	0.007
4/4/01	SSW	4903	1.8	5	-	0.003	0.007
		5680	1.2	<1			
5/9/01	SW	3434	13	35	-	0.004	0.123
		3434	14	38			
6/6/01	E	5150	0.12	17	-	0.003	0.003
		3171	0.24	16			
Average		3239.09	3.32	13.36	12.63	0.005	0.034

***Average of three readings**

** samples were collected on frozen lagoon

Table 6A. Summary of Air Testing at OutWest Nursery B Year 2000 & 2001

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S(ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
5/22/00	W	388	0.145	2	58.34	0.007	0.039
		326	0.150	2	6.27		
9/12/00	SE	4927	2.9	12	-	-	
		5138	3.5	-			
1/22/01**	WSW	597	0.025	0	-	0.005	0.006
		658	0.035	0			
4/401	S	3676	0.52	<1	-	.0002	0.002
5/9/01	SW	3434	25	63	-	0.009	0.096
		3434	26	70			
6/6/01	NE	5150	17	63	-	0.010	0.131
		5150	15	57			
Average		2988.91	8.21	27.00	32.31	0.006	0.055

***Average of three readings**

* *samples were collected on frozen lagoon

Table 7A. Summary of Air Testing at OutWest Nursery C Year 2000 & 2001

Date of Sampling	Wind Direction	Measured by Iowa State University Olfactometry Lab				Jerome Meter* H_2S(ppm)	
		Odor Threshold	Hydrogen Sulfide H_2S (ppm)	Ammonia NH_3 (ppm)	VOC (ppm)	Up-wind at Berm	Down-wind at Berm
9/12/00	SE	918	0.13	35	-	-	
		544	0.12	35			
1/22/01**	SSW	1188	0.027	0	-	0.006	0.005
4/2/01	E	10,500	5	22	-	0.007	0.056
5/9/01	S	2197	1.3	15	-	0.006	0.010
		1688	2.3	18			
6/4/01	SE	9682	12	43	-	0.006	0.002
		10966	14	54			
6/28/01	NNE	3062	7.8	n/a	-	0.004	0.018
Average		4527.22	4.74	27.75	0.000	0.006	0.018

***Average of three readings**

** samples were collected on frozen lagoon