

DEEP PIT SIMULATOR MODELING PROTOCOL FOR INDIVIDUAL METABOLISM CRATES DURING DIET STUDIES

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INTRODUCTION

Odor and gas emissions from swine production systems are important issues in the United States for both producers and their neighbors. As the swine industry continues to grow and integrate, problems associated with odors generated by pork production will become increasingly significant. The conflicts between pork producers and their neighbors emphasizes the need for technologies that decrease odor production and increase odor control. In order for producers to know which pit additives, dietary treatments, and other odor control technologies are effective, research is either conducted on full scale field systems or in simulated laboratory systems. Researchers must make sure that all experimental simulation are as close to typical production conditions as possible. The laboratory simulation protocol involves animal housing, manure collection, manure storage, and odor evaluation techniques. The purpose of this paper reports a laboratory protocol that determines odor concentration and emissions from manure storage where the animals or storage systems are subject to various experimental treatments.

Housing

Group pens over slats or individual metabolism crates are the two types of swine housing systems used in most odor and gas emission laboratory studies. The pigs were housed as groups in pens with slatted flooring (Riskowski et al., 1991; Aarnink et al., 1995; and Whitney et al., 1999). Only Cromwell et al. (1999) collected manure from pigs that were housed in individual metabolism crates.

Manure Collection

The method and frequency by which manure/slurry samples were collected differed among researchers. In some studies, manure was allowed to accumulate on the floor (Whitney et al., 1999) or in the pit (Aarnink et al., 1995; and Amon et al., 1995) located under the slatted floors. Odor and gas samples were taken directly from the farm location. In other studies, manure was collected from the farm and stored in secondary containers that were intended to simulate a pit. Air sample were then taken from these secondary containers to be evaluated for gas and odor levels.

Some researchers collected one manure sample from an operating swine facility to use for analysis (Ritter and Eastburn, 1980; Chung et al., 1996; and Hobbs et al., 1996). Others, such as Riskowski et al. (1991), collected manure (comprised of total excrement and wasted feed

and water) daily from pans located underneath the pens. The manure was mixed thoroughly to ensure uniform consistency with an electronically driven propeller before a 1.7 l (0.45 gal) sub-sample was added to the treatment barrels.

Liquid was collected once weekly, for 5 weeks, from an Iowa State University swine research farm in an experiment conducted by Zhu et al. (1997). The manure was then diluted to 4% total solids before being added to testing columns. During the first week, 30.5 cm (12 in.) of manure was added to the column followed by 15.3 cm (6 in.) of manure each subsequent week. Twice as much manure was added during the first week to simulate incomplete emptying of the pit due to limitations of cleaning equipment. Cole et al. (1975) also collected manure weekly. In this experiment, 113 l of pit contents were added to the 208 l pit simulator. Each week, approximately 4 l of fresh manure was added to the pit simulator to simulate actual production conditions.

In operating swine buildings, fecal, urinary, and feed waste is constantly being added to the pit. The constant addition of new waste causes changes in the composition of the pit contents and may alter the resulting gases and odors. Aarnink et al. (1995) found that ammonia emissions vary throughout the day and that these emissions appear to be related to the activity of the pigs. Consequently, research should simulate these changing conditions as close as possible.

Using manure samples that were gathered from a single collection may not accurately represent the manure composition of a typical facility. Samples from a single collection will almost certainly result in a different gaseous composition than samples that have fresh manure added to them daily or weekly.

Manure Storage

Storage containers and length of storage of the manure varied widely among experiments. A total of 15 treatment barrels were used to store manure samples in a study conducted by Riskowski et al. (1991). The barrels were 208 L (55 gal.) drums, 56.8 cm (22.4 in) in diameter, and 86.4 cm (34 in) high. The drums were lined with plastic to prevent corrosion and were covered with a fly screen. The fly screen was used to simulate slats, which reduce the mixture of fresh air with the air above the manure. The manure remained in the drums for the 12-week duration of the trial. Odor and gas measurements were conducted weekly. Cole et al. (1975) also used 208-L drums as pit simulators for evaluating long term methods of preventing odor formation.

Zhu et al. (1997) stored manure for 35 days in pit simulators. These simulators were polyvinyl chloride (PVC) columns, 38 cm (15 in) in diameter and 122 cm (48 in) high. Air was circulated through the sealed columns at a rate of 14 L/min. (0.5 cfm) to simulate typical air exchange in the pit underneath slatted floors in swine buildings.

Ritter and Eastburn (1980) conducted five experiments to determine the effective rate of applying polyphosphate fertilizer solution to control odors in dairy and swine manure storage containers and also to compare polyphosphates with several other commercial compounds. Initially, liquid manure was collected by mixing fresh semi-solid swine and dairy manure with water to obtain 5-7% total solids concentration. This mixture was then added to 114-L drums and allowed to stand for 30-40 days to allow anaerobic conditions to develop. In experiments 1 and 3, one time treatments were evaluated. For these experiments, manure was removed from the 114-L drums and treated in 3.8-L containers. In experiment 2, manure was treated at 10-day intervals for 44 days and in experiment 4, manure was treated weekly for four weeks. Because of the length of the trials and the volume of treatments that were added to each manure sample in experiments 2 and 4, 114-L drums were used.

Hobbs et al. (1997) collected slurry from pits beneath slatted floors during a 28-day trial. The samples were stored in 2 m x 0.5 m x 0.25 m enclosed stainless steel trays, which would later be placed in an odor and emission chamber (OEC) in order to evaluate the gases produced by the manure. The trays were placed in a 15° C water bath for one month before being evaluated. This method was used because it was felt that this would imitate actual production conditions and the resulting gases would closely match those found in operating swine buildings. Hobbs et al. (1997) reported that this method proved to be an effective research tool.

Odor Evaluation

Organoleptic techniques which utilize the human nose to measure odor intensity are the primary means of measuring odor (Reddell and Sweeten, 1975). Riskowski et al. (1991) identified five basic techniques that have been used for sensory odor analysis: ranking, rating, magnitude estimation, dilution, and forced choice.

When the ranking method of odor evaluation is used, samples are presented to a panelist in pairs or triplets. The panelist then ranks them in a sequential order according to the hedonic tone (pleasantness or offensiveness) of the odor. Riskowski et al (1991) used a ranking test during the last four weeks of a 12-week trial. Panelists were asked to compare two samples and determine which of the two was less offensive. Each treatment was given a score based on how it was ranked in comparison to the other sample in the pair. A score of "2" was given to the sample if it ranked as less offensive, a score of "1" if the samples were equally offensive, and a score of "0" if the sample was ranked more offensive. As Riskowski et al. (1991) states, the disadvantage of this method is that it does not determine the magnitude of difference between the two samples. To determine a magnitude of difference between two samples, a rating or magnitude estimation must be used.

With the rating method, panelists rate the intensity or strength of the odor on a scale of 1 to 10. On this scale, "0" represents "no odor or no offensive odor" and "10" represents "very strong or very offensive odor." Sobel (1972) first used the rating method to evaluate odor of poultry manure. In his study, panelists evaluated the poultry manure samples twice weekly for six

weeks. Results from the study showed an average standard deviation of 2.0 on a 1-10 scale for the last six observations. Variation can be influenced by differences in panelists or odor fatigue. Cole et al. (1975) and Ritter and Eastburn (1980) also used the rating method in their studies.

Magnitude estimation is a modified form of rating. When this method is used, panelists are given a reference point to use during the odor evaluation to help establish the magnitude of the scale. Ulrich and Ford (1975) used this method. Ten panelists were used to evaluate various manure treatments using untreated manure and wet sand as reference points. In their experiment, Riskowski et al. (1991) presented each panelist with eight jars, two for reference and six for evaluation. Panelists rated each of the six jars on a numerical scale ranging from 1 to 9. As a reference value, distilled water and untreated manure were used. The panelists were told that jar 1 (distilled water) had a value of "0" and jar 2 (untreated manure) had a value of "7." The disadvantage in this method is that it is difficult to determine what reference points should be used.

Dilution methods involve diluting the sample until odor can no longer be detected by the panelists. The sample can be diluted using air or water. The amount of dilution required to eliminate odor is related to the odor level. Barth et al. (1974); Hill and Barth (1976); Sweeten et al., (1977); Amon et al. (1995); and Zhu et al. (1997) have all used the dilution method of odor evaluation. The disadvantage to this type of odor evaluation is the possibility of experimental errors due to the various dilutions and the large amount of time that is required to dilute and evaluate diluted samples.

The forced-choice method of odor evaluation requires the panelist to choose one sample that is different between two or three other samples that are presented to the panelists. Amon et al. (1995) used this method to evaluate the effectiveness of a pit additive to reduce odor and ammonia. Hobbs et al. (1997) and Zhu (1997) also used this method of odor evaluation in their studies. Often n-butanol is used to calibrate the sensing ability of panelists using this method. (Hobbs et al., 1997; and Zhu et al., 1997). Of the five methods, only the forced-choice technique is considered a standard U.S. practice recommended by American Society of Testing and Materials (Zhu et al., 1997).

MATERIALS AND METHODS

The protocol for the manure storage simulation involves housing the swine, collecting the manure, sampling the air, and evaluating the odor and gasses.

Housing - Individual metabolism crates are used to house the pigs. Advantages over group housing included greater control over the pigs' environment, easier collection of fecal matter and urine, and increased replication.

Collection - Urinary and fecal material, collected daily, are added to a manure storage tank.

Storage - Manure storage is in a 40 cm (16 in) PVC pipe set in a concrete base to simulate a deep pit (Figure 1). The internal diameter of the pipe is 38 cm (15 in). Manure is added to the top, which disrupts any crust that may form. In another study, to simulate an outside manure storage basin with a cover or crust, manure is added to the bottom of the tank through a standpipe adjacent to the tank and connected by an elbow just above the base.

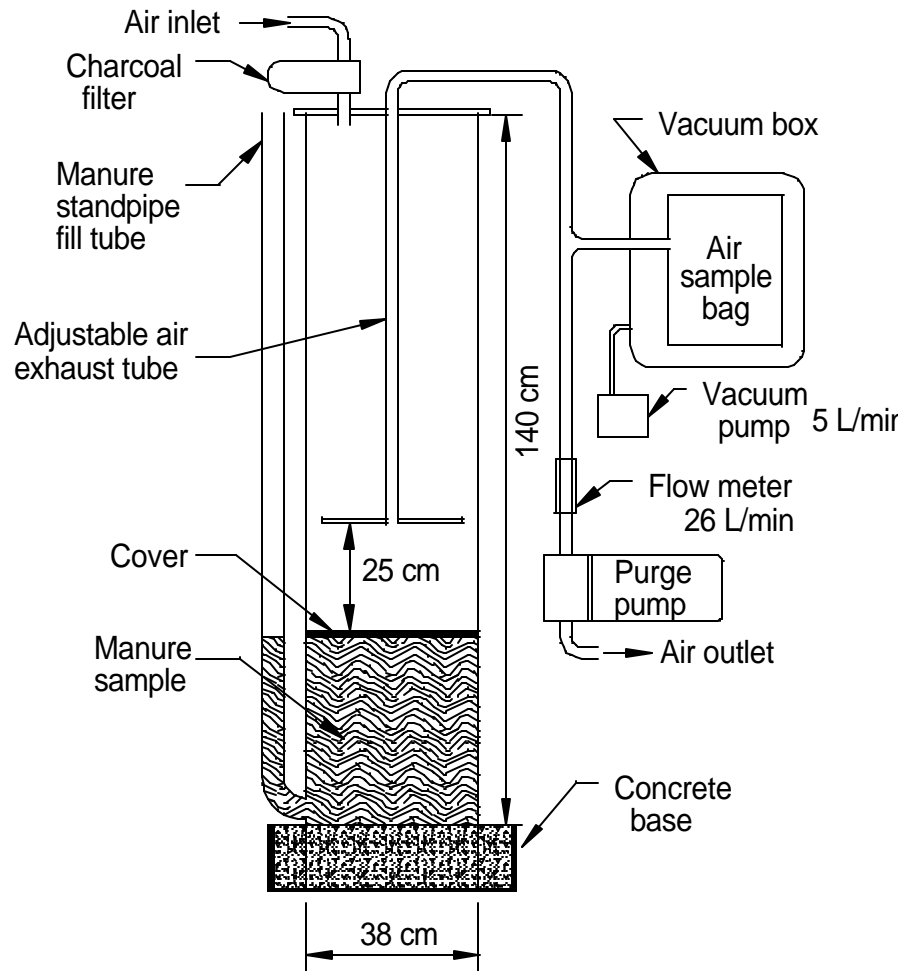


Figure 1. Manure storage simulation equipment.

Sampling - Air samples for odor evaluation are taken from the head space above the liquid manure. A cover placed on the top of the tank during air sampling allowed an air exchange rate of 50 l/m. This rate is similar to the minimum ventilation rate for a deep pit fully slatted swine finishing barn. Inlet air is drawn through a charcoal filter to remove background odors from adjacent tanks. Air flows from the top of the tank around a 35 cm (14 in) diameter baffle and then through the exhaust tube in the center of the baffle. The baffle and exhaust are adjustable to maintain a constant head space above the liquid manure surface. An inline flow meter before the purge pump measures air flow.

Air for odor evaluation is collected in a tedlar bag with a vacuum box system. The collection rate is 3 l/m from the exhaust tube.

Odor evaluation - A triangular forced choice olfactometer conforming to ASTM A-601 is used to determine odor dilution to threshold (Nicolai, 1997). The air sample is diluted with odorless air to a level at which the panelist cannot detect any odor. The dilution with clean air is reduced until the panelist can detect a difference between the mixture and a sample of odorless air. The ratio of the mixture at this level is reported as the dilution to threshold concentration in odor units. The calculated odor emissions are the product of the air exchange rate and dilution to threshold concentration divided by the surface area.

RESULTS AND DISCUSSION

The protocol was used for a storage basin cover project. Various cover types were placed on the liquid surfaces. Manure placed in the tanks initially totaled 20 percent of capacity and then was added twice each week to the bottom of the tank through the standpipe which simulates a pull-plug manure handling system. Figure 2 shows a typical hydrogen sulfide emission from one tank in that study over the 70-day trial period. For the first 30 days of the trial, the emission was relatively constant, averaging $0.73 \mu\text{g/s-m}^2$, but increased to $4.57 \mu\text{g/s-m}^2$ during the next 30 days. Jacobson et al. (1999) report hydrogen sulfide emissions ranging from $2 \mu\text{g/s-m}^2$ to $110 \mu\text{g/s-m}^2$ for swine finishing manure stored in earthen basins. As the microorganism population in the manure adapted to the new environment, they began to multiply and the emissions increased. Therefore, the first 30 days of data should be discarded.

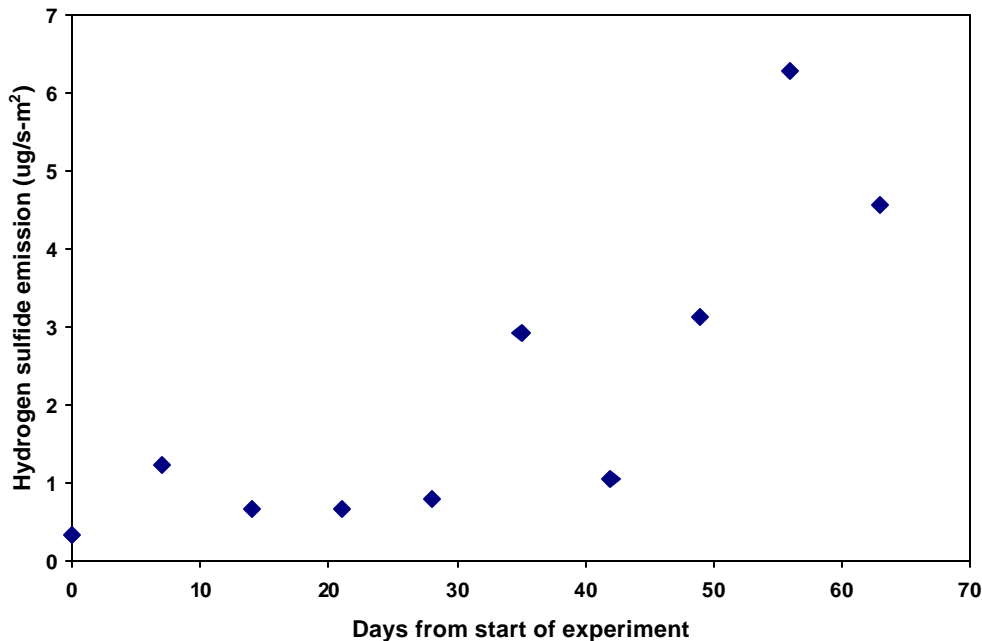


Figure 2. Hydrogen sulfide emission for one tank during a manure storage cover experiment.

The protocol was also used on a diet modification study. Various diets were fed to individual pigs in metabolism crates and the urine and feces collected daily were added to the top of the tank to simulate a deep pit. Hydrogen sulfide emissions from the manure are shown in Figure 3 for a modified diet fed for a 63 day trial period. Hydrogen sulfide emissions were constant at $0.92 \mu\text{g/s-m}^2$ for the first 30 days and then increased to $12.9 \mu\text{g/s-m}^2$ during the next 30 days at approximately the same rate as in the cover study. Jacobson et al. (1999) reported hydrogen sulfide emissions for a deep pit swine finishing barn to vary between 1 and $25 \mu\text{g/s-m}^2$.

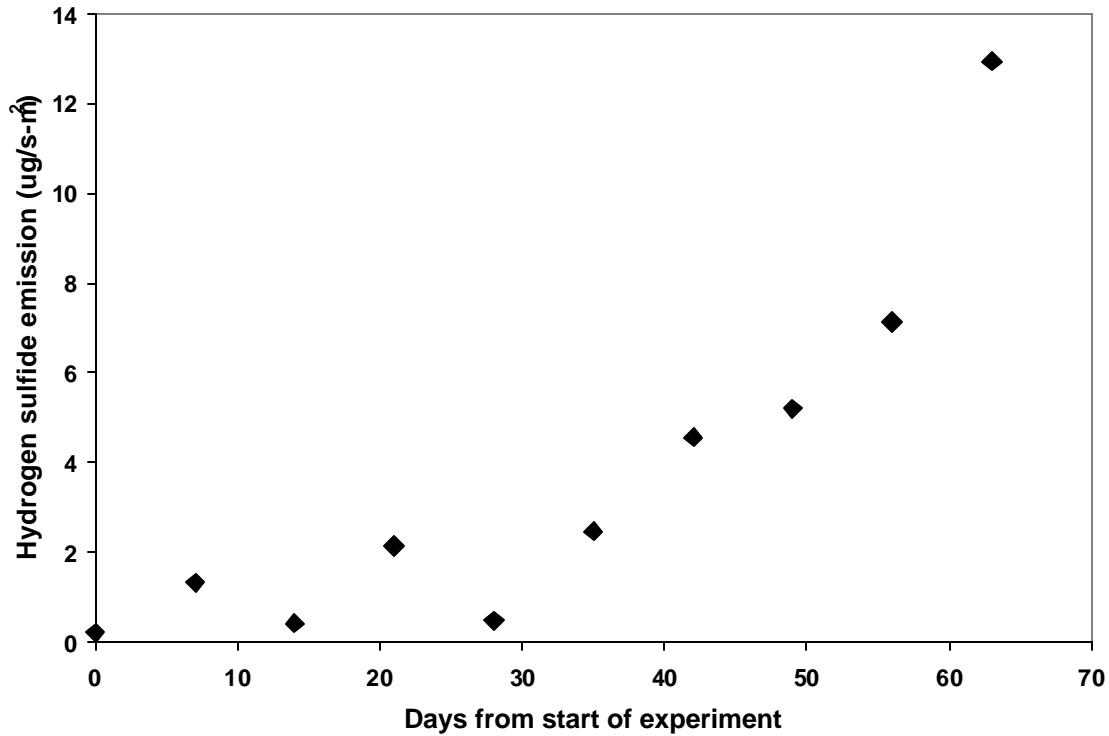


Figure 3. Hydrogen sulfide emission from one tank during a diet modification experiment.

CONCLUSIONS

A deep pit or earthen storage basin simulation protocol was developed for use in diet and other laboratory studies to investigate odor and gas emission effects. The procedure uses a tank to which manure is added daily or semi-weekly. The tank head space is ventilated at a known air exchange rate and air samples are collected from the exhaust. Hydrogen sulfide emissions for the first 30 days of the trial were low and should be discarded to allow the emissions to stabilize. Emission for the second 30 days from two simulation projects are similar to field data.

REFERENCES

- Aarnink, A.J.A., A. Keen, J.H.M. Metz, L. Speelman, and M.W.A. Verstegen. 1995. Ammonia Emissions Patterns during the Growing Periods of Pigs Housed on Partially Slatted Floors. *J. Agric. Engng. Res.* 62: 105-116.
- Amon, M., M. Dobeic, T.H. Misselbrook, B.F. Pain, V.R. Phillips, and R.W. Sneath. 1995. A Farm Scale Study on the Use of De-Odorase for Reducing Odour and Ammonia Emissions from Intensive Fattening Piggeries. *Bioresource Technology* 51: 163-169.
- Barth, C.L., D.T. Hill and L.B. Polkowski. 1974. Correlating odor intensity index and odorous compounds in stored dairy manure. *Transactions of the ASAE.* 17(4): 742-733.
- Chung, Y.C., C. Huang, and C. Tseng. 1996. Reduction of H₂S/NH₃ Production From Pig Feces By Controlling Environmental Conditions. *Journal of Environmental Science and Health.* A31(1): 139-155.
- Cole, C.A., H.D. Bartlett, D.H. Buckner, and D.E. Younkin. 1975. Odor Control of Liquid Dairy and Swine Manure Using Chemical and Biological Treatments. *Managing Livestock Wastes, ASAE PROC-275:* 374-377.
- Cromwell, G.L., L.W. Turner, R.S. Gates, J.L. Taraba, M.D. Lindemann, S.L. Traylor, W.A. Dozier III, and H.J. Monegue. 1999. Manipulation of swine diets to reduce gaseous emissions from manure that contribute to odor. Abstract presented at Midwestern Section ASAS 1999 Meeting, Des Moines, IA:187.
- Hill, D.T. and C.L. Barth. 1976. Quantitative prediction of odor intensity. *Transactions of the ASAE* 19(5): 939-944.
- Hobbs, P.J., B.F. Pain, R.M. Kay, and P.A. Lee. 1996. Reduction of Odorous Compounds in Fresh Pig Slurry by Dietary Control of Crude Protein. *J. Sci. Food Agric.* 71: 508-514.
- Hobbs, P.J., T.H. Misselbrook and B.F. Pain. 1997. Characterisation of Odorous Compounds and Emissions from Slurries Produced from Weaner Pigs Fed Dry Feed and Liquid Diets. *J. Sci. Food Agric.* 73: 437-445.
- Jacobson, L.D., D Paszek, R.E. Nicolai, D.R. Schmidt, B. Hetchler, and J. Zhu. 1999. Odor and Gas Emissions from Animal Manure Storage Units and Buildings. Presented July 1999 at the ASAE Annual International Meeting, Paper No. 994004. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA.
- Nicolai, R. E., L.D. Jacobson, D. R. Schmidt, C. McGinley. 1997. Livestock odor measurement using a venturi olfactometer and odor sampling using cloth swatches. In *Proceedings of the International Symposium on Ammonia and Odour Control from Animal Production Facilities.* October 6-10, Vinkeloord, The Netherlands.
- Reddell, D.L, and J.M Sweeten. 1975. Evaluation of Odor Intensities at Livestock Feeding Operations in Texas. *Managing Animal Wastes, ASAE PROC-275:*358-361.

Riskowski, G.L., A.C. Chang, M.P. Steinberg, and D.L. Day. 1991. Methods for Evaluating Odor from Swine Manure. *Applied Engineering in Agriculture* 7(2): 248-253.

Ritter and Eastburn. 1980. Odor Control in Liquid Swine and Dairy Manure with Commercial Products. *Canadian Agricultural Engineering* 22(2): 117-118.

Sobel, A.T. Olfactory Measurements of Animal Manure Odor. 1972. *Transactions of the ASAE* 15(3): 696-699, 703.

Ulich, W.L. and J.P. Ford. 1975. Malodor reduction in beef cattle feedlots. *Managing Animal Wastes*, ASAE PROC-275: 369-371.

Whitney, M.H., R. Nicolai, and G.C. Shurson. 1999. Effects of feeding low sulfur starter diets on growth performance of early weaned pigs and odor, hydrogen sulfide, and ammonia emissions in nursery rooms. Abstract presented at Midwestern Section ASAS 1999 Meeting, Des Moines, IA.:188.

Zhu, J., D.S. Bundy, X.W. Li, and N. Rashid. 1997. Reduction of Odor and Volatile Substances in Pig Slurries By Using Pit Additives. *J. Environ. Sci. Health*, A32(3): 605-619.