Laboratory Testing of Commercial Manure Additives for Swine Odor Control

Dr. Albert J. Heber,
Ph.D., P.E., Associate Professor (1) and Project Leader

Dr. Jiqin Ni, Ph.D., Technical Director [1]
Dr. Alan L. Sutton, Ph.D., Professor [2]
Dr. John A. Patterson, Ph.D., Professor [2]
Kate J. Fakhoury, M.S., Research Associate [1]
Dan T. Kelly, M.S., Research Assistant [2]
Ping Shao, Graduate Research Assistant [1]

[1] Agricultural and Biological Engineering Department
[2] Animal Sciences Department

This project was a product of the USDA-Agricultural Research Service National Swine Research and Information Center, Ames, IA. The collaboration of NPPC and ARS staff was invaluable to the project's success.

C. L. Tengman, A. K. Gralapp and R. N. Goodwin, editors.

January 25, 2001

Foreword

The results in this book are due to the cooperative efforts of the National Pork Producers Council Odor Solutions Initiative Committee, Purdue University, many product vendors and many university scientists who gave advice on protocols and procedures. Linda Aycock contributed much to this project. This program was funded by a grant of checkoff funds from the National Pork Board. We would like to extend appreciation for the hard work and dedication of the faculty, staff and students of Purdue University who worked on this project.

Dr. Albert J. Heber, Ph.D., P.E., Associate Professor [(1)] and Project Leader
Dr. Jiqin Ni, Ph.D., Technical Director [(1)]
Dr. Alan L. Sutton, Ph.D., Professor [(2)]
Dr. John A. Patterson, Ph.D., Professor [(2)]
Kate J. Fakhoury, M.S., Research Associate [(1)]
Dan T. Kelly, M.S., Research Assistant [(2)]
Ping Shao, Graduate Research Assistant [(1)]

[(1)] Agricultural and Biological Engineering Department
[(2)] Animal Sciences Department

This project was a product of the USDA-Agricultural Research Service National Swine Research and Information Center, Ames, IA. The collaboration of NPPC and ARS staff was invaluable to the project's success.

The results have been reviewed for errors. Any remaining errors are the responsibility of the editors.

C. L. Tengman, A. K. Gralapp and R. N. Goodwin, editors.

January 25, 2001

Executive Summary

Thirty-five manure storage pit additive products were evaluated by the Purdue University Agricultural Air Quality Laboratory in an experiment supported by the National Pork Board. Vendors voluntarily submitted their products to a well-defined evaluation protocol. Each product was tested three times (42 days each replicate) in an enclosed 15-inch diameter by 48-inch tall manure storage reactor. Product effectiveness was determined by comparing odor, hydrogen sulfide, and ammonia measurements in treated reactors against measurements in untreated reactors. Manure characteristics were evaluated at the beginning and end of each trial.

Each product summary includes a manufacturer/marketer product description, the method and rate of application of these products to the manure storage pits, any unique application instructions needed to calculate the amount of product to be applied, and the current retail price. The product tables list parameters measured in the manure or the airspace (headspace) above the manure surface. The table heading of least squares mean and standard error is the statistical average of the three replicate measurements. The graphs shown for each product represent odor dilution threshold (ODT) and hydrogen sulfide (H_2S). ODT, the best measure of odor, was measured on four (4) separate days during each replicate. H_2S was measured several times a day throughout the 42-day replicates. Each graph displays the product's ODT or H_2S value difference from the untreated manure value for each of the three replicates. The x-axis of the graph represents the day of sampling. Each line on the graph represents the difference between treated and untreated manure in the corresponding replicate of testing. The y-axis provides the measure of difference, calculated as treated concentration minus untreated concentration. A negative value indicates a decrease in concentration from the untreated reactor levels. A positive value indicates an increase in concentration above untreated reactor levels.

Statistical analysis provides measures of probability of differences in product activity. The comparison of interest is between untreated manure reactors and the product reactors. While scientists regularly use a 95% probability of success to declare product activity, many producers would be willing to make a decision from 75% probability of success. Results are reported at both levels of certainty, 95% and 75%. Each product summary table lists the degree of certainty and in what direction (increase or decrease) the treated manure was different from the untreated manure. Also presented is the percent (%) change in product response compared to the control.

Listed below are those products that were found to have either a 95% or 75% level of certainty that odor dilution threshold, hydrogen sulfide and ammonia would be decreased under these testing procedures as a result of the product treatment.

Odor Dilution Threshold

95% Certainty of Decrease

None of the products tested decreased odor dilution threshold at this level of certainty.

75% Certainty of Decrease

Alken Clear-Flo®	*see page 43*
Biological Manure Treatment (BMT)	*see page 55*
Super Microbial Odor Control (SMOC)	*see page 155*
Zymplex.	*see page 167*

Headspace Hydrogen Sulfide Concentration

95% Certainty of Decrease

Alken Clear-Flo®	*see page 43*
Biocharge Dry	*see page 51*
GT-2000OC & BC-2000AF	*see page 75*
INHIBODOR®	*see page 79*
Roebic Odor Eliminator (ROE)	*see page 143*
Super Microbial Odor Control (SMOC)	*see page 155*
Zymplex	*see page 167*

75% Certainty of Decrease

MBA-S	*see page 99*
PS1	*see page 135*
UC-40™ Microbe Formula	*see page 159*

Headspace Ammonia Concentration

95% Certainty of Decrease

75% Certainty of Decrease

This table shows the degree of certainty that products were successful in decreasing odor, H_2S, and NH_3 during Testing.

PRODUCT NAME	DECREASES ODOR (ODT)		DECREASES HYDROGEN SULFIDE (H_2S)		DECREASES AMMONIA (NH_3)		SEE PAGE
	Decrease %	Certainty	Decrease %	Certainty	Decrease %	Certainty	
Agri-Clean							31
Agricycle™					3%	75%	35
AgriKlenz Plus					6%	95%	39
Alken Clear-Flo®	27%	75%	47%	95%			43
AWL-80					10%	95%	47
Biocharge Dry			37%	95%	7%	95%	51
Biological Manure Treatment	25%	75%			5%	95%	55
BIO-MAX Biosystem							59
Conserve-N							63
Digest 54 Plus					2%	75%	67
EM Waste Treatment					15%	95%	71
GT-1000OC & BC-2000AF			34%	95%			75
INHIBODOR®			36%	95%			79
KOPROS®							83
Krystal Air™					7%	95%	87
Lagoon Aid							91
Manure Management Plus™					6%	95%	95
MBA-S			19%	75%	3%	75%	99

MICROBE-LIFT							103
MUNOX®							107
M_2 Acid Buffer							111
Nature’s Key Pit & Lagoon							115
N-P 50					3%	75%	119
OdorKlenz BMT							123
Peroxy Odor Control					3%	95%	127
Pit Remedy							131
PS1			14%	75%			135
Roebic Manure Liquefier							139
Roebic Odor Eliminator			23%	95%			143
SEPTI-SOL							147
Solmar AW-509							151
Super Microbial Odor Control	32%	75%	37%	95%			155
UC-40™ Microbe Formula			15%	75%			159
X12							163
Zymplex	28%	75%	27%	95%			167

Table of Contents

Introduction

Odor Solutions Initiative

1997-2000

The Odor Solutions Initiative (OSI) was originally funded in June 1997 as the World Odor Prize. A supervising committee of producers and scientists, chaired by Illinois producer John Kellogg, has met six to ten (6-10) times per year to develop programs to provide factual information about immediate pork producer air quality regulatory issues.

The first OSI project was hydrogen sulfide, ammonia and odor field measurement in five states. This information was used to help standardize odor measurement at the four olfactometry (odor) laboratories. The hydrogen sulfide measurements were done with monitoring equipment prescribed by the Minnesota Pollution Control Agency (MPCA) in the state's first ever farm air quality regulation. Little was known about the use and accuracy of the Single Point Monitor (SPM) monitoring equipment or about the producer risks associated with MPCA field monitoring.

OSI field measurements clearly showed that all Minnesota producers were at risk of incurring large MPCA fines during manure pit agitation and manure removal activities. The Minnesota Pork Producers Association (MPPA) used OSI data to help revise the state's hydrogen sulfide regulations to allow producer 'holidays' for proper manure removal and application. MPPA greatly reduced the risk of regulatory expense for its members. Other state regulatory agencies watched the Minnesota situation carefully as they planned their own regulations.

Another OSI project to monitor the effectiveness of waste treatment systems required the development of air quality field measurement protocols. Several experimental machines were tested in this project. Many state regulators are discussing producer use of lagoon/manure pit covers. A current OSI project is monitoring the effectiveness of geotextile lagoon covers in Minnesota. The University of Minnesota is a partner in this project. This project started in June 2000 and will be continued through 2001. Producer interest in this project has been high.

The OSI manure pit additive evaluation project was conducted at Purdue University. Thirty-five products have been evaluated for odor, H_2S, and NH_3 activity. Results give producers unbiased information about product effectiveness in a controlled setting. The results are presented in this book.

Odor Solutions Initiative Committee members:

John Kellogg. IL Producer
Roy Henry, KS Producer
Jimmy Pollack, NC Producer
Sharon Schwartz, KS Producer
Bob Uphoff, WI Producer
Max Waldo, NE Producer

John Crouse, USDA-ARS Scientist
Joe Ford, USDA-ARS Scientist
Jerry Hatfield, USDA-ARS Scientist
Robert Kraeling, USDA-ARS Scientist
Alan Lefcourt, USDA-ARS Scientist

Statistical Analysis

Each trial was 42 days long. Since most previous lab tests of manure additives have been 30 days long, the results of both days 35 and 41 were used for final evaluation of pit additive performance. The odor data from days 35 and 41, which were the third and fourth (final) days of sampling, were combined. Airspace gas concentration data from days 35, 38, 39, 40, 41, and 42 were combined. Days 36 and 37 were excluded since day 36 was a manure addition day. This procedure reduced variability in hydrogen sulfide data that resulted from the occasional 'bursts' of gas emission on any given day.

Prior to the final analyses, all data was examined for normality using the SAS univariate procedure. All measures of interest had normal distributions, appropriate for statistical analysis with linear models.

The general linear model procedure of SAS statistical software was used to evaluate the Purdue University data. Model classes included replicate and product number. Replicate, product, and the replicate by product interaction were included in the model. Probabilities of differences between the untreated manure reactors and product treated reactors were calculated using least squares means. Statistical analyses were also conducted on final manure characteristics from each reactor.

Results are shown for decision making with 95% certainty of success and 75% certainty of success. Some products did not perform differently than untreated manure. Some products increased odor and/or gas concentrations. Often, the hydrogen sulfide and ammonia concentrations were inversely related; that is, an increase in one gas was associated with a decrease in the other.

Relationship between Hydrogen Sulfide and Ammonia Concentrations as Affected by pH

Several products caused an increase in either hydrogen sulfide or by known and well understood science. A measure of manure content, pH is the negative log of the concentration of hydrogen

ions present in a solution. It is a measurement that describes the acidity or alkalinity of a solution.
As pH decreases, the concentration of hydrogen ions increases and a solution becomes more acidic. The number of hydrogen ions available increases, HS^- and S^{2-} are converted to hydrogen sulfide, and is volatized. Ammonia gains a hydrogen ion and becomes stable ammonium (NH^{4+}).

As pH increases, there are fewer hydrogen ions present and a solution is more basic, or alkaline. The number of hydrogen ions available decreases, hydrogen sulfide molecules lose hydrogen ions and become negatively charged. Thus, the hydrogen sulfide concentration decreases as H_2S is converted to HS^- and ultimately S^{2-}. Ammonium (NH^{4+}) loses a hydrogen ion, becoming NH^3, which is the gaseous form of ammonia volatilized.

Purdue University Materials and Methods

Dr. Albert J. Heber, Ph.D., P.E., Associate Professor [1]
Dr. Jiqin Ni, Ph.D., Technical Director [1]
Dr. Alan L. Sutton, Ph.D., Professor [2]
Dr. John A. Patterson, Ph.D., Professor [2]
Kate J. Fakhoury, M.S., Research Associate [1]
Dan T. Kelly, M.S., Research Assistant [2]
Ping Shao, Graduate Research Assistant [1]

[1] Agricultural and Biological Engineering Department
[2] Animal Sciences Department

Objectives

Odor emitted from swine production facilities is one of the most important environmental issues facing the U.S. pork industry today. Technically and economically feasible methods to reduce odor can improve the pork industry's image. One of the technologies most readily available to producers is the manure lagoon/pit additive product.

Commercial manure pit additive products claim to reduce odors and/or suppress odor production, decrease ammonia (NH_3) and hydrogen sulfide (H_2S) emissions, reduce storage solids, and increase the availability of manure nutrients to plants. These products are marketed in a variety of forms including chemicals, enzymes, masking agents, and bacteria. The performance of manure pit additive products has received limited unbiased study and published test results are highly variable.

The Odor Solutions Initiative (OSI) program of the National Pork Producers Council (NPPC) sponsored comprehensive testing on thirty-five commercial manure additive products. Purdue University conducted these tests between February 2 and July 5, 2000, using a protocol specified by the OSI committee.

Experimental Approach

Each product was tested in a simulated manure pit reactor (experimental unit) during each of three replicates. The experimental plan was to randomly assign each product to a reactor during each replication. There were also four untreated reactors of manure in each replicate that served as controls. A replicate was defined as a 42-day trial. The reactors were initially charged with manure on day 0 and the last gas samples were taken on day 42. The test replicates began on February 2, March 29, and May 24.

Reactors and Reactor Room

Reactors

The 122 cm (48 in) tall reactors were made of rigid 345 kPa (50 psi) PVC plastic pipe (37.9 cm or 14.9 in id) with slip caps on each end. Each reactor was lined with 0.05 mm (2 mil) thick Tedlar® film on the top 64 cm (25 in) of the inside walls and the "ceiling" of the reactor (inside the slip cap) to create a chemically inert headspace. The Tedlar "cylinder" was held in place at the top and bottom with 2.5 cm (0.98 in) and 0.6 cm (0.2 in) stainless steel spring bands, respectively. The Tedlar was discarded and replaced with new film between replicates. Before each trial, the reactor body, the reactor cap, and all internal accessories including the stainless steel bands, the polypropylene and Teflon fittings installed in the cap, the stainless steel plug, and the ventilation tube assembly were thoroughly cleaned. The external accessories (inlet and outlet tubing, etc.) were not cleaned or replaced between replicates.

Reactor Room

The product testing was conducted in the Agricultural and Biological Engineering Building located on the Purdue University West Lafayette campus. The reactors were placed in a 4.5 m × 2.7 m (14.8 ft × 8.9 ft) insulated, environmentally-controlled, walk-in chamber referred to as the reactor room. The reactor room was located inside a large laboratory and was adjacent to another laboratory referred to as the instrumentation room. Ten and eleven reactors were located along the north and south inside walls of the chamber, respectively. The other eighteen reactors were located in two rows of nine in the middle of the room. See Appendix B for diagrams.

A heating and air conditioning system maintained the reactor room temperature at 20°C (68°F). A manually-controlled 340 m^3/h (200 cfm) variable-speed exhaust fan vented fumes to the outside and drew in fresh air from the large laboratory. Fresh makeup air entered the reactor room from the large laboratory through a 15.2 cm (5.98 in) diameter perforated tube of galvanized steel sheet metal.

Reactor room temperature was measured with eight semiconductor sensors (Model AD592, Computer Boards, Inc., Mansfield, MA). The sensors were calibrated prior to use and re-calibrated after the completion of each replicate. The temperature and relative humidity of the air in the large laboratory was monitored continuously with a temperature/humidity probe (Model 2100 HumiCap® sensor, PhysChem Scientific Corp., New York, NY).

Reactor Ventilation

Odor-free ventilation air was supplied by a 5.6 kW (7.5 Hp) air compressor located immediately outside the reactor room. The compressor delivered air at approximately 283 Lpm (10 cfm) and 621-827 kPa (100-120 psi). Air was cooled by an after cooler before passing through a coalescing filter to remove oil and a charcoal filter to remove odor. A 6 m (20 ft) length of ventilation air supply tubing (6.35 mm or 0.25 in id) was located in the reactor room to allow the air to cool to nearly room temperature. Two pressure regulators reduced and stabilized the pressure of the compressed air. The first regulator reduced the pressure to 138-345 kPa (20-50 psi) (±3%). The second regulator reduced the air pressure in the air supply manifold to 34-48 kPa (5-7 psi) (±0.25%). The air supply manifold distributed air equally to all reactors using stainless steel precision orifices (0.84 mm or 0.033 in) (O'Keefe Controls, Trumbull, CT). Manifold pressure was recorded continuously with a 0-69 kPa (0-10 psi) precision (0.25%) pressure transmitter (WIKA Tronic Line, WIKA Instruments, Inc., Lawrenceville, GA). Prior to use, each orifice was individually calibrated at 41.4 kPa (16 psi) with a 20 – 6000 mL/min Gilian ® Gilibrator-2 Calibration System (Sensidyne®, Clearwater, FL). The error of the airflow rate of each orifice was less than ±1% of the mean airflow rate of forty orifices. Orifices with airflow rate errors greater than ±1% of the mean were replaced. An electronic temperature and humidity probe (Humitter 50 YC, Vaisala, Woburn, MA) was installed in the air supply manifold to monitor temperature and relative humidity.

Reactor headspaces were continuously ventilated with 7.1 Lpm (0.25 cfm) of fresh air. Teflon® tubes of 6.4 mm (0.25 in) id and 3 m (10 ft) length, connected with Kynar® fittings, transported air from the orifices on the air supply manifold to the reactors. All parts of the ventilation inlet air system were made of stainless steel. The baffled air inlet opening of each reactor was adjustable and telescoping to allow the inlet to always be located 15.2 cm (6 in) above the manure surface. The air inlet baffle directed air radially in all horizontal directions. The baffle opening required to keep a constant jet momentum number (2.59×10^{-5}) in the headspace ranged from 2.9 to 5.3 mm (0.11 to 0.21 in). A 5 cm (2 in) diameter plastic knob at the top of the ventilation inlet system was used to manually adjust the baffle opening after each addition of manure to the reactor.

A 0-10 Lpm (0-0.43 cfm) mass-flow meter (Model 50S-10, McMillan, Georgetown, TX) was used to monitor the airflow rate from each reactor simultaneously with gas concentration measurements.

Reactor Cleaning

The reactors were emptied by a vacuum pump system, rinsed of all solids, and cleaned with a 1% solution of Alconox®. Following a minimum of 24 h of soaking, the Alconox® solution was removed and the reactors were rinsed with water. Reactor cleanliness was checked by randomly selecting two reactors, lining them with Tedlar film, and filling them with 61 cm (24 in) of clean water. The two reactors were connected to the ventilation and sampling system and all odor variables including NH_3, H_2S, and odor dilution threshold were measured. All measurements were required to be nondetectable from zero.

Manure and Manure Handling

Manure Source

The manure was collected from one of sixteen identical 850-head grow-finish buildings at a commercial swine operation located 40 km (25 mi) from West Lafayette, Indiana. During each replicate, manure was collected from one building, with a different building used for each of the three replicates. Manure was taken from barns 12, 1, and 11 for replicates 1, 2, and 3, respectively. The buildings had fully-slatted floors with 0.6 m (2 ft) deep pits that could store accumulating manure for up to 8 weeks. The manure source building housed pigs heavier than 45 kg (100 lb), except for the first two weeks of the third replicate (Table 1).

The pit was drained 19, 20, and 18 days prior to replicates 1, 2, and 3, respectively. Manure was collected from the pit on each day of manure addition to the reactors, and then the manure remaining in the pit was drained. The dry matter content of the source manure ranged from 4.5 to 12.2% (Table 1).

Table 1. Manure source information.

Date	Activity	Dry matter, %	Manure depth, inches	Manure age, days	Number of pigs	Pig weight, lb
2/1	Day 0 input	7.8	5	20	842	120
2/9	Addition	6.4	4	7	818	135
2/16	Addition	6.1	6.5	7	812	145
2/23	Addition	6.7	6.5	7	811	160
3/1	Addition	6.2	6.5	7	811	180
3/8	Addition	11.9	8	7	811	200
3/29	Day 0 input	8.9	7	21	823	140
4/5	Addition	5.8	4.5	7	821	165
4/12	Addition	11.1	3.5	7	820	175
4/19	Addition	10.2	6	7	819	185
4/26	Addition	12.2	6.5	7	818	200
5/3	Addition	8.1	9.5	7	817	225
5/24	Day 0 input	4.5	7.5	19	755	70
5/31	Addition	8.3	6.5	7	755	90
6/7	Addition	7.2	6	7	751	110
6/14	Addition	7.0	8	7	749	130
6/21	Addition	6.1	4.5	7	744	160
6/28	Addition	6.5	7	7	743	185

Pig weights were estimated.

Manure Transportation

A 3,785 L (1,000 gal) manure transfer tank system (MTT) was used to pump the required amount of manure from the pit and transport it to the laboratory.

A truck loaded with the MTT system was parked immediately outside the east end of the manure source building at the farm. One end of the 7.6 m (25 ft) umbilical hose of the MTT was inserted into the sump hole, and the pump was turned on. Valves were set to suck manure from the building into the MTT. The end of the hose was repeatedly raised and lowered in the sump while the pump was sucking manure out. The pump was turned off after the required volume of manure was pumped into the MTT. The truck hauled the MTT 40 km (25 mi) to the Agricultural and Biological Engineering building on campus.

The MTT had a mixing system powered by a 1.12 kW (1.5 Hp) diaphragm pump. The pump was located outside the MTT and used a 5 cm (2 in) hose to connect the MTT between the pump inlet and discharge. The pump discharge hose was connected to an ejector inside the MTT. The pump flow rate was approximately 114 to 228 Lpm (30 to 60 gpm) depending on back pressure created by the MTT contents.

Hose connection fittings in the inlet and discharge hoses allowed the connection of a 7.6 m (25 ft) long removable umbilical hose. Manual valves were located 1.2 m (4 ft) from the end of the umbilical hose and in the inlet and discharge hoses. The manure transportation system allowed personnel to: 1) fill the MTT with an external source of liquid or slurry, 2) agitate manure in the MTT, 3) fill the reactors from the MTT, and 4) empty reactors into the MTT.

Manure Input to Reactors

On day 0, reactor caps were removed during initial manure input. For subsequent weekly inputs, a 61 cm (24 in) stainless steel manure tube (2.4 cm or 15/16 in id) was used to add manure. With ventilation tubes raised, the manure tube was inserted through an access port (3.8 cm NPT) in the reactor cap. The manure tube was held vertical with a 7.6 cm (3 in) diameter Lenax® plastic bushing. The manure tube was adjusted before each manure addition so that the bottom of the tube was at least 7.6 cm (3 in) above the manure surface. Exactly 5.76 L (1.52 gal) (measured by equivalent weight) of manure was poured into the tube using a stainless steel funnel which was inserted into the cylinder. The manure tube was purged with a Teflon® plunger to ensure that all the manure entered the reactor.

Each reactor was filled with 74.9 L (19.8 gal) of manure to a depth of 66 cm (26 in) on day 0. On days 7, 14, 21, 28, and 35, 5.76 L (1.5 gal) of additional manure were added to each reactor, which increased the manure depth by 5.1 cm (2.0 in) each time. The reactors were loaded with manure to a maximum level of 91 cm (36 in) during the test to allow a minimum of 30 cm (12 in) of headspace. However, several reactors had less than 30 cm headspace due to large volumes of additive dosages

The contents of the MTT were completely mixed for 15 min before filling the reactors. Reactors were emptied at the end of each replicate using the MTT system.

Mixing Reactor Contents

The reactors were not mixed during manure additions; the only disturbances during the testing period were the additions of manure, applications of additives, and the final manure agitation on day 41. On day 41 of each replicate, short-term (30 s) mixing was conducted with a variable-speed mixer. The mixer rotated a 7.9 mm (5/16 in) stainless steel shaft with a 9.2 cm (3.6 in) diameter impeller, which was inserted through a 4.13 cm (1.63 in) diameter access port. An airtight sleeve bearing for the impeller shaft was installed into the access port and held the shaft at an angle to enhance uniformity of mixing.

Additive Applications to Manure

Additives were applied to the manure in the reactors according to the quantity, frequency, and procedures recommended by the manufacturers. Some additives required dosing only once at the beginning of the test while others required more frequent application. The additives were available in several forms including liquids, powders, sprays, and granules. They had a wide range of instructions for application. Most of the additives were poured into the reactors. Seven additives were applied by spraying. One additive required dumping and one additive needed to be presoaked for 8 h before application.

On day 0, additives were applied to each reactor after the manure was added and before the caps were reinstalled. On the weekly manure addition days (days 7, 14, 21, 28, and 35), additives that required pouring were applied through the 3.8 cm (1.5 in) off-centered port after the stainless steel plug was removed. The additives were applied either before or after the manure addition as specified by the manufacturers.

Spray additives were applied onto the manure surface using a 6-660 rpm peristaltic pump (Model 7521-40, Master-Flex®, Cole-Parmer Instrument Co., Vernon Hills, IL) with a single nozzle. A stainless steel full-cone nozzle was installed on the end of a 61 cm (24 in) long, 3.2 mm (1/8 in) id stainless steel threaded pipe. The pipe was inserted in a machined plastic bushing that screwed into the center hole of the reactor cap, replacing the ventilation tube momentarily to spray on the additive. The nozzle pipe was adjusted vertically to position the nozzle 27 cm

(11 in) above the manure surface. A 3.2 mm (1/8 in) id Tygon® tube, approximately 1.8 m (6 ft) long, was attached to a stainless steel pipe. With the peristaltic pump turned off, the free end of the Tygon® tube was inserted into a graduated cylinder that contained the amount of additive to be sprayed into the reactor. The pump was operated for the few seconds necessary to empty the graduated cylinder.

Automated Air Stream Control and Measurement

Continuous Air Sampling

From each reactor, a continuous exhaust air stream flowed under slight pressure through a 7 m (23 ft) long, 6.4 mm (1/4 in) id Teflon tube. A Teflon® filter holder with only a filter support mesh and no actual filter was installed before the air exhaust tube to remove manure flies. The tube conducted exhaust air to a computer-controlled 3-way Teflon®-lined 24-VDC solenoid (3.2 mm NPT, 4.0 mm orifice) in the instrumentation room. The normally open side of the solenoid was connected to the air exhaust located under the laboratory hood to allow air exhaust through the laboratory hood when the airflow rate and gas concentrations were not measured. The normally closed side of the solenoid was connected to the gas-sampling manifold. An array of solenoids allowed the selected reactor exhaust air to pass through a ported Teflon® gas-sampling manifold. The air flowing directly from the air supply manifold was similarly sampled to provide a blank air check during each sampling cycle.

The internal pumps of the hydrogen sulfide analyzer and carbon dioxide sensor and the external pump of the ammonia analyzer drew air from the ported Teflon® gas-sampling manifold through 3.2 mm (1/8 in) Teflon® tubes. The total airflow rate (< 3 Lpm) drawn by the analyzers from manifold #3 was significantly less than the airflow rate (7 Lpm) passing through the manifold. The airflow to the analyzers did not cause an air pressure drop in manifold #3, which was connected to the air exhaust. Therefore, reactor ventilation airflows were not significantly affected by gas sampling airflows.

All air plumbing fixtures, tubes, manifolds, and solenoids for exhaust/sampled air were Teflon® with the exception of the stainless steel (Type 316) wetted surface of the mass-flow meter. A suitable Teflon® mass-flow meter was commercially unavailable.

Data Acquisition and Control System

The data acquisition and control system consisted of a personal computer, an 8-channel IO board (Model 1602/16, Computer Boards, Inc., Mansfield, MA), a 24-channel input/output card, and a 32-channel temperature measurement board designed for semiconductor sensors encased in stainless steel probes (Model AD592, Computer Boards, Inc., Mansfield, MA). The data acquisition program was written using icon-level software (LabView for Windows®, National Instruments, Austin, TX).

A PC-controlled gas sampling system was constructed to allow automatic sequential air sampling from the 40 air streams (39 reactors plus 1 blank air). The sampling time was computer selectable and the sampling order of air streams, e.g. random, sequential, etc., was configured by an editable "waveform" file.

A 3.1 kW uninterruptible power system (PowerWorks® Model RST31, Deltec Electronics Corporation, San Diego, CA) conditioned poor quality AC power and provided short-term power protection to the data acquisition system and the gas analyzers.

On-line real-time results of all the continuous variables were displayed on the PC monitor. The real-time data acquisition was accessible on the World Wide Web so that research personnel could check it from remote locations. The on-line display was checked at least twice daily. Logged PC data files were inspected the next business day to discover and correct any problems with the system. The reactor room was checked each business day for proper operation of the compressor and reactor ventilation systems and the reactor room ventilation and temperature.

Gas Concentration Sampling and Continuous Measurement

High Frequency Sampling

Each of the forty exhaust ventilation streams was sampled and measured continuously for 6 min every 4 h during replicate 1, and for 12 min every 8 h during replicates 2 and 3. All but the last 60 s of gas concentration data were discarded to allow the measurement system to equilibrate. Six readings of NH_3, H_2S, and CO_2 were collected daily from each reactor during replicate 1. Three readings were collected daily for replicates 2 and 3.

Hydrogen sulfide was converted catalytically to sulfur dioxide (SO_2) at 325°C (617°F) with a converter (Model 340, Thermo Environmental Instruments (TEI), Franklin, MA). Sulfur dioxide was measured with a SO_2 Analyzer (TEI Model 43C) using pulsed fluorescence method (TEI, 1996) at a 1.0 Lpm flow rate. Hydrogen sulfide was measured between 5 and 20,000 ppb with an accuracy of 1.0% of full scale.

Ammonia was measured with an NH_3 analyzer (TEI Model 17C) using a 0.3 Lpm flow rate. Ammonia was converted to nitric oxide (NO) with a solid state converter at 825°C . The NO was measured with a chemiluminescence detector. The guaranteed accuracy was 1% of full scale or 2 ppm. It had a lower detectable limit of 1 ppb. The measurement range of the NH_3 analyzer was set at 0-200 ppm to cover the range of the NH_3 concentrations in the reactor headspace.

Carbon dioxide concentrations were used to verify similarity of manure decomposition between replicates and treatments and to detect headspace ventilation problems. The measurement limit of the photoacoustic infrared CO_2 analyzer (Model 3600, Mine Safety Appliances, Co., Pittsburgh, PA) was set at 10,000 ppm. The accuracy of the instrument, when set at measurement limit of 5,000 ppm, was ±100 ppm as specified by the manufacturer.

Calibration of Gas Analyzers

The gas instruments were calibrated every 3 to 4 days with the following certified calibration gases:

1. Zero air
2. Nitric oxide (23.4 ppm)
3. Ammonia in air (165 ppm)
4. Sulfur dioxide in air (2.7 ppm)
5. Hydrogen sulfide in nitrogen (16.5 ppm)
6. Carbon dioxide in nitrogen (3990 ppm)

The gas suppliers (BOC Gases, Port Allen, LA) analyzed the gases twice with a minimum of one week between analyses and both analyses agreeing within 1%.

Response of the Gas Measurement System

The response of the gas measurement system was evaluated by introducing calibration gases to the inlet of the air filter that was installed in the reactor cap. This test simulated the fluctuations of gas concentrations in the reactor headspace and the effect on gas concentration measurements. The time constant (τ) is defined as the time needed for the measurement system to indicate 63% of the final gas concentration from initial gas concentration.

The system time constants were measured by step input and zero input using NH_3, H_2S, and zero air calibration gases. The overall mean time constants for the NH_3 and H_2S measurement systems were 85 and 103 s, respectively.

Odor Sampling and Measurement

Odor Sampling

The reactors were sampled in numerical order and simultaneously with sampling of NH_3, H_2S, and CO_2. To aid in simultaneously sampling odor, light-emitting diodes (LED's) in the reactor room indicated which reactor was being sampled by the gas analyzers. The reactor to be sampled first was randomly selected and the odor sampling bags were randomly assigned to the reactors. An odor sample was also taken from the reactor air supply manifold to provide a blank air check.

On days 5, 19, 33, and 40, odor samples were collected from each reactor into 10-L Tedlar bags. The bags were attached with a small Teflon® tube to a polypropylene sampling port on top of each reactor and filled directly from the headspace to minimize losses and adsorption to tubing. Positive pressure within each reactor forced the reactor headspace air into the bags at approximately 3 Lpm (0.1 cfm). Each bag was pre-conditioned by filling 2/3 full with reactor headspace air and completely emptying directly into the exhaust fan of the reactor room before taking the actual sample. The evaluation of all odor samples occurred within 30 h of collection to minimize storage losses.

Odor Sample Evaluation

Odor Detection Thresholds

Odor detection thresholds (ODTs) were measured with a dynamic dilution forced-choice olfactometer (AC'SCENT International Olfactometer, St. Croix Sensory, Stillwater, MN). Odor samples are evaluated by a human odor panel. An odor panel is normally composed of eight individuals who have been screened to determine their odor sensing ability (ASTM, 1986). The odor detection threshold is the number of dilutions of sample air with odor-free air required for the odor to be just detected by 50% of the panel members. The olfactometer delivers a precise mixture of odorous and odor-free air to a panelist through a Teflon®-coated presentation mask. The dilution ratio (Z) of the mixture is the ratio of total diluted sample volumetric flow rate to the volumetric flow rate of the sample. For example, a dilution ratio of 10,000 is achieved with 2 cc/min of sample flow and 20 L/min of total flow.

The olfactometer continuously dilutes the odor sample, and, starting with an extremely high dilution ratio, presents a step by step series of ascending concentrations (step factor = 2) of the odor sample to each panelist at a flow rate of 20 Lpm. A triangle test is conducted whereby panel members sniff three sequential air streams at each dilution ratio. One air stream is randomly assigned to have the odor while the other two air streams are odor-free.

In the triangular forced-choice method, the panelist must select which of the three presentations is "different" (even if no difference is perceived) and thus contains the odor (ASTM, 1991). The panelist declares by pressing a button whether the selection is a "guess" (no perceived difference), "detection" (selection is different from the other two), or "recognition" (selection smells like something). Initial samples are so dilute that they cannot be distinguished from odor-free air. Higher and higher odor concentrations (2-fold increases), or lower and lower dilutions (50% reductions), are presented to each panelist until the sample is correctly detected in two consecutive steps.

The strength or concentration of an odor is measured by determining the dilution factor required to reach the odor detection threshold (ODT). As odor strength increases, ODT also increases because more odor-free air is needed to dilute the sample to the ODT. An individual panelist's best estimate ODT is calculated by taking the geometric mean of the last nondetectable dilution ratio and the first detectable dilution ratio. The panel ODT is calculated as the geometric mean of the individual ODTs. To assess panelist performance, a reference odorant, n-butanol, (at a certified concentration of 40 to 60 ppm) was included in each odor session and was evaluated like the other samples.

All new 10-L Tedlar bags were flushed by filling them 1/2 to 2/3 full with certified zero air and then emptying them using a vacuum pump. At least 10% of new bags were chosen randomly from each shipment, filled with a neutral gas such as pure air or nitrogen, stored for 24 h, and tested for odorlessness using olfactometry. A bag was considered odorless if the highest ODT was less than a factor of 2^5 of the typical ODT's of reactor headspace samples. For example, if ODT's of 320 are expected, then the odorlessness threshold is $320/2^5=10$.

Precision airflow calibrators (Mini-Buck Calibrator M-1 for 0.1 to 300 cc/min flows and Gilian Airflow Calibrators for 0.02-6 Lpm and 2-30 Lpm flows) were used to calibrate the dilution airflows of the olfactometer. Flow calibrations were conducted over the full dilution range before each day of testing.

Odor Intensity, Odor Offensiveness, and Character

Odor intensity is the relative perceived psychological strength of an odor that is above its detection threshold and is independent of the knowledge of the odor concentration (McGinley and McGinley, 2000). For a single chemical odorant, odor intensity increases as a power function of its concentration. Intensity can only be used to describe an odor at suprathreshold concentrations or concentrations above its ODT.

Intensity can be assessed using either category or reference scaling. Because category scale numbers do not reference equivalent odorant concentrations and different category scales are used by different researchers, data cannot be compared between studies. Thus, it is preferred to use reference odorant concentrations as a evaluation scale to improve reproducibility and to allow direct comparisons between research studies (Harssema, 1991).

Intensity using referencing scales is assessed by either dynamic or static scale methods (ASTM, 1999). The dynamic scale method utilizes a special olfactometer that presents a series of specific concentrations of a reference odorant (e.g. n-butanol) in a continuous flow of air to each panelist. The static scale method utilizes a set of bottles with increasing concentrations of a reference odorant in water. For this study, the static method and an n-butanol reference scale were used.

Panelists were required to memorize the intensity levels (1-5) of serial dilutions of n-butanol in water. A small glass funnel was used to present air to the panelist from the sample bag while the bag was compressed with a weight. The odor panel judged the intensity of the samples by comparing them to the memorized intensities of n-butanol at known concentrations (ASTM, 1988).

Hedonic tone, or odor offensiveness, is the degree to which an odor is subjectively perceived as pleasant or unpleasant and has the closest relationship to odor annoyance versus other odor measurement variables (McGinley et al., 2000). Hedonic tone is derived from the word "hedonistic"; the Greek word *hedone* means pleasure. The hedonic tone scale used is –10 to +10. In this study, hedonic tone values were always on the unpleasant or offensive side of the hedonic tone scale (-10 to 0). Therefore, it will be referred to as odor offensiveness in this report. Perceptions of odor offensiveness vary widely among people and are strongly influenced by individual odor experience, personal odor preference, and the emotional context in which the odor is perceived.

In addition to odor dilution threshold and odor intensity, the panel also judged odor offensiveness. The offensiveness was subjectively rated from –10 (extremely offensive) to 0 (neither pleasant nor offensive) to +10 (extremely pleasant). These ratings were highly dependent on the individual panelist. The subjects, as required by Purdue University, were told that they would be evaluating agricultural odors, specifically from swine. However, they were not informed as to the contents of each particular bag on the day of a session; whether it was a blank, a control, or a treatment. This knowledge of the sample source may have influenced panelists' ranking of odor offensiveness. However, each panelist indicated in a screening survey that they did not have any ill feelings toward the swine industry.

Odor character allows one to distinguish between different odors. For example, ammonia gas has a pungent and irritating smell. It may be evaluated by a comparison with some known odors (direct-comparison method) or through the use of descriptive words (describing-profile method). The character of an odor may change with dilution, for example, during the atmospheric dispersion process. The character of the odor was also described by the panel, who used, but were not restricted to, a list of character descriptors (earthy, floral, rancid, etc.) (ASTM, 1992).

Odor Panel

The odor panel was managed in accordance with ASTM STP 758, Guidelines for the Selection and Training of Sensory Panel Members (ASTM, 1986) and ANSI/ASQC Q2-1991, Quality Management and Quality System Elements for Laboratories (ANSI, 1991).

Panelists avoided eating and drinking (except water) during the hour before the evaluation sessions. They also did not use aftershaves, perfumes, and strong deodorants on the day of the evaluation. All panel members were non-smokers.

Panelists were required to participate in three formal training sessions and one actual odor evaluation session as a panelist-in-training. The first training session oriented trainees to odor characteristics, olfactory sensation, and olfactometry. The second session provided hands-on experience with prepared odor samples. Reference odorants were used in the third session to test trainee performance. Finally, trainees were required to participate in an actual odor session and produce results that were consistent with the trained panel. Panelists were required to have at least a 4-h break between sessions. They were also required to serve as a trainee if they had not served on a panel for one month or longer.

A reference odorant (about 40 ppm n-butanol) was used to document the performance of the olfactometer and the odor panel during each odor evaluation session.

Liquid Sampling and Analysis

Liquid Manure Sampling

The manure source was sampled in triplicate (at minimum) during each reactor filling operation. The samples were taken from the umbilical hose connected to the discharge side of the pump into an empty bucket after the the full tank had mixed for at least 15 min and after the hose had discharged for 30 s. Samples were taken at the beginning, middle, and end of the reactor filling process.

Manure samples were also collected upon emptying the reactors on day 43. Mixing manure prior to liquid sampling was done to ensure the retrieval of a representative sample from each reactor.

Laboratory Analysis

Total solids (TS), volatile solids (VS), total suspended solids (TSS), chemical oxygen demand (COD), pH, total Kjeldahl nitrogen (TKN) and ammonium nitrogen (NH_4^+-N) for the influent and effluent of the reactors were analyzed by standard methods. Total Kjeldahl nitrogen was determined by the micro-Kjeldahl nitrogen method of Nelson and Sommers (1972). Ammonium nitrogen was determined using the steam distillation method of Bremner and Keeney (1965). For dry matter, the samples were analyzed gravimetrically at 90°C (194°F). For P and K, manure samples were wet ashed by refluxing with concentrated nitric acid ($HNO_{3)}$ for 2 h prior to analysis of the digest. Analysis of K was determined by atomic absorption spectrophotometry. Analysis of P was evaluated according to Murphy and Riley (1962), using a colorimetric procedure with ammonium molybdate, antimony potassium tartrate, and ascorbic acid.

The depths of settled solids were measured on source manure for the weekly additions to the reactors. A 1 L diluted sample was poured into a settling column and the suspension was allowed to settle. The volume occupied by the settled sludge after complete settling occurred was measured and reported as a percent of the total volume.

Gas Chromatographic Analysis

A gas chromatograph (Model 8610C, SRI Instruments, Torrance, CA) equipped with NPD, FID and FPD detectors and an autosampler was used to analyze manure source samples for phenol, p-cresol, indole, and skatole. The GC was operated using PeakSimple software (SRI Instruments, Torrance, CA). Phenol and p-cresol concentrations in acidified samples were analyzed with an FID detector. The analysis included using an Alltech GS-Q column (30 m, 0.53 mm id) with helium as a carrier gas and a temperature program ramped from 50 to 160°C. Skatole and indole concentrations in chloroform-extracted samples (Jensen et al. 1995) were determined with an NPD detector. For this procedure an Alltech DB-WAX column (30 m, 0.53 mm id) with helium as a carrier gas and a temperature program ramped from 120 to 220°C was used.

A GC (Model 5890A, Hewlett Packard, Avondale, PA) equipped with an FID detector and an integrator (Model HP3392A, Hewlett Packard) was used to analyze manure source and reactor samples for volatile fatty acids. Samples were acidified with 8% m-phosphoric acid and were analyzed isothermally using a Supelco 2100 packed column at 130°C (266°F) with nitrogen as a carrier gas (Mathew, et al., 1993).

Summary

Controlled laboratory tests were conducted to evaluate 35 commercial manure additives for control of odor and odorants. Swine manure was added to vertical cylindrical reactors at regular intervals during each of three 42-day replicates. The reactors were held at 20°C (and ventilated with 7 Lpm (0.25 cfm) of odor-free air. Ammonia, hydrogen sulfide, and carbon dioxide concentrations from each reactor were measured automatically. Air samples were collected four times during each replicate and evaluated for odor concentrations using olfactometry. Initial and final manure characteristics were also analyzed. Raw data submitted for analysis by the National Pork Producers Council was tabulated.

Abbreviations

cfm:	cubic feet per minute (ft^3/min)
COD:	chemical oxygen demand
FID:	flame ionization detector
FPD:	flame photometric detector
gpm:	gallons per minute
hp:	horsepower
id:	inside diameter
IO:	input/output
kPa:	kilopascal
kW:	kilowatt
Lpm:	liters per minute (L/min)
mil:	length, equals 0.001 inch
NPD:	nitrogen-phosphorus detector
NPT:	National Pipe Taper

ODT: odor detection threshold
psi: pounds per square inch (lb/in^2), equals 6894.757 pascals (Pa)
PVC: polyvinyl chloride
rpm: revolution per minute
TKN: total Kjeldahl nitrogen
VDC: volts direct-current

References

ANSI. 1991. Quality Management and Quality System Elements for Laboratories, ANSI/ASQC Q2-1991, American National Standards Institute. 19 p.

ASTM. 1986. Guidelines for Selection and Training of Sensory Panel Members. Special Publication ASTM 758. American Society for Testing and Materials, Philadelphia, PA.

ASTM. 1988. Standard Practice for Referencing Suprathreshold Odor Intensity. E544-75. Annual Book of Standards, American Society for Testing and Materials, Philadelphia.

ASTM. 1991. Standard Practice for Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits. E679-91. 1991 Annual Book of Standards, American Society for Testing and Materials. 5 p.

ASTM. 1992. Atlas of Odor Character Profiles. DS 61. Annual Book of Standards, American Society for Testing and Materials, Philadelphia.

ASTM. 1999. *Standard Practice for Referencing Suprathreshold Odor Intensity.* ASTM Standard E544-99. Annual Book of Standards, American Society for Testing and Materials, Philadelphia, July.

Bremner, J.M. and D.R. Keeney. 1965. Steam distillation methods for determination of ammonium, nitrate and nitrite. Anal. Chim. Acta. 32: 485-495.

CEN. 1999. Air Quality - Determination of odour concentration by dynamic olfactometry. Draft prEN 13725 Standard CEN TC264/WG2'ODOURS'. European Committee for Standardisation. Central Secretariat: Rue de Stassart 36, B-1050 Brussels, April 5.

Harssema, H. 1991. Field measurements of odorous air pollution with panels. In *Odour and Ammonia Emissions from Livestock Farming,* Eds. V.C. Nielsen, J.H. Voorburg and P. L'Hermite, 203-211, Elsevier Applied Science, New York.

Jensen, M.T., R. Cox and B.B. Jensen. 1995. 3-methylindole (skatole) and indole production by mixed populations of pig fecal bacteria. Applied Environmental Microbiology 61:3180-3184.

McGinley, M. 2000. Personal communication. April 2000.

McGinley, C.M. and M.A. McGinley. 2000. Odor intensity scales for enforcement, monitoring and testing. In Proc. Annual Conference of the Air and Waste Management Association. Salt Lake City, Utah. June 18-22.

McGinley, C.M., M.A. McGinley and D.L. McGinley. 2000. "Odor basics", Understanding and using odor testing. Presented at The 22nd Annual Hawaii Water Environment Association Conference, Honolulu, Hawaii: June 6-7.

Murphy, J. and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta 27:31-36.

Nelson, D.W. and L.E. Sommers. 1972. A simple digestion procedure for estimation of total nitrogen in soils and sediments. J. Environ. Qual. 1: 423-425.

Sneath, R.W. and C. Clarkson. 2000. A standard that ensures repeatable odour measurements. Proceedings of the Second International Conference on Air Pollution from Agricultural Operations, Des Moines, IA, October 9-11. pp. 170-179.

TEI. 1996. Model 43C Pulsed Fluorescence SO_2 Analyzer Instruction Manual. Thermo Environmental Instruments Inc., Franklin, Massachusetts. February 23.

Zahn, J.A., J.L. Hatfield, Y.S. Do, A.A. DiSpirito, D.A. Laird and R.L. Pfeiffer. 1997. Characterization of volatile organic emissions and wastes from a swine production facility. J. Environ. Qual. 26:1687-1696.

Testing Results

Replicate Differences

Thirty-five pit additive products were tested in three replicates. There were significant differences among the three replicates for a number of measures.

Odor Measures

While the mean odor dilution thresholds of replicates 1 and 2 were not significantly different, the dilution threshold of replicate 3 was significantly greater than either of the two previous replicates ($P < .05$). The replicates did not differ significantly in odor intensity ($P < .05$). The mean odor offensiveness of replicate 2 was significantly higher than both replicates 1 and 3, with the offensiveness rating in replicate 3 higher than replicate 1 ($P < .05$).

Final Odor Measures

Replicate	Least Squares Means and Standard Error		
	Dilution Threshold	Intensity	Offensiveness
1	558 ± 41^{a}	3.2 ± 0.1^{a}	-6.4 ± 0.1^{a}
2	551 ± 41^{a}	3.2 ± 0.1^{a}	-5.2 ± 0.1^{b}
3	1402 ± 41^{b}	3.2 ± 0.1^{a}	-5.4 ± 0.1^{c}

Means with common superscripts do not differ ($P < .05$).

Gas Concentrations Measures

Significant differences among the replicates ($P < .05$) in reactor airspace hydrogen sulfide and ammonia concentrations were observed. The mean hydrogen sulfide value was greatest in replicate 3 and lowest in replicate 2. Conversely, ammonia concentrations were greatest in replicate 2 and lowest in replicate 3.

Final Gas Concentration Measures

Replicate	Least Squares Means and Standard Error	
	Hydrogen Sulfide (ppb)	Ammonia (ppm)
1	932 ± 32[a]	92.1 ± 0.5[a]
2	649 ± 33[b]	133.8 ± 0.5[b]
3	1977 ± 32[c]	84.4 ± 0.5[c]

Means with common superscripts do not differ (P < .05).

Manure Characteristics

Replicate differences were found to be statistically significant (P < .05) for each of the manure characteristics evaluated. Manure pH was greatest in replicate 3 and lowest in replicate 1. The dry matter, total nitrogen, ammonia, and phosphorus content and chemical oxygen demand of the manure were significantly greater in replicate 2 than replicate 1, and the values from replicate 3 were significantly lower than the first two replicates. The manure ash (wet basis) content in replicate 2 was significantly greater than replicates 1 and 3, with replicate 3 having the lowest mean ash value. The potassium in the manure was greatest in replicate 2 and least in replicate 3.

Final Manure Physical and Chemical Characteristics

Replicate	Least Squares Means and Standard Error		
	pH	Dry Matter (%)	Ash (%)
1	6.9 ± 0.01[a]	7.0 ± 0.1[a]	2.1 ± 0.01[a]
2	7.2 ± 0.01[b]	8.7 ± 0.1[b]	2.3 ± 0.01[b]
3	7.2 ± 0.01[c]	4.8 ± 0.1[c]	1.6 ± 0.01[c]

Means with common superscripts do not differ (P < .05).

Final Manure Nitrogen

Replicate	Least Squares Means and Standard Error	
	Total Nitrogen (ppm)	Ammonia (ppm)
1	7986 ± 113[a]	6391 ± 42[a]
2	8616 ± 113[b]	7819 ± 42[b]
3	7203 ± 113[c]	5575 ± 42[c]

Means with common superscripts do not differ (P < .05).

Final Manure Chemical Characteristics

Replicate	Least Squares Means and Standard Error		
	Phosphorus (ppm)	Potassium (ppm)	Chemical Oxygen Demand (g/L)
1	1779 ± 17[a]	2903 ± 27[a]	95 ± 3[a]
2	2462 ± 17[b]	3313 ± 27[b]	112 ± 3[b]
3	1580 ± 17[c]	2789 ± 27[c]	82 ± 3[c]

Means with common superscripts do not differ (P < .05).

Volatile Fatty Acids

Analysis of manure for acetic acid, iso-butyric acid, butyric acid, and valeric acid revealed significant replicate differences (P < .05). Acetic acid was greatest in replicate 2 and least in replicate 1. Manure from replicate 1 had the highest iso-butyric acid concentration, replicate 3 the least. Butyric acid content was greatest for replicate 2, least for replicate 3. In replicate 3, valeric acid concentration was highest; it was lowest in replicate 2. The mean propionic acid concentration of replicate 2 was greater than that of replicates 1 and 3. Also, the iso-valeric acid content of the manure in replicate 3 was significantly greater than that of the two previous replicates.

Final Manure Volatile Fatty Acid (VFA) Analysis

Replicate	Least Squares Means and Standard Error					
	Acetic Acid (mM/L)	Propionic Acid (mM/L)	iso-Butyric Acid (mM/L)	Butyric Acid (mM/L)	iso-Valeric Acid (mM/L)	Valeric Acid (mM/L)
1	159.6 ± 3.0^{a}	43.5 ± 0.5^{a}	16.8 ± 0.1^{a}	55.6 ± 0.5^{a}	8.4 ± 2.2^{a}	2.2 ± 0.05^{a}
2	210.9 ± 3.0^{b}	59.2 ± 0.5^{b}	14.2 ± 0.1^{b}	59.3 ± 0.5^{b}	8.7 ± 2.2^{a}	2.0 ± 0.05^{b}
3	178.3 ± 3.0^{c}	44.1 ± 0.5^{a}	13.8 ± 0.1^{c}	37.6 ± 0.5^{c}	78.0 ± 2.2^{b}	4.3 ± 0.05^{c}

Means with common superscripts do not differ (P < .05).

Phenolic and Indolic Compounds

Significant differences were observed among the three replicates in the analysis of manure phenol and skatole concentrations (P < .05). Phenol concentrations were highest in replicate 1 and lowest in replicate 3. Manure skatole content was observed to be greatest in replicate 2 and least in replicate 1. The mean para-cresol concentration of replicate 1 was greater than that of replicates 2 and 3. Also, the indole content of the manure in replicate 1 was significantly lower than that of the two following replicates.

Final Manure Phenolic and Indolic Compound Analysis

Replicate	Least Squares Means and Standard Error			
	Phenol (g/L)	para-Cresol (g/L)	Indole (g/L)	Skatole (g/L)
1	0.06 ± 0.002^{a}	0.10 ± 0.006^{a}	0.001 ± 0.005^{a}	0.01 ± 0.001^{a}
2	0.05 ± 0.003^{b}	0.06 ± 0.007^{b}	0.03 ± 0.005^{b}	0.05 ± 0001^{b}
3	0.04 ± 0.002^{c}	0.07 ± 0.006^{b}	0.04 ± 0.005^{b}	0.02 ± 0.001^{c}

Means with common superscripts do not differ (P < .05).

Untreated Manure

In each of the three replicates, there were four reactors that contained untreated manure. These four untreated reactors served as controls. The untreated manure was treated in the same manner as the test reactors, in terms of reactor design, sample collection, and analyses conducted. The sole difference between untreated and test reactors was the addition of manure additive products to the test reactors. Within the reactor room, the reactors were located in four rows. One untreated reactor was randomly located in each of the four rows during each of the three replicates.

The source manure was taken from a commercial grow-finish swine operation. The characteristics of this source manure are described in Table One of the Purdue Materials and Methods section.

The statistical results reported here are for all the untreated manure (4 reactors x 3 replicates). These are the final manure characteristics. These numbers are used for comparison to determine product treated reactors differences.

Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Untreated Manure**

Measure		Least Squares Mean and Standard Error
Odor Dilution Threshold	Airspace	771 ± 72
Odor Intensity		3.2 ± 0.1
Odor Offensiveness		-5.6 ± 0.1
Hydrogen Sulfide (ppb)		1107 ± 57
Ammonia (ppm)		105.2 ± 0.8
pH	Manure	7.1 ± 0.02
Dry Matter (%)		6.8 ± 0.1
Ash (%)		2.0 ± 0.02
Total Nitrogen (ppm)		8012 ± 201
Ammonia (ppm)		6672 ± 75
Phosphorus (ppm)	Manure	1981 ± 30
Potassium (ppm)		3034 ± 49
Chemical Oxygen Demand (g/L)		103 ± 5
Acetic Acid (mM/L)		172.9 ± 5.4
Propionic Acid (mM/L)		47.9 ± 0.9
Isobutyric Acid (mM/L)	Manure	15.0 ± 0.3
Butyric Acid (mM/L)		49.9 ± 0.9
Isovaleric Acid (mM/L)		33.6 ± 4.0
Valeric Acid (mM/L)		2.7 ± 0.1
Phenol (g/L)		0.05 ± 0.01
para-Cresol (g/L)	Manure	0.07 ± 0.01
Indole (g/L)		0.04 ± 0.01
Skatole (g/L)		0.02 ± 0.002

Agri-Clean

Cal-Agri Products, LLC
110 Rose Briar Dr.
Longwood, FL 32750
407/332-9352 phone
407/332-7153 fax

e-mail address: ldwizard@earthlink.net

TECHNOLOGY DESCRIPTION: Chemical

This technology is a customized blend of colloidal material (non-toxic, natural, and biodegradable), which is produced in concentrated form and diluted with the appropriate ratio of water to achieve the purposes of the individual application.

The technical requirements to apply the material are quite simple and spray the manure as the farm cleans the barns.

PRODUCT APPLICATION RATE:

Combine the product with water at a typical dilution (one part product to 100 parts water) and spray the barn surfaces as needed. For application to manure storages, add 1 part Agri-Clean to 300 parts liquid waste. Dilution may be increased or decreased depending on the application and local conditions to achieve desired results. Product should be applied at the frequency to achieve desired result.

RETAIL PRICE (Year 2001):

$11.00 per gallon of concentrate

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in odor dilution threshold, odor intensity, and odor offensiveness
MANURE	-increase in pH, dry matter content, and butyric acid concentration -decrease in ash, phosphorus content, isobutyric acid concentration

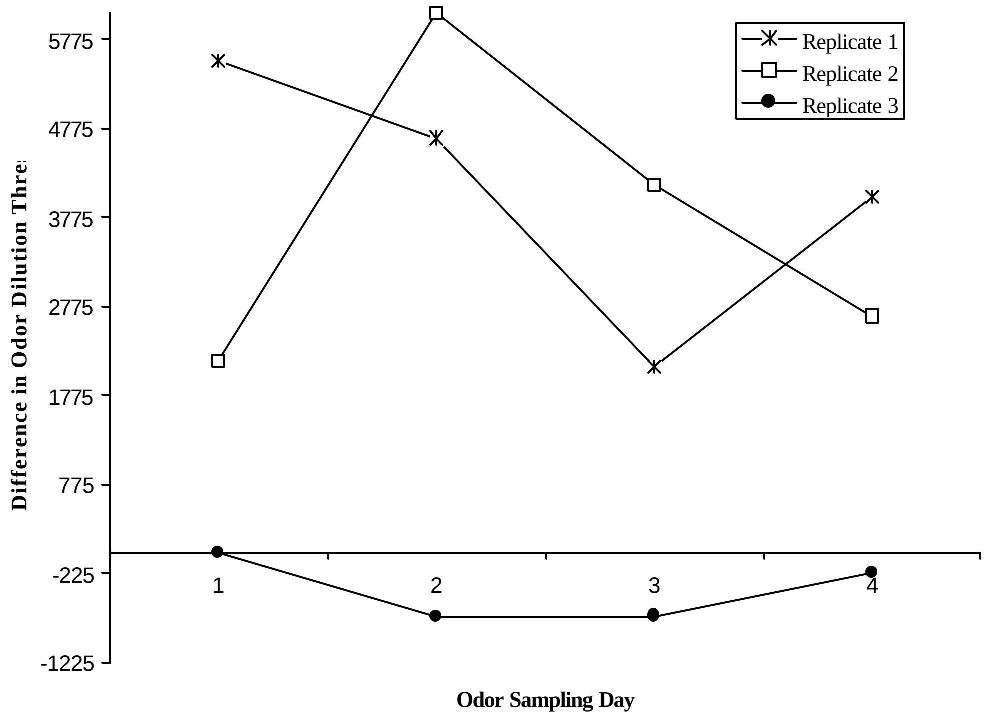
75% Certainty

MANURE	-increase in total nitrogen content, chemical oxygen demand, acetic acid, and indole concentrations -decrease in phenol concentration

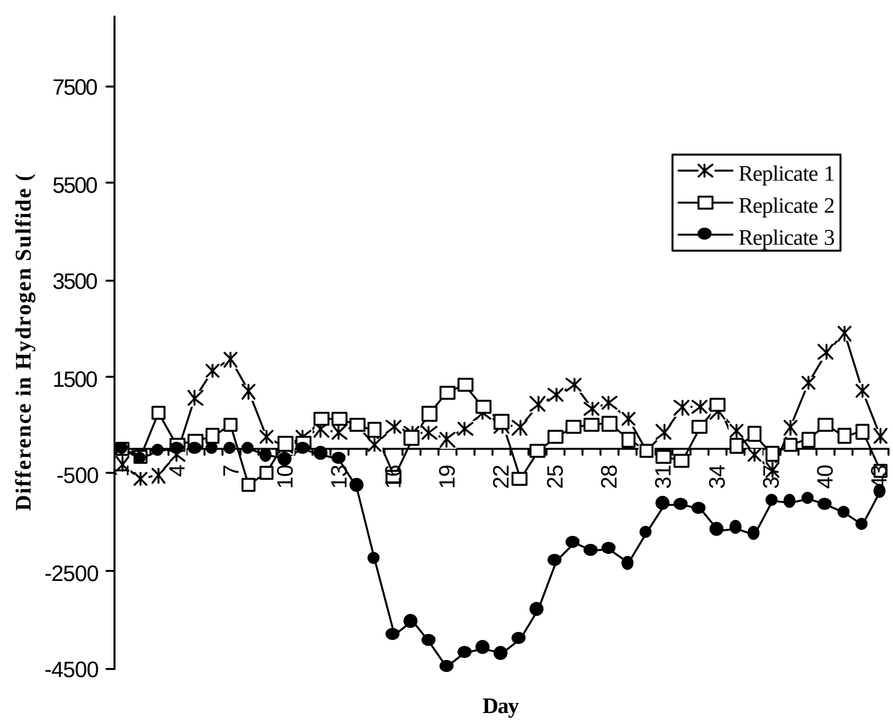
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Agri-Clean**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	2767 ± 144	**25% increase**	**95%**
Odor Intensity		3.7 ± 0.2	**16% increase**	**95%**
Odor Offensiveness		-6.8 ± 0.3	**21% increase**	**95%**
Hydrogen Sulfide (ppb)		1200 ± 113	none	none
Ammonia (ppm)		104.7 ± 1.6	none	none
pH	Manure	7.3 ± 0.04	**3% increase**	**95%**
Dry Matter (%)		7.9 ± 0.2	**16% increase**	**95%**
Ash (%)		1.9 ± 0.03	none	none
Total Nitrogen (ppm)		8538 ± 403	**7% increase**	**75%**
Ammonia (ppm)		6774 ± 149	none	none
Phosphorus (ppm)	Manure	1770 ± 59	none	none
Potassium (ppm)		2928 ± 98	none	none
Chemical Oxygen Demand (g/L)		118 ± 10	**15% increase**	**75%**
Acetic Acid (mM/L)		187.8 ± 10.7	**9% increase**	**75%**
Propionic Acid (mM/L)		47.5 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	11.6 ± 0.5	**23% decrease**	**95%**
Butyric Acid (mM/L)		62.6 ± 1.7	**25% increase**	**95%**
Isovaleric Acid (mM/L)		31.2 ± 8.0	none	none
Valeric Acid (mM/L)		2.5 ± 0.2	none	none
Phenol (g/L)		0.04 ± 0.01	**20% decrease**	**75%**
para-Cresol (g/L)	Manure	0.05 ± 0.02	none	none
Indole (g/L)		0.08 ± 0.02	**100% increase**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Agri-Clean** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Agri-Clean** and Untreated Columns by Replicate



Agricycle™ (ABC100, ABC200) & Microcycle™ (Microspur)

American Bio Catalysts
P.O. Box 15104
Richmond, VA 23227-0504
804/515-0564 phone
804/515-0566 fax

TECHNOLOGY DESCRIPTION: Organic enzyme

Agricycle™ is a biocatalytic odor abatement and remediation technology developed to significantly reduce the release of noxious and toxic gases such as ammonia, hydrogen sulfide, and volatile fatty acids produced by the aerobic and anaerobic bacteria in swine waste.

Agricycle™ is an all-natural product made entirely of food-grade materials. It is non-toxic, non-hazardous, and 100% biodegradable.

Microcycle™ is a research-selected mixture of several strains of non-pathogenic, facultative aerobic bacteria. In the absence of sufficient oxygen, all of these selected strains convert to the anaerobic state, and return to the aerobic condition when free oxygen is available. These strains have been carefully selected to work synergistically with Agricycle™.

PRODUCT APPLICATION RATE:

Treatment requires one unit of each product. Therefore, the cost for initial treatment is $195.00 per 100,000 gallons. Maintenance applications require 0.1 gallon each of Agricycle™ and Microcycle™. Maintenance applications therefore cost $19.50 per 100,000 gallons. Maintenance applications are required twice a month.

RETAIL PRICE (Year 2001):

$130.00 per gallon for Agricycle™
$65.00 per gallon for Microcycle™.

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration
MANURE	-increase in phosphorus and potassium contents

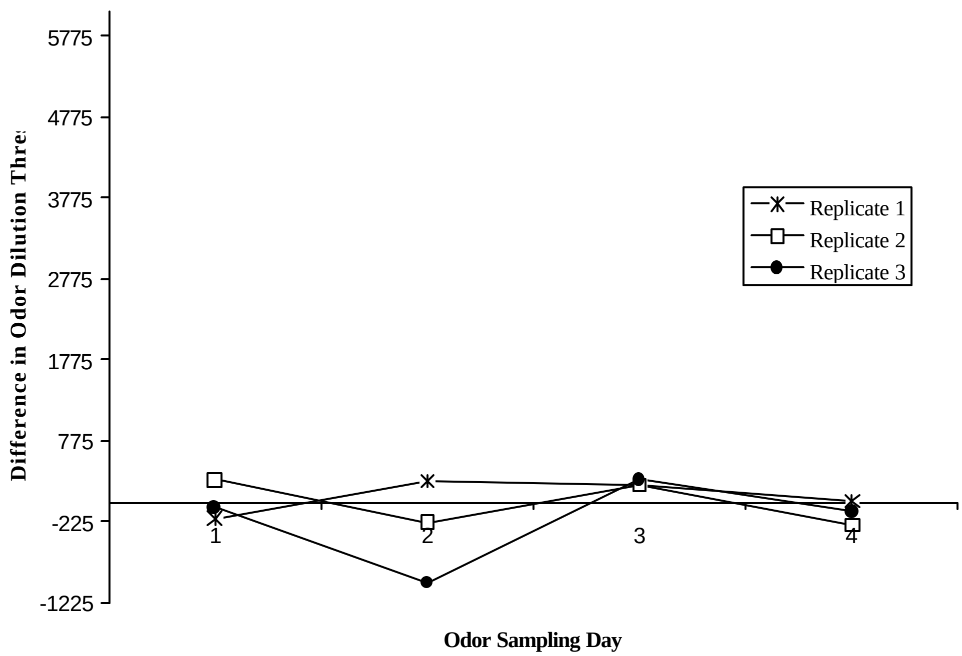
75% Certainty

AIRSPACE	-decrease in ammonia concentration
MANURE	-increase in acetic acid, propionic acid, and butyric acid concentrations
	-decrease in isovaleric acid and indole concentrations

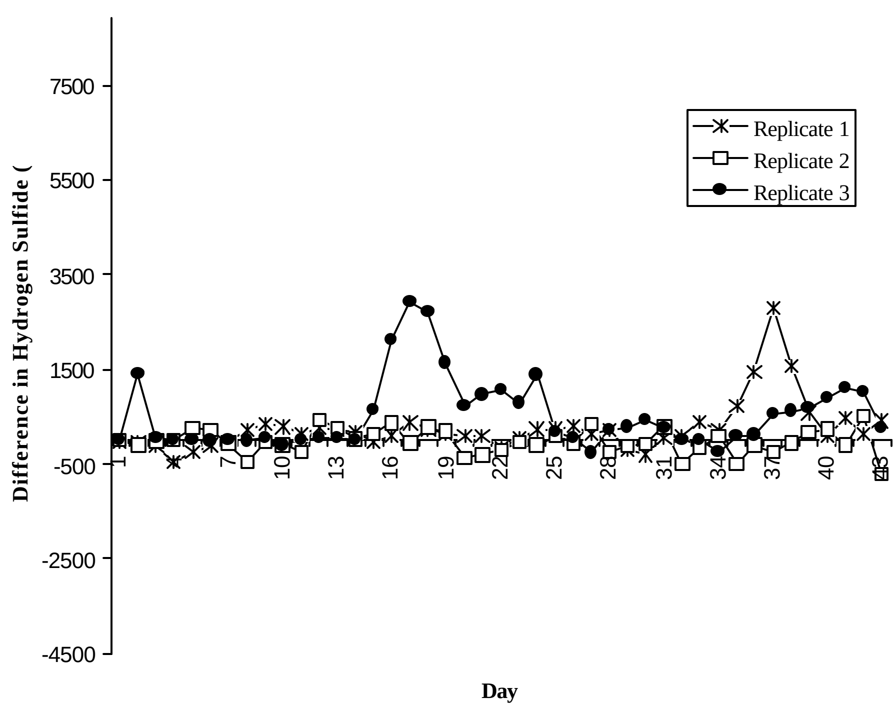
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Agricycle™ & Microcycle™**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	832 ± 144	none	none
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.6 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1559 ± 113	**41% increase**	**95%**
Ammonia (ppm)		101.9 ± 1.6	**3% decrease**	**75%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7992 ± 403	none	none
Ammonia (ppm)		6639 ± 149	none	none
Phosphorus (ppm)	Manure	2127 ± 59	none	none
Potassium (ppm)		2907 ± 98	none	none
Chemical Oxygen Demand (g/L)		101 ± 10	none	none
Acetic Acid (mM/L)		195.0 ± 10.7	**13% increase**	**75%**
Propionic Acid (mM/L)		50.4 ± 1.7	**5% increase**	**75%**
Isobutyric Acid (mM/L)	Manure	15.3 ± 0.5	none	none
Butyric Acid (mM/L)		53.5 ± 1.7	**7% increase**	**75%**
Isovaleric Acid (mM/L)		23.2 ± 8.0	**31% decrease**	**75%**
Valeric Acid (mM/L)		2.8 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.07 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Agricycle™ & Microcycle™** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Agricycle™ & Microcycle™** and Untreated Columns by Replicate



AgriKlenz Plus

Aqualogy BioRemedics
4331 E. Western Star Blvd.
Phoenix, AZ 85044-1007
602/893-9234 phone
602/244-0522 fax

TECHNOLOGY DESCRIPTION: Bacteria

The AgriKlenz Plus is an integrated biological treatment system for the automated daily treatment of generated hog waste. It bioaugments aerobic biological treatment of accumulated organic waste and ammonia, with non-pathogenic microorganisms. The result is mass malodor suppression, and a reduction in waste loading to existing treatment systems.

The process we use is generally known as bioaugmentation, introducing specific biocultures with unique biochemical properties, into waste streams. These biocultures carry out controlled degradation of defined contaminants, such as swine waste, into basic components (hydrogen, oxygen, carbon dioxide, etc.).

Biological activity will be stronger under conditions with oxygen in them. Flushing operations should provide acceptable levels of oxygen. Certain systems may require the addition of horizontal aspirator aerators in the wastewater lagoon, for optimum biological activity. Optimum biological activity occurs at pH 7.2 to 7.8.

PRODUCT APPLICATION RATE:

One gallon per month of AgriKlenz Plus should be used per 1000 hogs

RETAIL PRICE (Year 2001):

$99.00 per gallon

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration -decrease in ammonia concentration

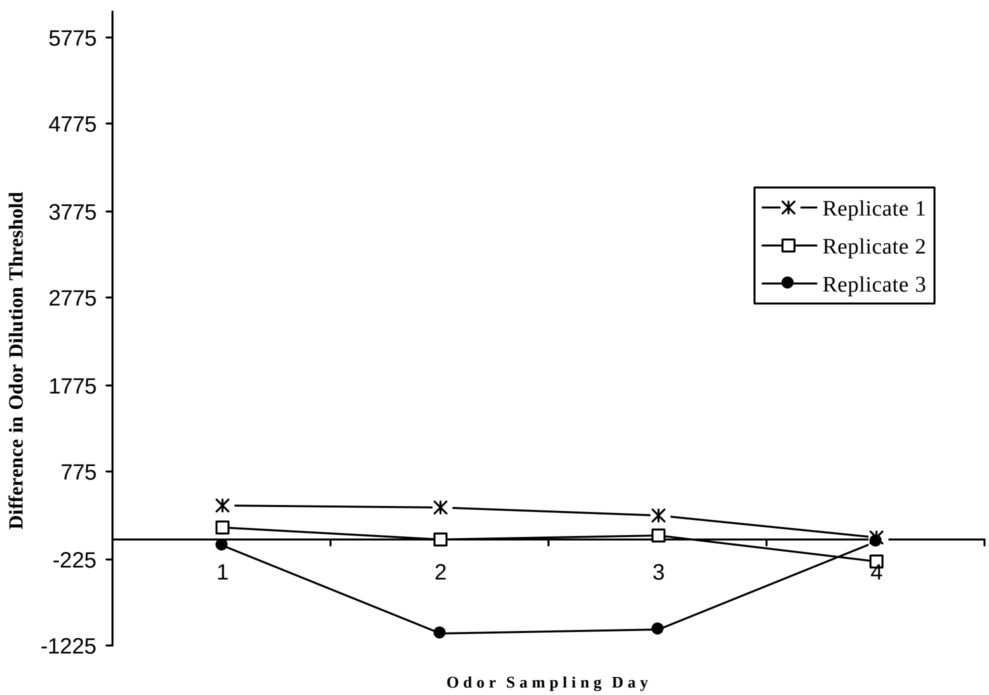
75% Certainty

MANURE	-increase in total nitrogen content, and valeric acid concentration -decrease in chemical oxygen demand, and isovaleric acid concentration

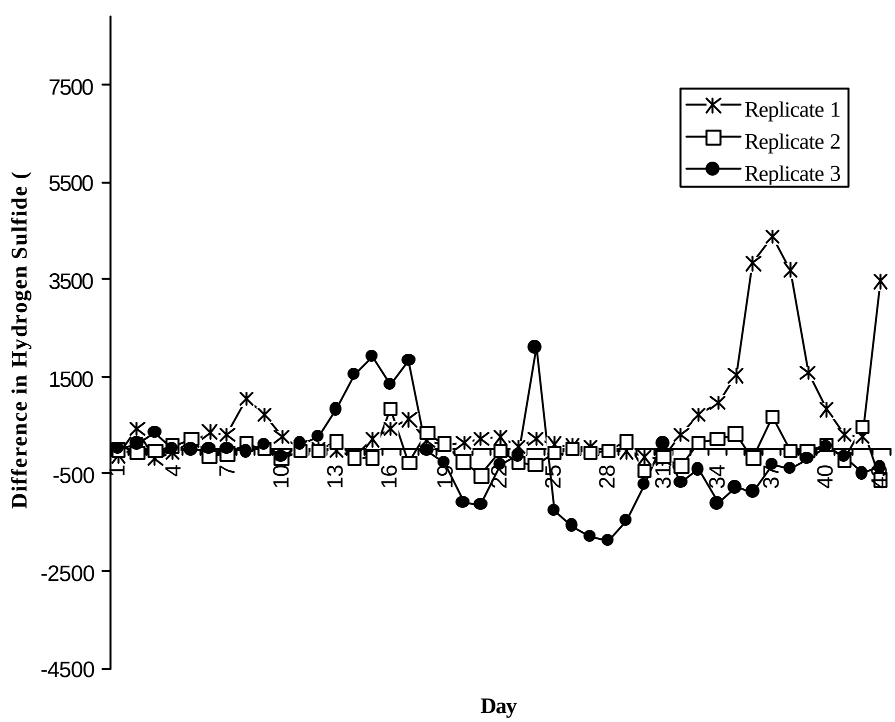
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **AgriKlenz Plus**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	604 ± 144	none	none
Odor Intensity		3.4 ± 0.2	none	none
Odor Offensiveness		-5.9 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1485 ± 113	**34% increase**	**95%**
Ammonia (ppm)		98.8 ± 1.6	**6% decrease**	**95%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		7.0 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8659 ± 403	**8% increase**	**75%**
Ammonia (ppm)		6523 ± 149	none	none
Phosphorus (ppm)	Manure	1932 ± 59	none	none
Potassium (ppm)		3014 ± 98	none	none
Chemical Oxygen Demand (g/L)		89 ± 10	**14% decrease**	**75%**
Acetic Acid (mM/L)		184.8 ± 10.7	none	none
Propionic Acid (mM/L)		49.8 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	15.1 ± 0.5	none	none
Butyric Acid (mM/L)		49.4 ± 1.7	none	none
Isovaleric Acid (mM/L)		22.7 ± 8.0	**32% decrease**	**75%**
Valeric Acid (mM/L)		2.9 ± 0.2	**7% increase**	**75%**
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.07 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.03 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **AgriKlenz Plus** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **AgriKlenz Plus** and Untreated Columns by Replicate



Alken Clear-Flo®

Pheonix Processes, Inc.
33405 Clear Pond Rd.
Shawnee, OK 74801
405/878-9400 or
1-877/976-9400 phone
405/878-8908 fax

e-mail address: 4phoenix@ionet.net
website: www.phoenixprocesses.com

TECHNOLOGY DESCRIPTION: Bacteria and enzyme

Alken Clear-Flo® is a concentrated dry blend of specially adapted strains of bacteria and other ingredients. Alken Clear-Flo® is ideally suited for use in holding tanks, manure pits, drainage systems and lagoons. This product has been specially balanced for the C/N ratio of swine manure, to produce a more usable fertilizer that will be better utilized by plants.

PRODUCT APPLICATION RATE:

Apply 13 lbs of Alken Clear-Flo® and 5 lbs of ALKEN® 895, per week per 6000 gallons manure until improvement in odor and consistency is achieved; thereafter for each 6000 gallons manure, apply monthly 5 lbs of Alken Clear-Flo® plus 5 lbs of ALKEN® 895.

RETAIL PRICE (Year 2001):

ALKEN ENZ-ODOR® 5

25 lb plastic pail	$144.92
50 lb fiber drum	$283.85
500 lb bulk bin	$2560.62

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in ammonia concentration
	-decrease in hydrogen sulfide concentration

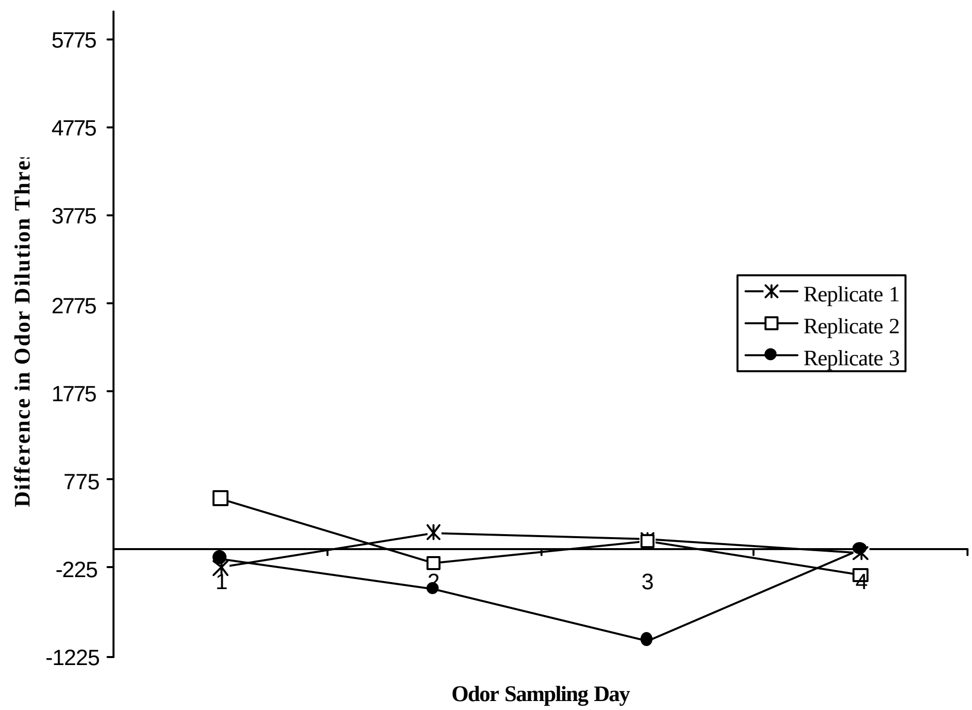
75% Certainty

AIRSPACE	-decrease in odor dilution threshold
MANURE	-increase in isovaleric acid concentration
	-decrease in pH, and chemical oxygen demand

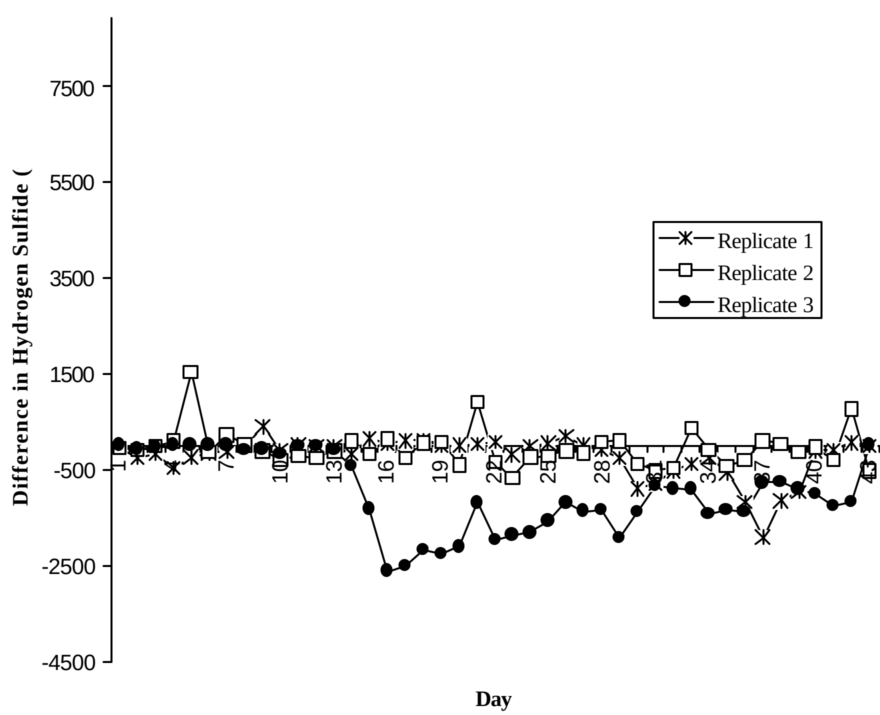
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Alken Clear-Flo®**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	565 ± 144	**27% decrease**	**75%**
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.6 ± 0.3	none	none
Hydrogen Sulfide (ppb)		587 ± 113	**47% decrease**	**95%**
Ammonia (ppm)		109.9 ± 1.6	**4% increase**	**95%**
pH	Manure	7.1 ± 0.04	**1% decrease**	**75%**
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.1 ± 0.03	none	none
Total Nitrogen (ppm)		8262 ± 403	none	none
Ammonia (ppm)		6529 ± 149	none	none
Phosphorus (ppm)	Manure	1848 ± 59	none	none
Potassium (ppm)		2896 ± 98	none	none
Chemical Oxygen Demand (g/L)		122 ± 10	**18% increase**	**75%**
Acetic Acid (mM/L)		167.5 ± 10.7	none	none
Propionic Acid (mM/L)		45.8 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.5 ± 0.5	none	none
Butyric Acid (mM/L)		49.9 ± 1.7	none	none
Isovaleric Acid (mM/L)		45.9 ± 8.0	**37% increase**	**75%**
Valeric Acid (mM/L)		2.8 ± 0.2	none	none
Phenol (g/L)		0.04 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.07 ± 0.02	none	none
Indole (g/L)		0.03 ± 0.02	none	none
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Alken Clear-Flo**[R]
and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Alken Clear-Flo**[R]
and Untreated Columns by Replicate



AWL-80

NatRx, Inc.
203 S. Main
Muleshoe, TX 79347
877/NAT-RX4U phone
806/272-5745 phone
806/272-3799 fax

TECHNOLOGY DESCRIPTION: Bacteria

NatRx has developed a system that utilizes a combination of a biocatalyst and microbial agents augmented with sprinkling for aeration. AWL-80 is recommended to be used two fold. First as an inoculate followed by daily maintenance treatments. Sprinkling is necessary to induce oxygen into the lagoon and must be installed prior to any treatment with the product.

PRODUCT APPLICATION RATE:

Inoculation with AWL-80 should be at the rate of 10 to 20 gallons per millions gallons of lagoon volume based on lagoon conditions. The daily maintenance treatments will be 7 to 10 ounces of AWL-80 per million gallons of lagoon volume.

RETAIL PRICE (Year 1999):

$60.00 per gallon

RESEARCH RESULTS

95% Certainty

AIRSPACE	-decrease in ammonia concentration
MANURE	-decrease in manure ammonia content

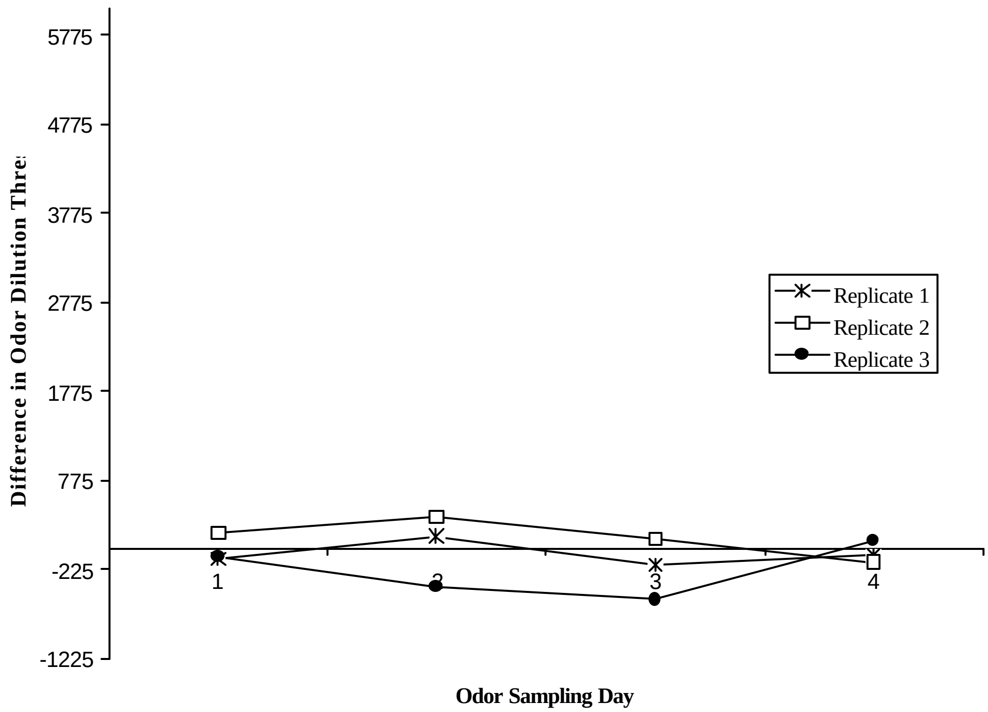
75% Certainty

MANURE	-decrease in isobutyric acid and indole concentrations

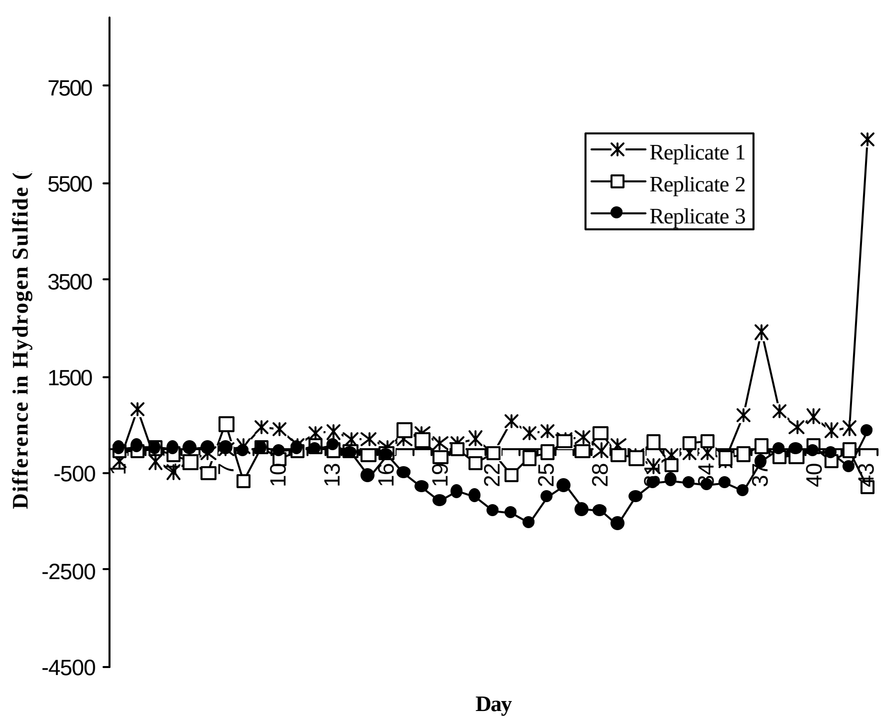
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **AWL-80**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	648 ± 144	none	none
Odor Intensity		3.2 ± 0.2	none	none
Odor Offensiveness		-5.7 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1132 ± 113	none	none
Ammonia (ppm)		94.3 ± 1.6	**10% decrease**	**95%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8264 ± 403	none	none
Ammonia (ppm)		6339 ± 149	**5% decrease**	**95%**
Phosphorus (ppm)	Manure	1921 ± 59	none	none
Potassium (ppm)		2931 ± 98	none	none
Chemical Oxygen Demand (g/L)		92 ± 10	none	none
Acetic Acid (mM/L)		177.7 ± 10.7	none	none
Propionic Acid (mM/L)		47.4 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.0 ± 0.5	**7% decrease**	**75%**
Butyric Acid (mM/L)		48.6 ± 1.7	none	none
Isovaleric Acid (mM/L)		35.0 ± 8.0	none	none
Valeric Acid (mM/L)		2.7 ± 0.2	none	none
Phenol (g/L)		0.06 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.10 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **AWL-80** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **AWL-80** and Untreated Columns by Replicate



Biocharge Dry

Biotal, Inc.
6595 Edenvale Blvd., Suite 155
Eden Prairie, MN 55346
952/934-1105 phone
952/934-0741 fax

TECHNOLOGY DESCRIPTION: Bacteria

Each gram of Biocharge is a proprietary formulation of selected strains of waste degrading bacteria. These strains have been chosen for their ability to produce enzymes to break down fiber, starch, fats, and protein residues, to grow in low oxygen conditions and to remain active across a range of temperatures.

The product is manufactured in 5-ounce water-soluble pouches, 100 pouches per pail.

PRODUCT APPLICATION RATE:

For the initial application use one pouch per 10,000 gallons of slurry in the storage system. The maintenance dose is one pouch per 200 animals per week (Sows/finishing hogs each count as one animal, feeder pigs 0.5 animals each, and nursery pigs 0.25 animals each).

RETAIL PRICE (Year 2001):

$6.95 per pouch

RESEARCH RESULTS

95% Certainty

AIRSPACE	-decrease in hydrogen sulfide and ammonia concentrations

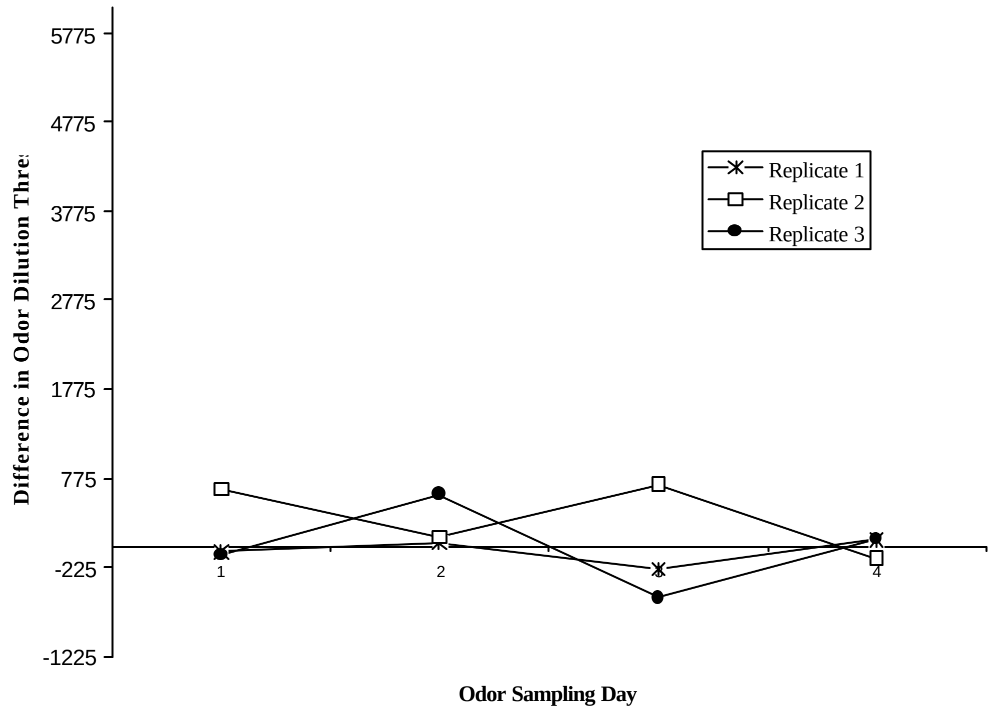
75% Certainty

MANURE	-increase in acetic acid concentration -decrease in chemical oxygen demand

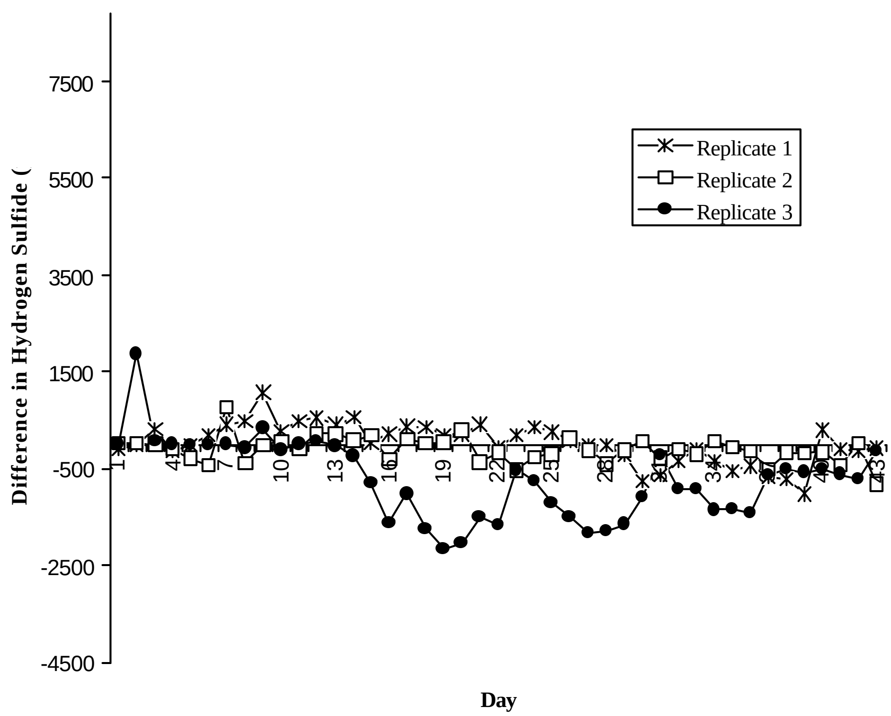
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Biocharge Dry**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	760 ± 144	none	none
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.6 ± 0.3	none	none
Hydrogen Sulfide (ppb)		694 ± 113	**37% decrease**	**95%**
Ammonia (ppm)		98.2 ± 1.6	**7% decrease**	**95%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7931 ± 403	none	none
Ammonia (ppm)		6553 ± 149	none	none
Phosphorus (ppm)	Manure	1975 ± 59	none	none
Potassium (ppm)		3132 ± 98	none	none
Chemical Oxygen Demand (g/L)		87 ± 10	**16% decrease**	**75%**
Acetic Acid (mM/L)		191.3 ± 10.7	**11% increase**	**75%**
Propionic Acid (mM/L)		48.4 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	15.4 ± 0.5	none	none
Butyric Acid (mM/L)		51.6 ± 1.7	none	none
Isovaleric Acid (mM/L)		24.0 ± 8.0	none	none
Valeric Acid (mM/L)		2.9 ± 0.2	none	none
Phenol (g/L)		0.06 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.09 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Biocharge Dry** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Biocharge Dry** and Untreated Columns by Replicate



Biological Manure Treatment (BMT)

K-Zyme Laboratories
3807 Brandon Rd., Suite 217
Roanoke, VA 24018
540/989-1216 phone

TECHNOLOGY DESCRIPTION: Bacteria

BMT works by a microbial mode of action. The product incorporates the action of stable, highly active microbial cultures specifically selected for rapid uptake of ammonia ions with non-toxic ingredients. A proprietary biological metabolic enhancer and nutrients are added to increase the rate of activity for both naturally occurring and bioaugmented microbes that biologically degrade the manure.

PRODUCT APPLICATION RATE:

New operations: Dilute 1 volume of BMT with 9 volumes of tap water. Mix well and spray evenly over the manure surface for interface. Apply weekly at the rate of 2 gallons of the diluted BMT solution per 5000 square foot area containing an approximate level of 2 inch deep of accumulated manure mass. Use commercial sprayer typically used in swine production facilities. Equipment must be free of bactericides, etc.

RETAIL PRICE (Year 2001):

$15.40 per 24 ounces
$192.50 per 2.5 gallons

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration
	-decrease in ammonia concentration
MANURE	-decrease in total nitrogen content

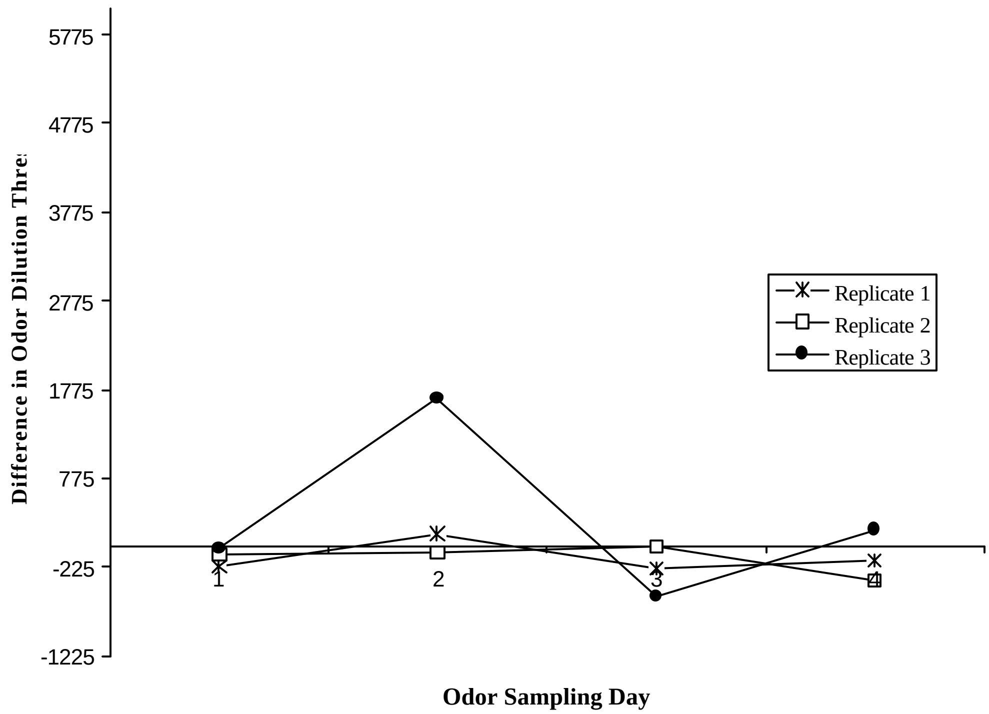
75% Certainty

AIRSPACE	-decrease in odor dilution threshold
MANURE	-increase in valeric acid concentration
	-decrease in phenol concentration

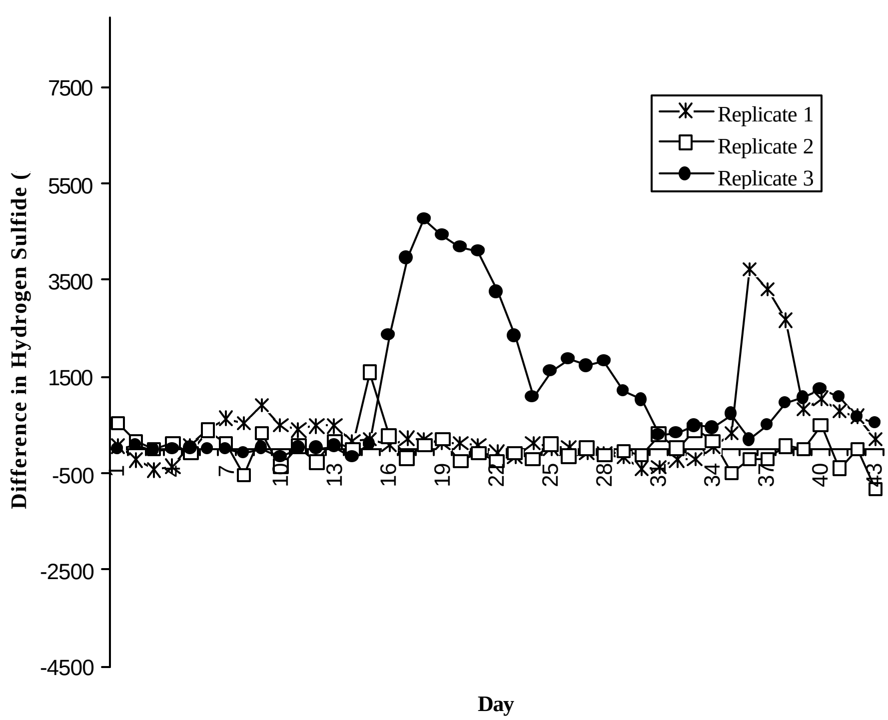
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Biological Manure Treatment**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	582 ± 144	**25% decrease**	**75%**
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.5 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1753 ± 113	**58% increase**	**95%**
Ammonia (ppm)		100.0 ± 1.6	**5% decrease**	**95%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7116 ± 403	**11% decrease**	**95%**
Ammonia (ppm)		6701 ± 149	none	none
Phosphorus (ppm)	Manure	1992 ± 59	none	none
Potassium (ppm)		2849 ± 98	none	none
Chemical Oxygen Demand (g/L)		92 ± 10	none	none
Acetic Acid (mM/L)		184.1 ± 10.7	none	none
Propionic Acid (mM/L)		49.0 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.7 ± 0.5	none	none
Butyric Acid (mM/L)		49.7 ± 1.7	none	none
Isovaleric Acid (mM/L)		35.6 ± 8.0	none	none
Valeric Acid (mM/L)		3.0 ± 0.2	**11% increase**	**75%**
Phenol (g/L)		0.04 ± 0.01	**20% decrease**	**75%**
para-Cresol (g/L)	Manure	0.05 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Biological Manure Treatment** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Biological Manure Treatment** and Untreated Columns by Replicate



BIO-MAX Biosystem

RK Industries, Inc.
BIOSTAR
1039 State St., Suite 203
P.O. Box 803
Bettendorf, IA 52722
319/359-9500 phone
319/359-9555 fax

TECHNOLOGY DESCRIPTION: Bacteria, chemical and enzyme

A combination of biological products formulated to address odor and solids digestion, whether in a deep pit, basin, lagoon, or push-off type of manure handling systems. The goal has been to combine products that are compatible with each other and create a synergism.

PRODUCT APPLICATION RATE:

Application rates are computed in gallons of influent and by the number of animals present. We determine the amount required by evaluating the content of the storage unit into 50,000 gallon amounts and use BIO-MAX in predetermined quantities. Once the shock treatment has been initiated, it is necessary only to do maintenance treatments thereafter as long as a portion of the biosystem treated manure is retained during pump-out (about 8 inches).

The shock treatment cost $330.00 per 100,000 gallons manure.

RETAIL PRICE (Year 2001):

BIO-MAX Biosystem

Bio Bac X	$29.95 per pound
Micro-Boost ™	$40.00 per 3 gallons
Biozyme	$75.00 per liter

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration

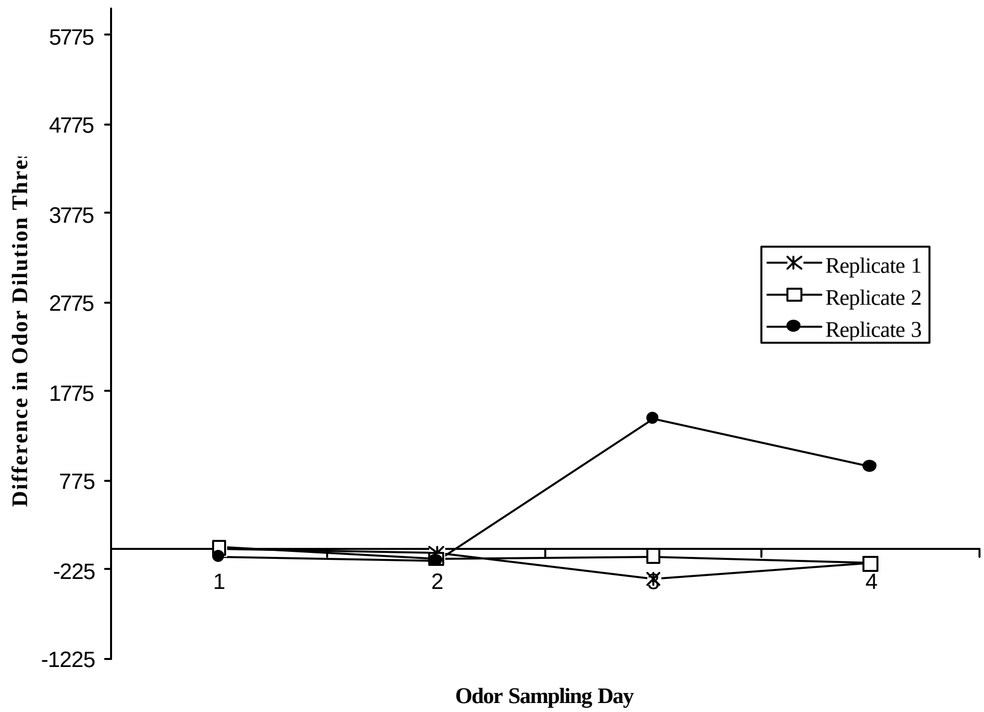
75% Certainty

AIRSPACE	-increase in odor dilution threshold
MANURE	-decrease in total nitrogen, manure ammonia contents, and butyric acid, isovaleric acid, valeric acid, phenol, and indole concentrations

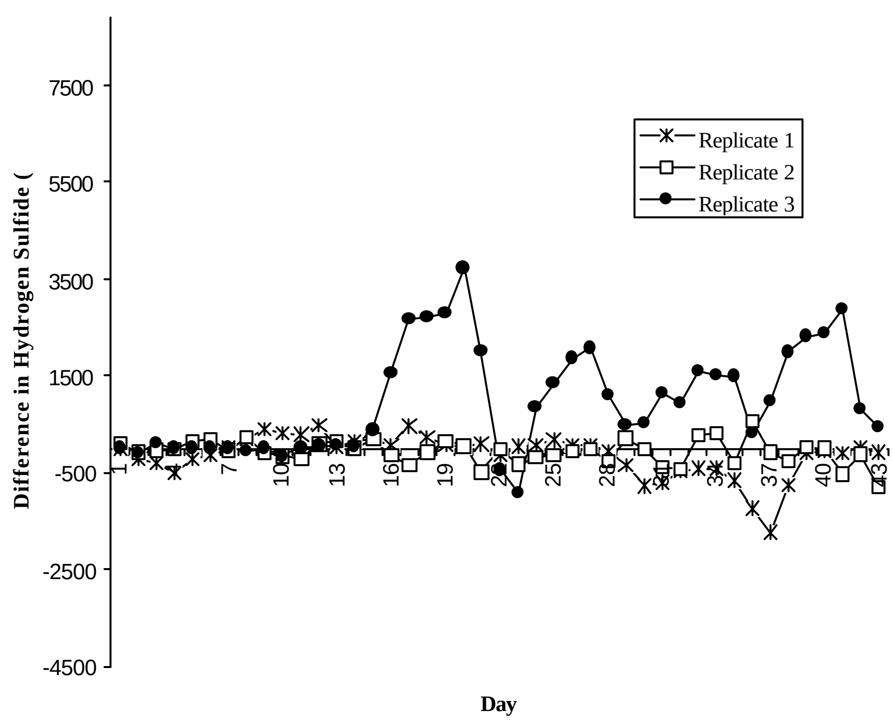
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **BIO-MAX Biosystem**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	1048 ± 144	**36% increase**	**75%**
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.8 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1610 ± 113	**45% increase**	**95%**
Ammonia (ppm)		103.8 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.8 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7167 ± 403	**11% decrease**	**75%**
Ammonia (ppm)		6363 ± 149	**5% decrease**	**75%**
Phosphorus (ppm)	Manure	1823 ± 59	none	none
Potassium (ppm)		2853 ± 98	none	none
Chemical Oxygen Demand (g/L)		99 ± 10	none	none
Acetic Acid (mM/L)		165.5 ± 10.7	none	none
Propionic Acid (mM/L)		48.3 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.9 ± 0.5	none	none
Butyric Acid (mM/L)		47.2 ± 1.7	**5% decrease**	**75%**
Isovaleric Acid (mM/L)		22.2 ± 8.0	**34% decrease**	**75%**
Valeric Acid (mM/L)		2.5 ± 0.2	**7% decrease**	**75%**
Phenol (g/L)		0.04 ± 0.01	**20% decrease**	**75%**
para-Cresol (g/L)	Manure	0.05 ± 0.03	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **BIO-MAX Biosystem** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **BIO-MAX Biosystem** and Untreated Columns by Replicate



Conserve-N

IMC
100 S. Saunders Rd., Suite 300
Lake Forest, IL 60045-2561
847/739-1427 phone
847/739-1632 fax

website: www.imcfeed.com

TECHNOLOGY DESCRIPTION: Chemical

Conserve-N is the registered trade name for NBPT. It is N-(n-butyl) thiophosphoric triamide urease enzyme that converts urea to ammonia.

PRODUCT APPLICATION RATE:

Conserve-N should be applied to the manure surface weekly at a rate of 0.0097 ounces per gallon of liquid manure (128 ounces = 1 gallon).

RETAIL PRICE (Year 2001):

$150.00 per gallon

RESEARCH RESULTS

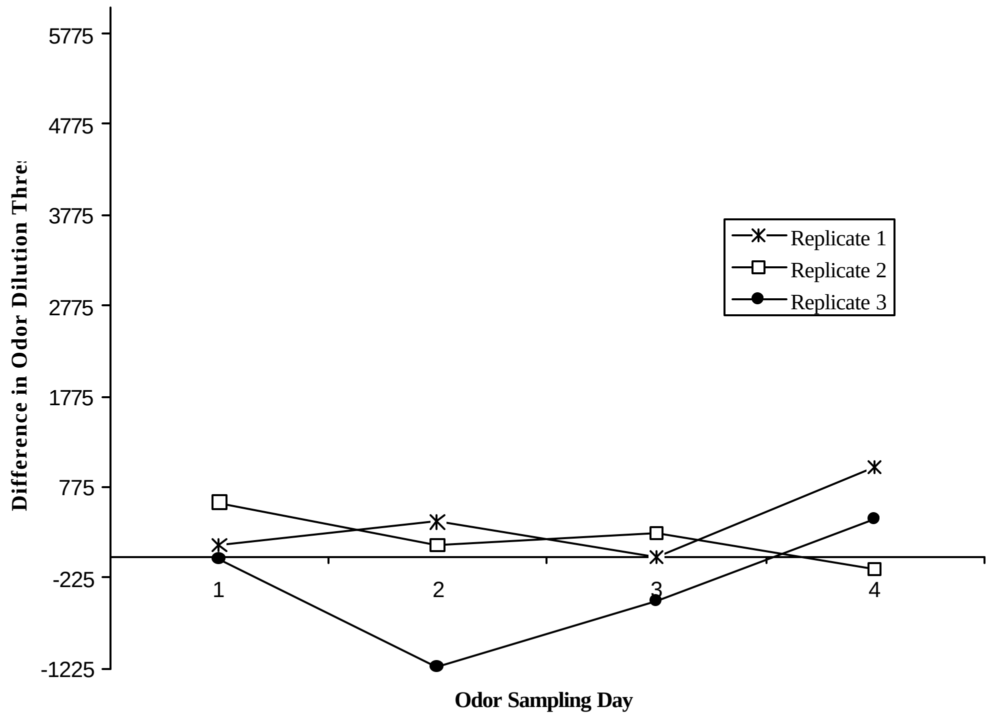
75% Certainty

MANURE	-increase in acetic acid, propionic acid, isobutyric acid, butyric acid, and valeric acid concentrations

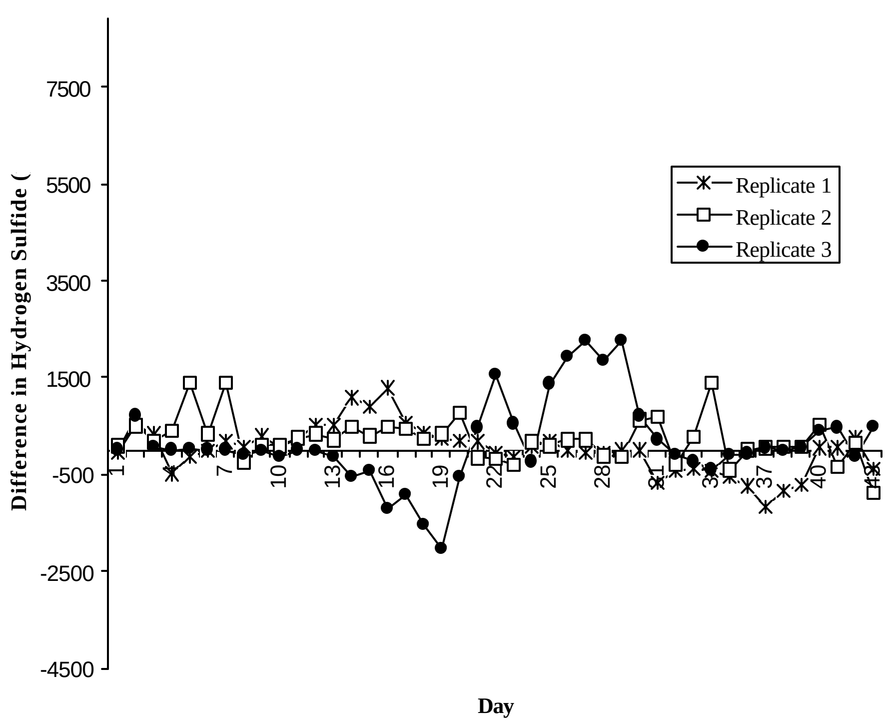
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Conserve-N**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	950 ± 144	none	none
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.5 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1049 ± 113	none	none
Ammonia (ppm)		103.4 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7850 ± 403	none	none
Ammonia (ppm)		6694 ± 149	none	none
Phosphorus (ppm)	Manure	1886 ± 59	none	none
Potassium (ppm)		3109 ± 98	none	none
Chemical Oxygen Demand (g/L)		92 ± 10	none	none
Acetic Acid (mM/L)		188.4 ± 10.7	**9% increase**	**75%**
Propionic Acid (mM/L)		50.3 ± 1.7	**5% increase**	**75%**
Isobutyric Acid (mM/L)	Manure	15.9 ± 0.5	**6% increase**	**75%**
Butyric Acid (mM/L)		52.4 ± 1.7	**5% increase**	**75%**
Isovaleric Acid (mM/L)		28.7 ± 8.0	none	none
Valeric Acid (mM/L)		2.9 ± 0.2	**7% increase**	**75%**
Phenol (g/L)		0.04 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.06 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.03 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Conserve-N** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Conserve-N** and Untreated Columns by Replicate



Digest 54 Plus

Alltech, Inc.
3031 Catnip Hill Pike
Nicholasville, KY 40356
859/885-9613 phone
859/885-6736 fax

TECHNOLOGY DESCRIPTION: Microbial

Digest 54 Plus comes in a powder form and in an all-natural product containing glycocomponents from the Yucca plant, enzymes and yeast for use as a direct treatment on inactive lagoons and lagoons not responding to normal treatments.

Extracted components of the Yucca plant and live yeast cells work in different ways to stimulate growth and activity of waste decomposition bacteria.

PRODUCT APPLICATION RATE:

Digest 54 Plus is a powder and can be applies by mixing in a slurry with water and applying as directed below or by injecting the powder into the liquid area below the lagoon surface. The initial dose requires the addition of Digest 54 Plus at a rate of one pound per 2,500 cubic feet. Follow with treatment two weeks later at four (4) ounces per 2,500 cubic feet. Maintenance applications are monthly at two (2) ounces per 2,500 cubic feet (2,500 cubic feet = 18,700 gallons).

RETAIL PRICE (Year 2001):

$9.50 per pound

RESEARCH RESULTS

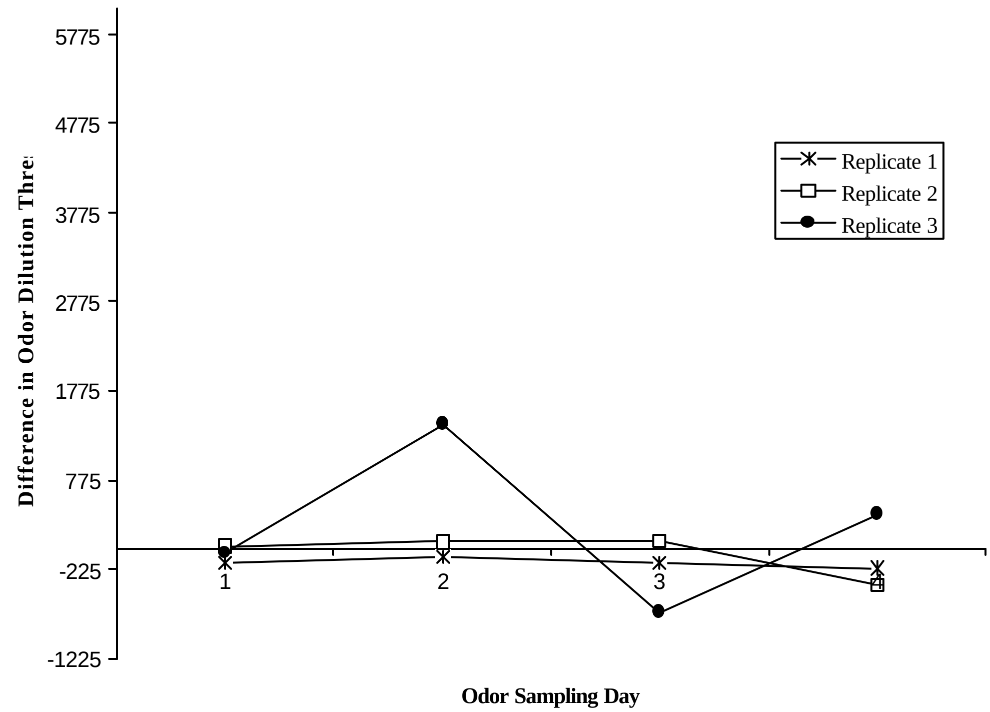
75% Certainty

AIRSPACE	-decrease in odor intensity, and ammonia concentration
MANURE	-decrease in indole concentration

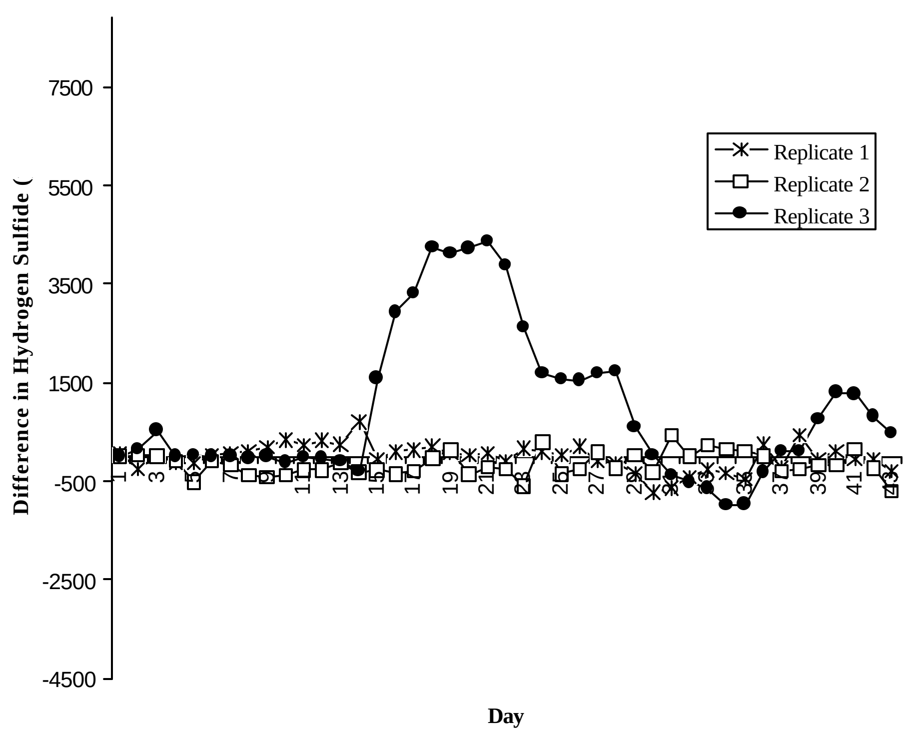
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Digest 54 Plus**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	601 ± 144	none	none
Odor Intensity		2.8 ± 0.2	**13% decrease**	**75%**
Odor Offensiveness		-5.4 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1251 ± 113	none	none
Ammonia (ppm)		102.8 ± 1.6	**2% decrease**	**75%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8221 ± 403	none	none
Ammonia (ppm)		6524 ± 149	none	none
Phosphorus (ppm)	Manure	1960 ± 59	none	none
Potassium (ppm)		2946 ± 98	none	none
Chemical Oxygen Demand (g/L)		95 ± 10	none	none
Acetic Acid (mM/L)		179.1 ± 10.7	none	none
Propionic Acid (mM/L)		49.4 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	15.1 ± 0.5	none	none
Butyric Acid (mM/L)		50.8 ± 1.7	none	none
Isovaleric Acid (mM/L)		37.2 ± 8.0	none	none
Valeric Acid (mM/L)		2.9 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.07 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.03 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Digest 54 Plus** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Digest 54 Plus** and Untreated Columns by Replicate



EM Waste Treatment

EM Technologies, Inc.
1802 West Grant Rd., Suite 122
Tucson, AZ 85745
630/293-1866 phone
630/293-4993 fax

e-mail address: scd@emtrading.com

TECHNOLOGY DESCRIPTION: Bacteria and enzyme

EM Waste Treatment can be manually added to the pit or incorporated into the swine house wash water.

PRODUCT APPLICATION RATE:

The prescribed application rate is 1.3 – 2.6 gallons of concentrate (diluted to 5-10% solution) to 24,000 gallons of pit manure. For the first month, add product weekly. Months 2-4 add product every other week. Thereafter add product once per month for the maintenance dose.

RETAIL PRICE (Year 1999):

$55.00 per gallon or $230.00 per 5 gallons of concentrate

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in odor dilution threshold, and hydrogen sulfide concentration -decrease in ammonia concentration
MANURE	-decrease in manure ammonia content

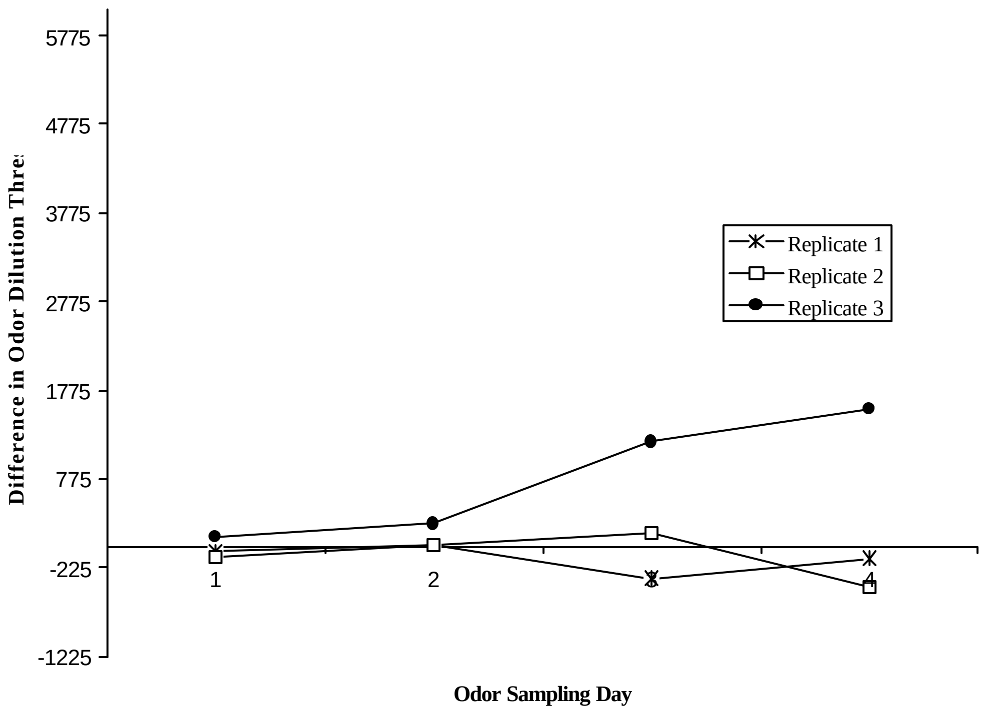
75% Certainty

AIRSPACE	-increase in odor intensity and odor offensiveness
MANURE	-increase in chemical oxygen demand -decrease in pH, dry matter content, and isobutyric acid, isovaleric acid, and indole concentrations

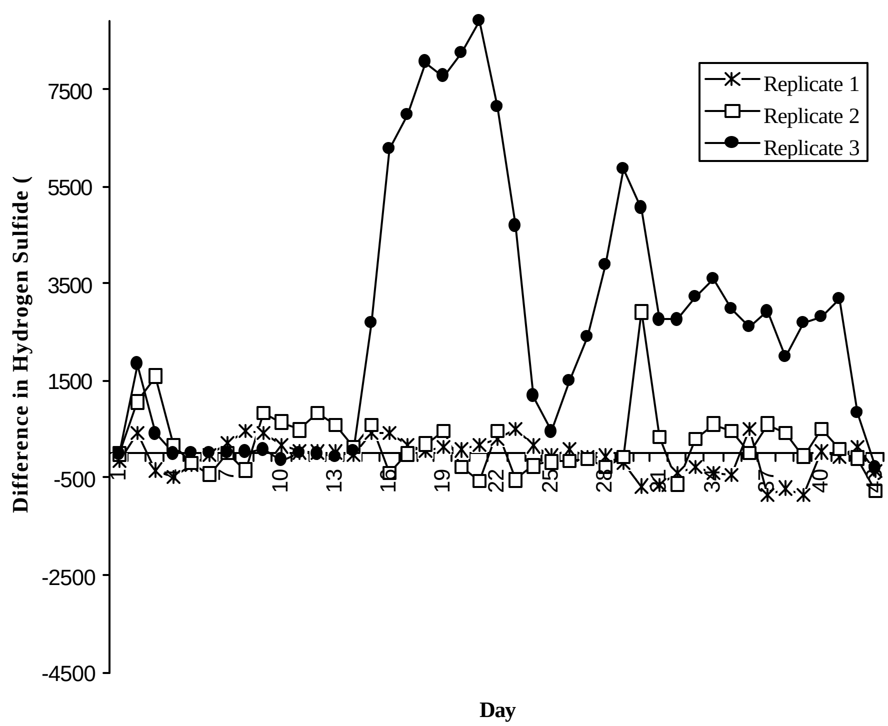
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **EM Waste Treatment**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	1106 ± 144	**43% increase**	**95%**
Odor Intensity		3.4 ± 0.2	**6% increase**	**75%**
Odor Offensiveness		-6.0 ± 0.3	**7% increase**	**75%**
Hydrogen Sulfide (ppb)		1885 ± 113	**70% increase**	**95%**
Ammonia (ppm)		89.4 ± 1.6	**15% decrease**	**95%**
pH	Manure	7.0 ± 0.04	**1% decrease**	**75%**
Dry Matter (%)		6.5 ± 0.2	**4% decrease**	**75%**
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8139 ± 403	none	none
Ammonia (ppm)		5967 ± 149	**11% decrease**	**95%**
Phosphorus (ppm)	Manure	1835 ± 59	none	none
Potassium (ppm)		3001 ± 98	none	none
Chemical Oxygen Demand (g/L)		123 ± 10	**19% increase**	**75%**
Acetic Acid (mM/L)		176.1 ± 10.7	none	none
Propionic Acid (mM/L)		47.8 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.1 ± 0.5	**6% decrease**	**75%**
Butyric Acid (mM/L)		49.2 ± 1.7	none	none
Isovaleric Acid (mM/L)		20.7 ± 8.0	**38% decrease**	**75%**
Valeric Acid (mM/L)		2.5 ± 0.2	none	none
Phenol (g/L)		0.04 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.07 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.03 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **EM Waste Treatment** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **EM Waste Treatment** and Untreated Columns by Replicate



GT-2000OC and BC-2000AF

G.T. Environmental Technology, Inc.
7801-C Thomson St.
Pearland, TX 77581
281/997-0200 phone
281/997-0201 fax

TECHNOLOGY DESCRIPTION: Bacteria, chemical and enzyme

GT-2000 is not a mask or perfume, but actually causes changes in bacterial activity. BC-2000 is a specialized microbial blend to provide performance over a range of organic waste related applications.

PRODUCT APPLICATION RATE:

Add one quart of each product per 50,000 gallons of wastewater per day.

RETAIL PRICE (Year 2001):

GT-2000OC Odor Control	$40.00 per gallon in 5 gallon buckets
BC-2000AF Microbes	$17.50 per gallon in 5 gallon buckets

<u>RESEARCH RESULTS</u>

95% Certainty

AIRSPACE	-decrease in hydrogen sulfide concentration
MANURE	-decrease in total nitrogen content

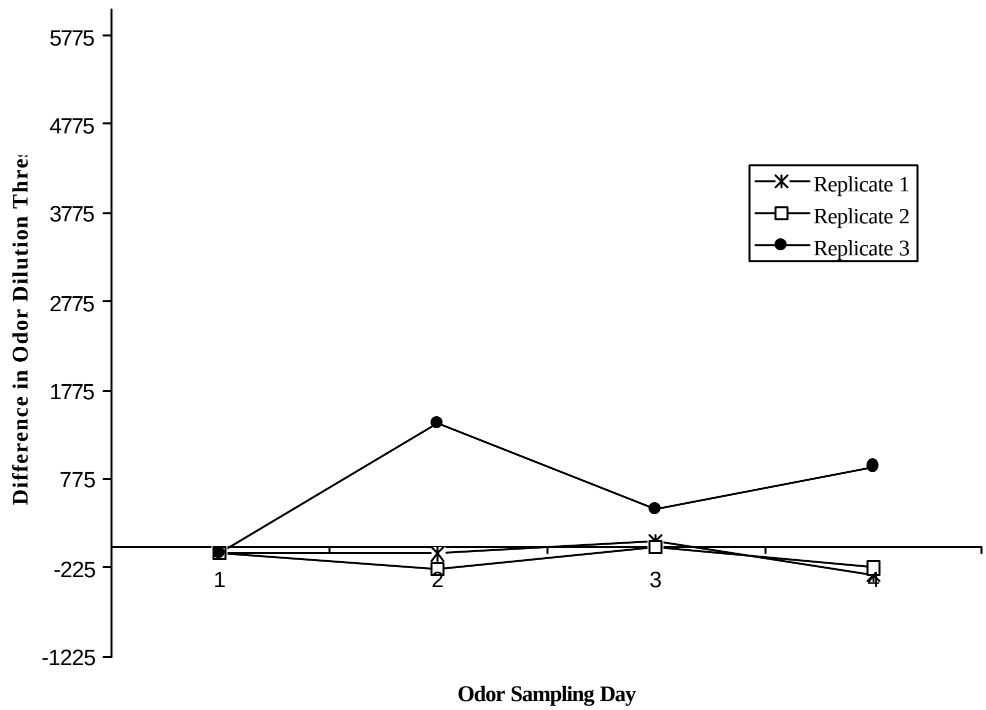
75% Certainty

AIRSPACE	-increase in ammonia concentration
MANURE	-increase in chemical oxygen demand, and isovaleric acid concentration

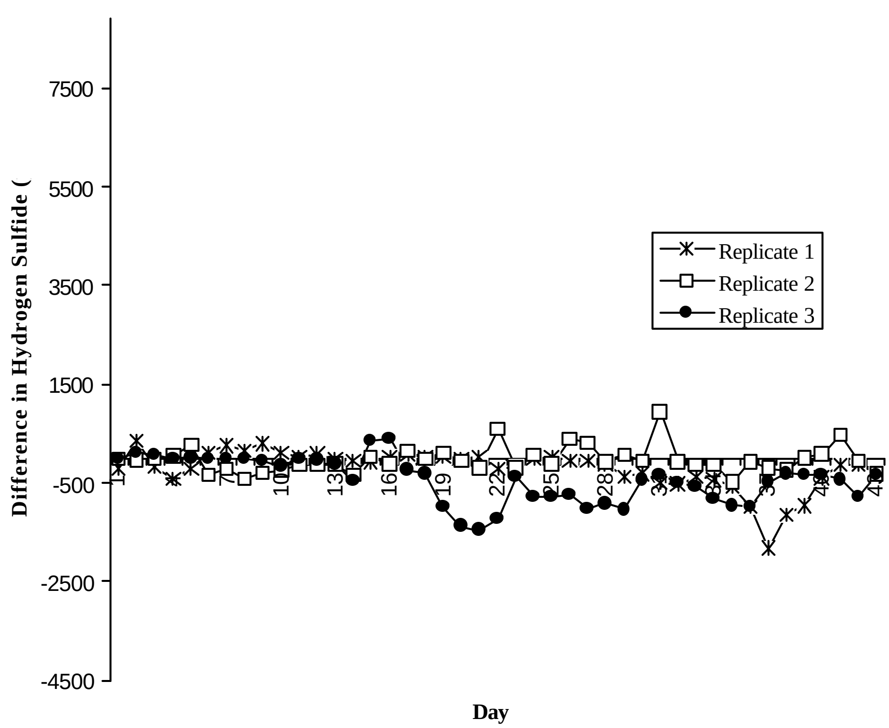
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **GT-2000OC & BC-2000AF**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	918 ± 144	none	none
Odor Intensity		3.3 ± 0.2	none	none
Odor Offensiveness		-5.2 ± 0.3	none	none
Hydrogen Sulfide (ppb)		733 ± 113	**34% decrease**	**95%**
Ammonia (ppm)		107.4 ± 1.6	**2% increase**	**75%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.1 ± 0.03	none	none
Total Nitrogen (ppm)		7046 ± 403	**12% decrease**	**95%**
Ammonia (ppm)		6544 ± 149	none	none
Phosphorus (ppm)	Manure	1928 ± 59	none	none
Potassium (ppm)		2955 ± 98	none	none
Chemical Oxygen Demand (g/L)		118 ± 10	**15% increase**	**75%**
Acetic Acid (mM/L)		181.0 ± 10.7	none	none
Propionic Acid (mM/L)		49.3 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.5 ± 0.5	none	none
Butyric Acid (mM/L)		52.2 ± 1.7	none	none
Isovaleric Acid (mM/L)		48.9 ± 8.0	**46% increase**	**75%**
Valeric Acid (mM/L)		2.8 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.07 ± 0.02	none	none
Indole (g/L)		0.03 ± 0.02	none	none
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **GT-2000OC & BC-2000AF** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **GT-2000OC & BC-2000AF** and Untreated Columns by Replicate



INHIBODOR®

Conklin Company, Inc.
Animal Products Division
551 Valley Park Drive
P.O. Box 155
Shakopee, MN 55379

Jen's Consumer Products
400 Commercial St.
Lacon, IL 61540
309/246-2275 phone
309/246-8456 phone
309/246-3117 fax

e-mail address: jen@Hardin-Inc.com

TECHNOLOGY DESCRIPTION: Plant derivative

Inhibodor® features a concentrated extract from the *Yucca schidigera* plant to bind ammonia. This easy-to-use concentrate is soluble in water and is non-corrosive to your facilities and equipment. Inhibodor® is so versatile it can be added to confinement pits and lagoons.

PRODUCT APPLICATION RATE:

The suggested application rate for the initial treatment is to dilute two ounces of Inhibodor® in at least one gallon of water and distribute over every 100 cubic feet of manure. For monthly maintenance treatments, dilute one-half to one ounce of Inhibodor® in at least one gallon of water and distribute over every 100 cubic feet of slurry added to the pit or lagoon monthly.

RETAIL PRICE (Year 2001):

$535.00 per four-gallon case

RESEARCH RESULTS

95% Certainty

AIRSPACE	-decrease in hydrogen sulfide concentration
MANURE	-increase in isobutyric acid concentration

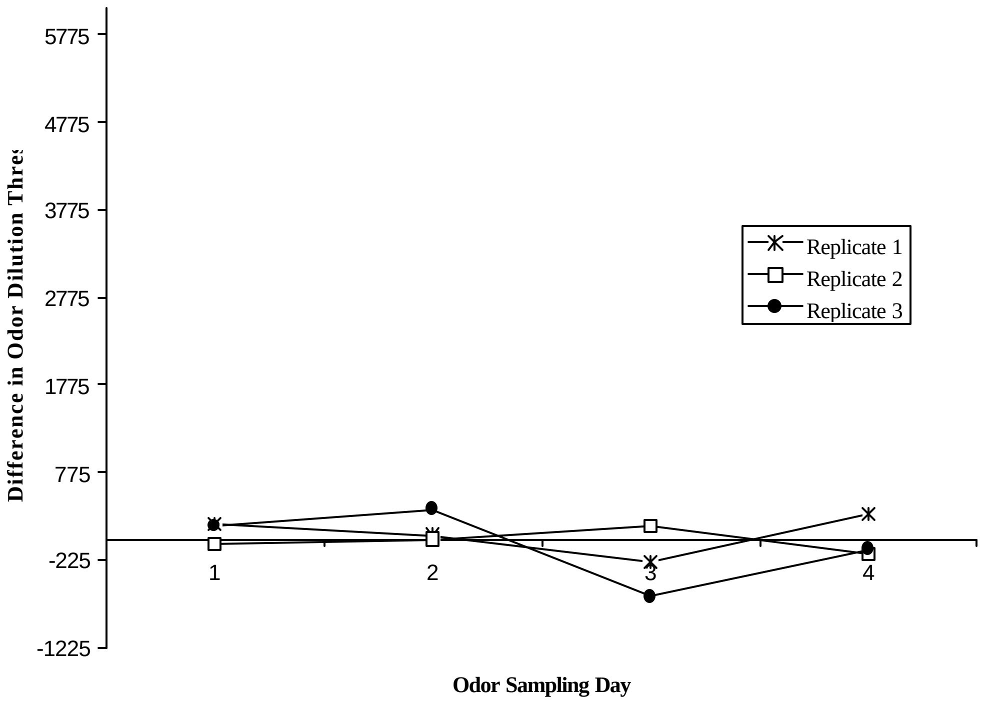
75% Certainty

AIRSPACE	-increase in odor intensity, odor offensiveness, and ammonia concentration
MANURE	-decrease in isovaleric acid concentration

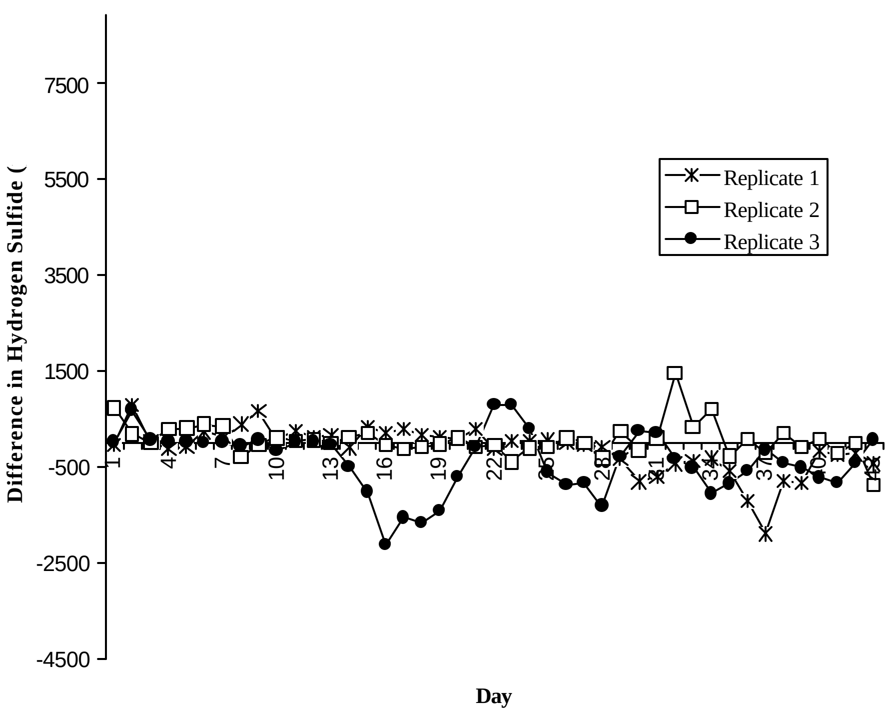
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **INHIBODOR®**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	654 ± 144	none	none
Odor Intensity		3.5 ± 0.2	**9% increase**	**75%**
Odor Offensiveness		-6.1 ± 0.3	**9% increase**	**75%**
Hydrogen Sulfide (ppb)		713 ± 113	**36% decrease**	**95%**
Ammonia (ppm)		107.4 ± 1.6	**2% increase**	**75%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ±0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8165 ± 403	none	none
Ammonia (ppm)		6530 ± 149	none	none
Phosphorus (ppm)	Manure	1973 ± 59	none	none
Potassium (ppm)		3159 ± 98	none	none
Chemical Oxygen Demand (g/L)		91 ± 10	none	none
Acetic Acid (mM/L)		171.5 ± 10.7	none	none
Propionic Acid (mM/L)		48.2 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	16.3 ± 0.5	**9% increase**	**95%**
Butyric Acid (mM/L)		51.3 ± 1.7	none	none
Isovaleric Acid (mM/L)		22.8 ± 8.0	**32% decrease**	**75%**
Valeric Acid (mM/L)		2.9 ± 0.2	none	none
Phenol (g/L)		0.04 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.06 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.03 ± 0.01	none	none

Differences in Odor Dilution Threshold between **INHIBODOR**[R] and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **INHIBODOR**[R] and Untreated Columns by Replicate



KOPROS®

Pennsylvania International Trade Corp.
234 North St.
Harrisburg, PA 17101
717/234-6449 phone
717/234-4739 fax

e-mail address: pitc@pa.net

TECHNOLOGY DESCRIPTION: Enzyme

Geolife® Bio Boost 200 Stock (KOPROS®) biological product (a product for bioremediation in the zootechnical field) is a combination of an activation substrate, a set of enzymes that vary depending on the product and its specific application, and an activator solution.

PRODUCT APPLICATION RATE:

One box of KOPROS® will treat approximately 10,000 square feet of building space.

RETAIL PRICE (Year 1999):

RESEARCH RESULTS

95% Certainty

MANURE	-increase in skatole concentration

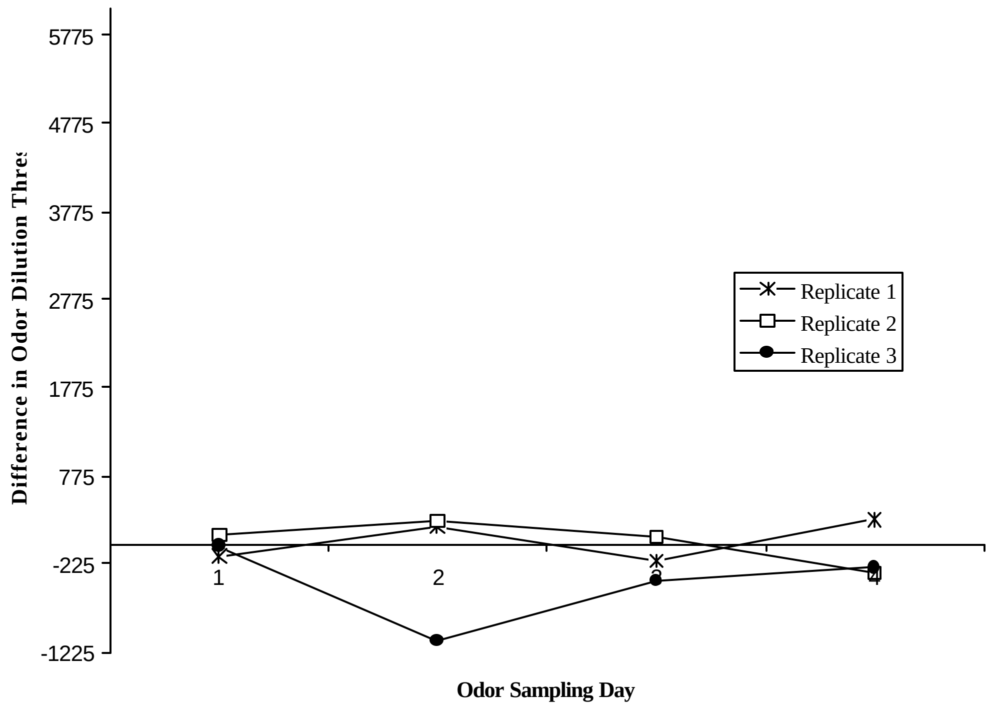
75% Certainty

MANURE	-increase in acetic acid concentration
	-decrease in chemical oxygen demand

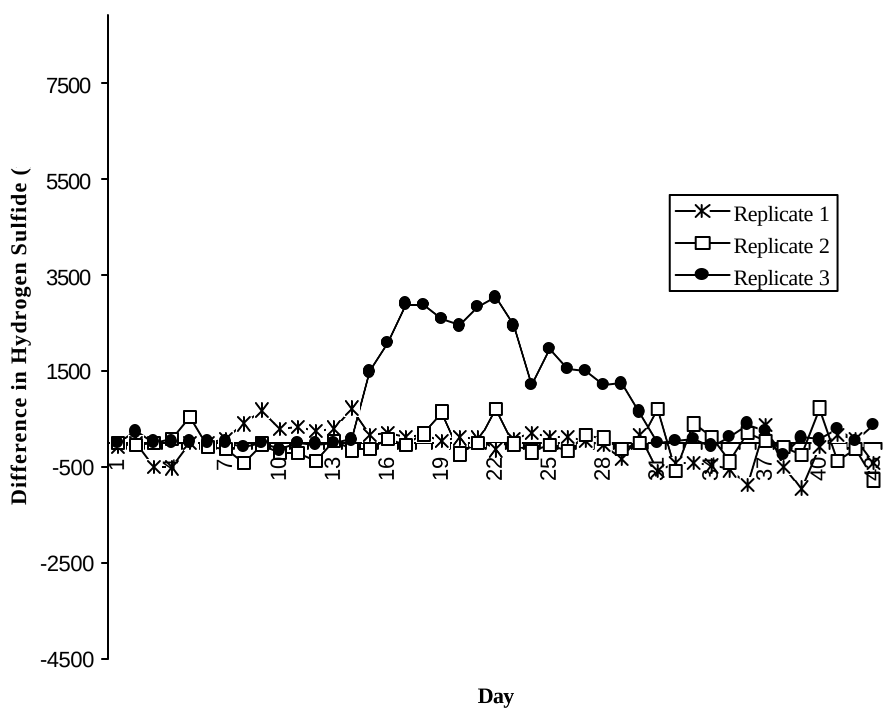
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **KOPROS®**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	633 ± 144	none	none
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.9 ± 0.3	none	none
Hydrogen Sulfide (ppb)		991 ± 113	none	none
Ammonia (ppm)		106.9 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		7.0 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8247 ± 403	none	none
Ammonia (ppm)		6753 ± 149	none	none
Phosphorus (ppm)	Manure	1913 ± 59	none	none
Potassium (ppm)		2950 ± 98	none	none
Chemical Oxygen Demand (g/L)		85 ± 10	**17% decrease**	**75%**
Acetic Acid (mM/L)		188.4 ± 10.7	**9% increase**	**75%**
Propionic Acid (mM/L)		49.9 + 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.9 + 0.5	none	none
Butyric Acid (mM/L)		49.6 + 1.7	none	none
Isovaleric Acid (mM/L)		29.8 + 8.0	none	none
Valeric Acid (mM/L)		2.8 + 0.2	none	none
Phenol (g/L)		0.05 + 0.01	none	none
para-Cresol (g/L)	Manure	0.10 + 0.02	none	none
Indole (g/L)		0.03 + 0.02	none	none
Skatole (g/L)		0.04 + 0.01	**100% increase**	**95%**

Differences in **Odor Dilution Threshold** between **KOPROS**[R] and
Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **KOPROS**[R] and
Untreated Columns by Replicate



Krystal Air™

Fischer Enterprises, Inc.
2415 Utah Ave.
Thor, IA 50591
515/378-3365 phone
515/378-3375 fax

TECHNOLOGY DESCRIPTION: Chemical

Krystal Air utilizes a complex combination of both chemical and biophysical reactions. The product can be diluted down with clean water and added to the manure storage.

PRODUCT APPLICATION RATE:

The suggested dosage is one gallon Krystal Air concentrate to 75,000 gallons of manure. It is preferred to start applying the product when the pit is empty. Apply product as needed.

RETAIL PRICE (Year 2001):

$60.00 per gallon of concentrate

RESEARCH RESULTS

95% Certainty

AIRSPACE	-decrease in ammonia concentration
MANURE	-increase in propionic acid concentration

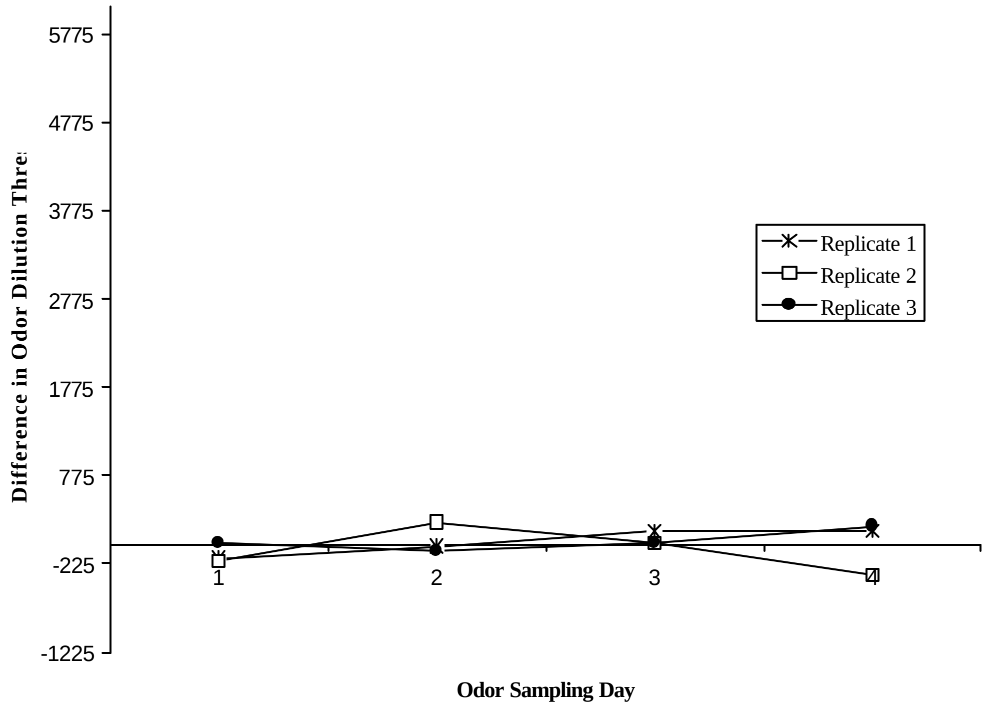
75% Certainty

MANURE	-increase in acetic acid concentration
	-decrease in indole concentration

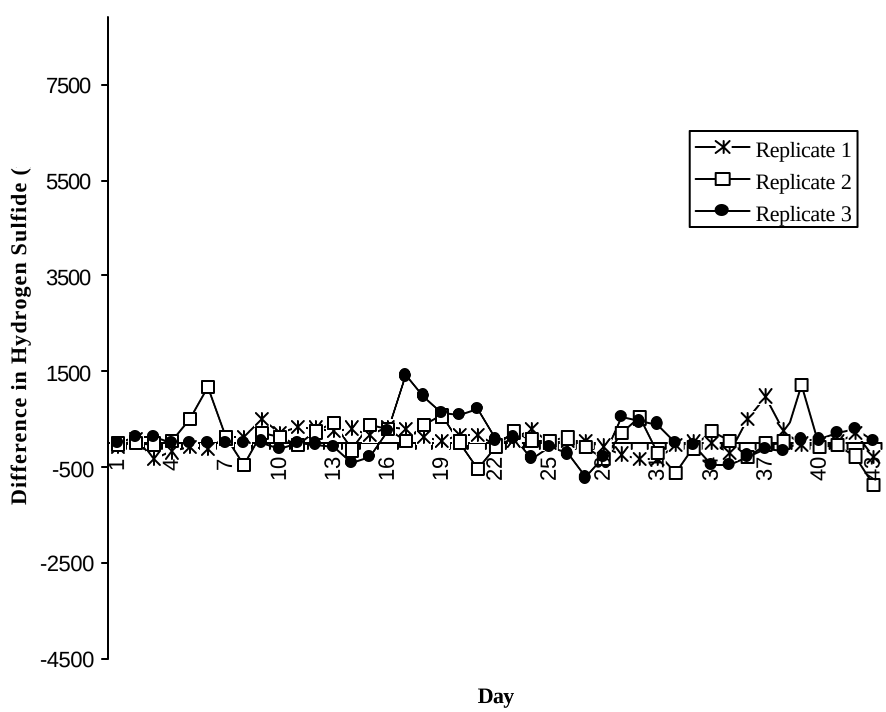
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Krystal Air™**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	798 ± 144	none	none
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.7 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1171 ± 113	none	none
Ammonia (ppm)		97.7 ± 1.6	**7% decrease**	**95%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8372 ± 403	none	none
Ammonia (ppm)		6622 ± 149	none	none
Phosphorus (ppm)	Manure	1943 ± 59	none	none
Potassium (ppm)		2925 ± 98	none	none
Chemical Oxygen Demand (g/L)		95 ± 10	none	none
Acetic Acid (mM/L)		192.5 ± 10.7	**11% increase**	**75%**
Propionic Acid (mM/L)		52.3 ± 1.7	**9% increase**	**95%**
Isobutyric Acid (mM/L)	Manure	15.6 ± 0.5	none	none
Butyric Acid (mM/L)		51.8 ± 1.7	none	none
Isovaleric Acid (mM/L)		24.1 ± 8.0	none	none
Valeric Acid (mM/L)		2.8 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.05 ± 0.02	none	none
Indole (g/L)		0.01 ± 0.02	**75% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Krystal Air™**
and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Krystal Air™** and
Untreated Columns by Replicate



Lagoon Aid

Biotac Agri - Life Systems
1919 South 40th St. #106
Lincoln, NE 68506
402/489-2411 phone & fax

TECHNOLOGY DESCRIPTION: Bacteria and enzyme

Lagoon Aid is based on biological and organic technologies.

PRODUCT APPLICATION RATE:

One-gallon of product per 150,000 gallon capacity of lagoon or one-gallon of product per 75,000 gallon capacity of pit. An additional one-gallon per pit or lagoon for each 200,000 estimated cubic feet of solid waste. Treat every other week.

RETAIL PRICE (Year 2001):

$80.00 per gallon

RESEARCH RESULTS

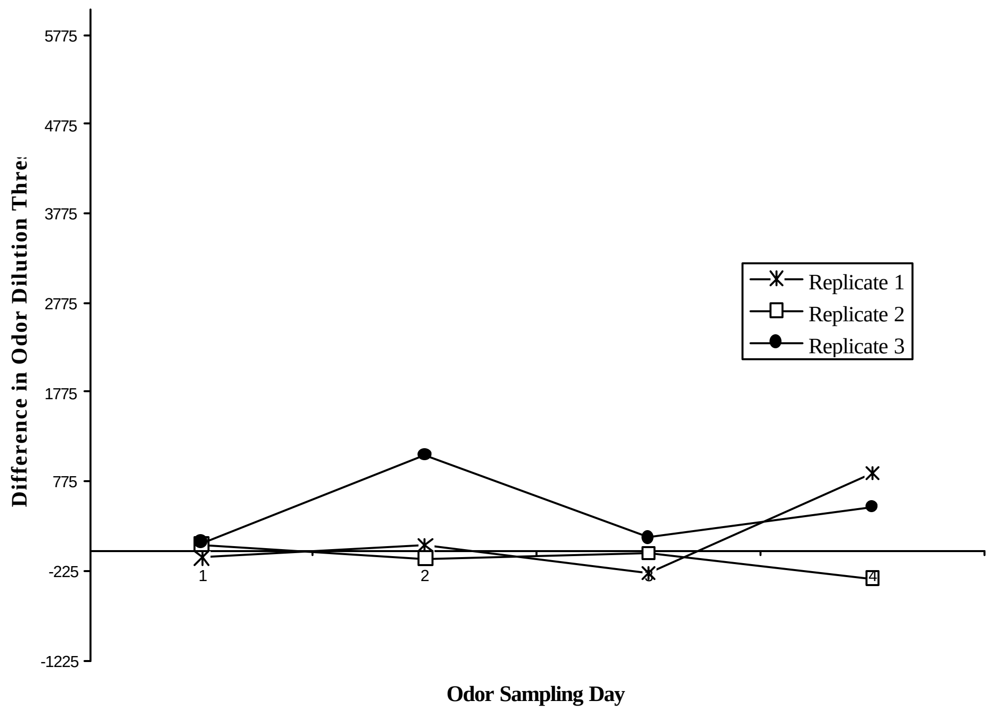
75% Certainty

AIRSPACE	-increase in hydrogen sulfide and ammonia concentrations
MANURE	-increase in ash content
	-decrease in dry matter content, and propionic acid, butyric acid, isovaleric acid, and indole concentrations

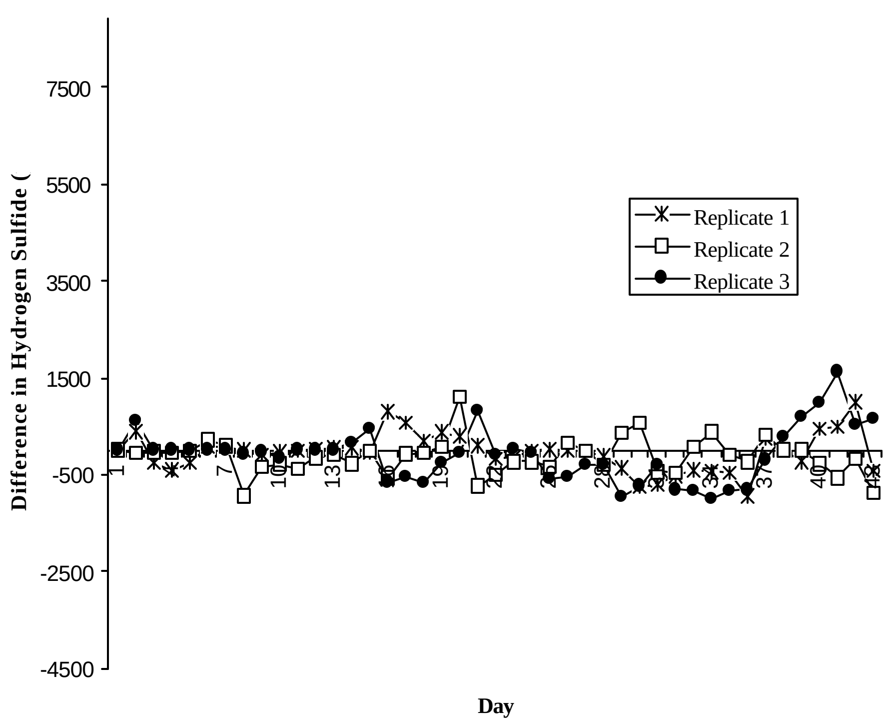
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Lagoon Aid**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	925 ± 144	none	none
Odor Intensity		3.2 ± 0.2	none	none
Odor Offensiveness		-5.5 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1276 ± 123	**15% increase**	**75%**
Ammonia (ppm)		107.9 ± 1.7	**3% increase**	**75%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.6 ± 0.2	**3% decrease**	**75%**
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7734 ± 403	none	none
Ammonia (ppm)		6603 ± 149	none	none
Phosphorus (ppm)	Manure	1843 ± 59	none	none
Potassium (ppm)		3106 ± 98	none	none
Chemical Oxygen Demand (g/L)		106 ± 10	none	none
Acetic Acid (mM/L)		178.7 ± 10.7	none	none
Propionic Acid (mM/L)		44.6 ± 1.7	**7% decrease**	**75%**
Isobutyric Acid (mM/L)	Manure	14.4 ± 0.5	none	none
Butyric Acid (mM/L)		47.3 ± 1.7	**5% decrease**	**75%**
Isovaleric Acid (mM/L)		20.5 ± 8.0	**39% decrease**	**75%**
Valeric Acid (mM/L)		2.7 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.07 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Lagoon Aid** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Lagoon Aid** and Untreated Columns by Replicate



Manure Management Plus™

Cytozyme Laboratories, Inc.
134 South 700 West
Salt Lake City , UT 84104
800/654-1726 toll free
801/537-1312 fax

e-mail address: cytozyme@cytozyme.com

TECHNOLOGY DESCRIPTION: Bacteria, chemical and enzyme

Manure Management Plus™ is produced through a multistage fermentation process, using a complex nutrient medium to culture multiple strains of selected bacteria.

PRODUCT APPLICATION RATE:

The initial application rate applied to the manure storage is one gallon of product per 50,000 gallons of manure, followed by a maintenance dose of one gallon per 100,000 gallons of manure, weekly.

RETAIL PRICE (Year 2001):

$48.00 per gallon

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration
	-decrease in ammonia concentration
MANURE	-increase in para-cresol concentration
	-decrease in chemical oxygen demand

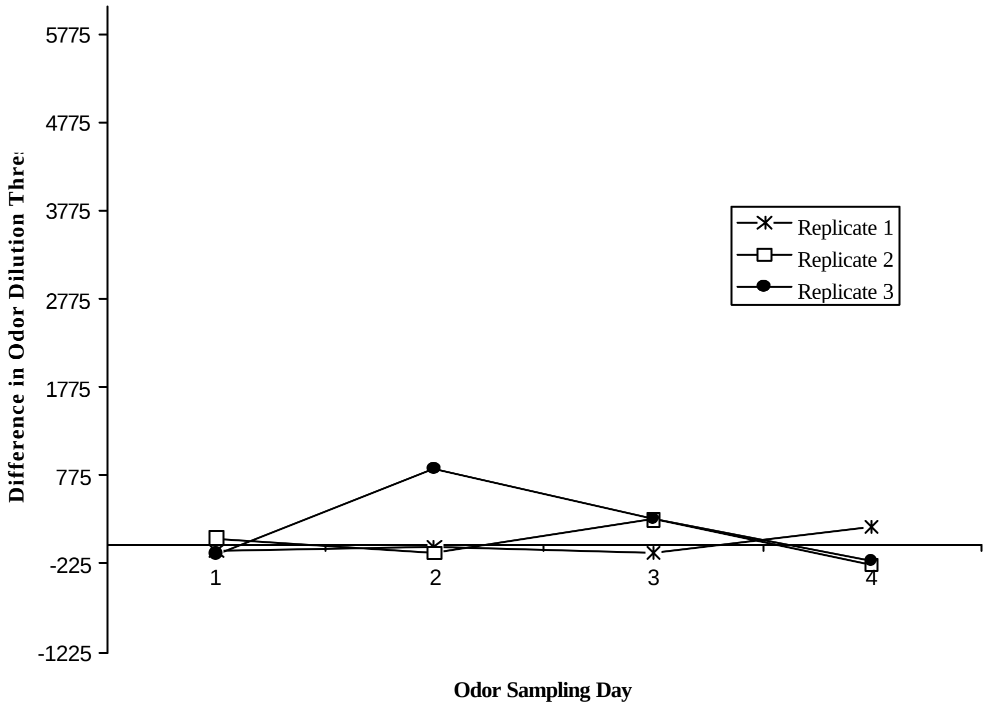
75% Certainty

AIRSPACE	-decrease in odor offensiveness
MANURE	-increase in acetic acid concentration
	-decrease in isovaleric acid and indole concentrations

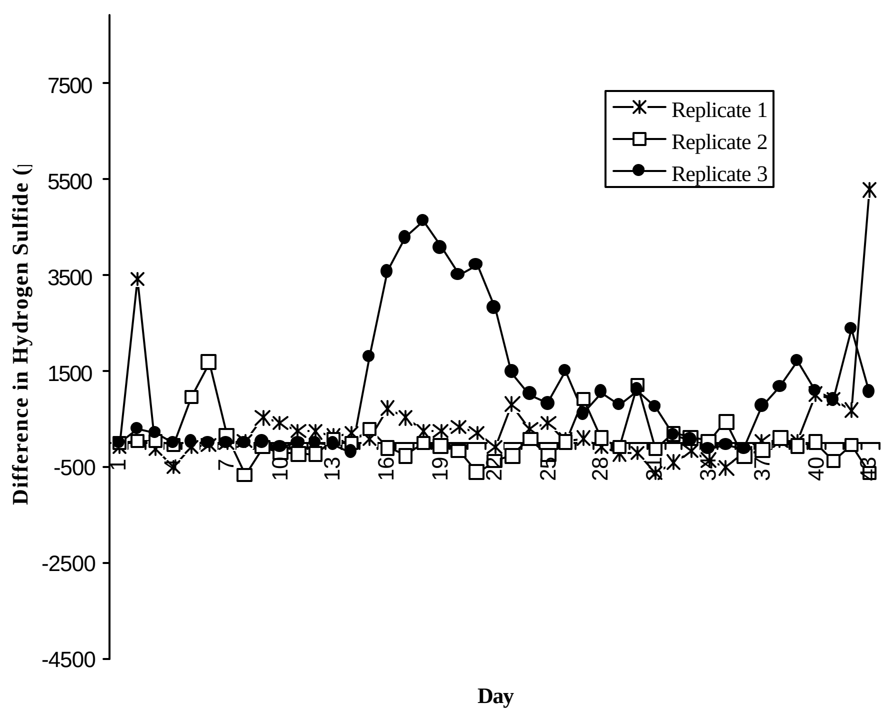
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Manure Management Plus™**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	810 ± 144	none	none
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.2 ± 0.3	**7% decrease**	**75%**
Hydrogen Sulfide (ppb)		1625 ± 113	**47% increase**	**95%**
Ammonia (ppm)		99.0 ± 1.6	**6% decrease**	**95%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		7.0 ± 0.2	none	none
Ash (%)		2.1 ± 0.03	none	none
Total Nitrogen (ppm)		8119 ± 403	none	none
Ammonia (ppm)		6581 ± 149	none	none
Phosphorus (ppm)	Manure	1953 ± 59	none	none
Potassium (ppm)		2882 ± 98	none	none
Chemical Oxygen Demand (g/L)		78 ± 10	**24% decrease**	**95%**
Acetic Acid (mM/L)		187.8 ± 10.7	**9% increase**	**75%**
Propionic Acid (mM/L)		48.8 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.5 ± 0.5	none	none
Butyric Acid (mM/L)		47.7 ± 1.7	none	none
Isovaleric Acid (mM/L)		23.1 ± 8.0	**31% decrease**	**75%**
Valeric Acid (mM/L)		2.6 ± 0.2	none	none
Phenol (g/L)		0.06 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.16 ± 0.03	**129% increase**	**95%**
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.03 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Manure Management Plus™** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Manure Management Plus™** and Untreated Columns by Replicate



MBA-S

Desert Microbial Products
2069 E. Carson
Tempe, AZ 85282-7405
480/839-8063 phone
480/838-7581 fax

TECHNOLOGY DESCRIPTION: Bacteria

MBA-S is a concentrated and specialized blend of bacteria, specifically selected and adopted to degrade swine manure and liquid waste. MBA-S comes in a small package that dissolves in liquids. Therefore, you just toss a package into the manure liquids.

PRODUCT APPLICATION RATE:

MBA-S is applied directly to the manure surface at a rate of one pack per 300 hogs/week.

RETAIL PRICE (Year 2001):

$4.70 per pack or $940 for a 200 count pail.

RESEARCH RESULTS

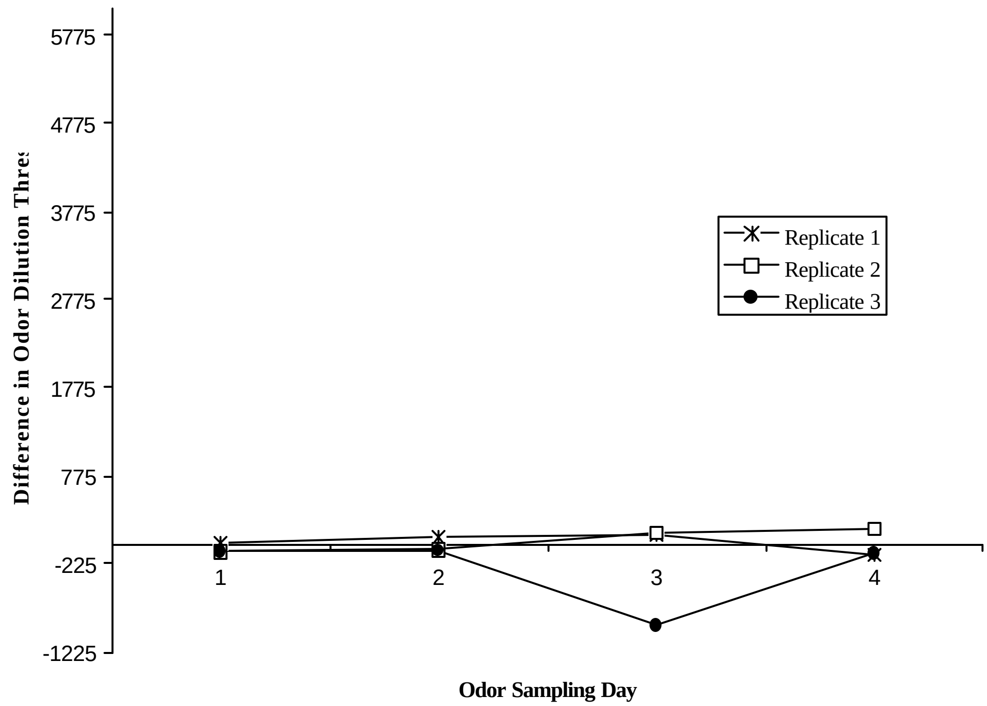
75% Certainty

AIRSPACE	-decrease in hydrogen sulfide, and ammonia concentrations
MANURE	-decrease in indole concentration

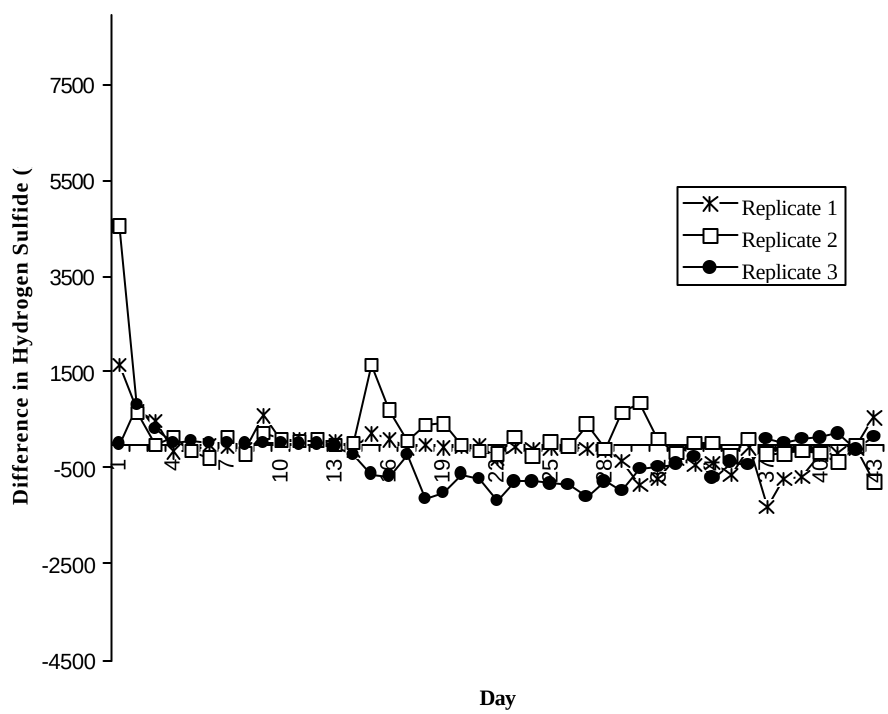
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **MBA-S**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	646 ± 144	none	none
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.7 ± 0.3	none	none
Hydrogen Sulfide (ppb)		893 ± 113	**19% decrease**	**75%**
Ammonia (ppm)		102.2 ± 1.6	**3% decrease**	**75%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7811 ± 403	none	none
Ammonia (ppm)		6629 ± 149	none	none
Phosphorus (ppm)	Manure	1978 ± 59	none	none
Potassium (ppm)		3128 ± 98	none	none
Chemical Oxygen Demand (g/L)		95 ± 10	none	none
Acetic Acid (mM/L)		178.6 ± 10.7	none	none
Propionic Acid (mM/L)		47.5 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	15.0 ± 0.5	none	none
Butyric Acid (mM/L)		50.6 ± 1.7	none	none
Isovaleric Acid (mM/L)		33.6 ± 8.0	none	none
Valeric Acid (mM/L)		2.7 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.06 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **MBA-S** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **MBA-S** and Untreated Columns by Replicate



MICROBE-LIFT

Ecological Laboratories, Inc.
215 N. Main St., P.O. Box 132
Freeport, NY 11520
516/379-3441 phone
800/645-2976 toll free
516/379-3632 fax

e-mail: ecolog1@aol.com
website: www.microbelift.com

TECHNOLOGY DESCRIPTION: Bacteria

MICROBE-LIFT has been produced by Ecological Laboratories for the past 13 years and is made from a formulation of many naturally occurring strains of bacteria that are found on our planet.

PRODUCT APPLICATION RATE:

Manure volume (gallons)	**1st Application**	**Next 4 weeks** (once per week)	**Maintenance** (once per month)
5,001-10,000	3 gallons	1 quart	1 quart
10,001-50,000	4 gallons	2 quarts	2 quarts
50,001-100,000	5 gallons	3 quarts	3 quarts
100,001-300,000	6 gallons	1 gallons	1 gallon
300,001-500,000	7 gallons	1½ gallons	1½ gallons
500,001-1,000,000	10 gallons	2 gallons	2 gallons
1,000,000-1,500,000	15 gallons	3 gallons	3 gallons

RETAIL PRICE (Year 2001):

$19.95 per gallon in 55 gallon drum

RESEARCH RESULTS

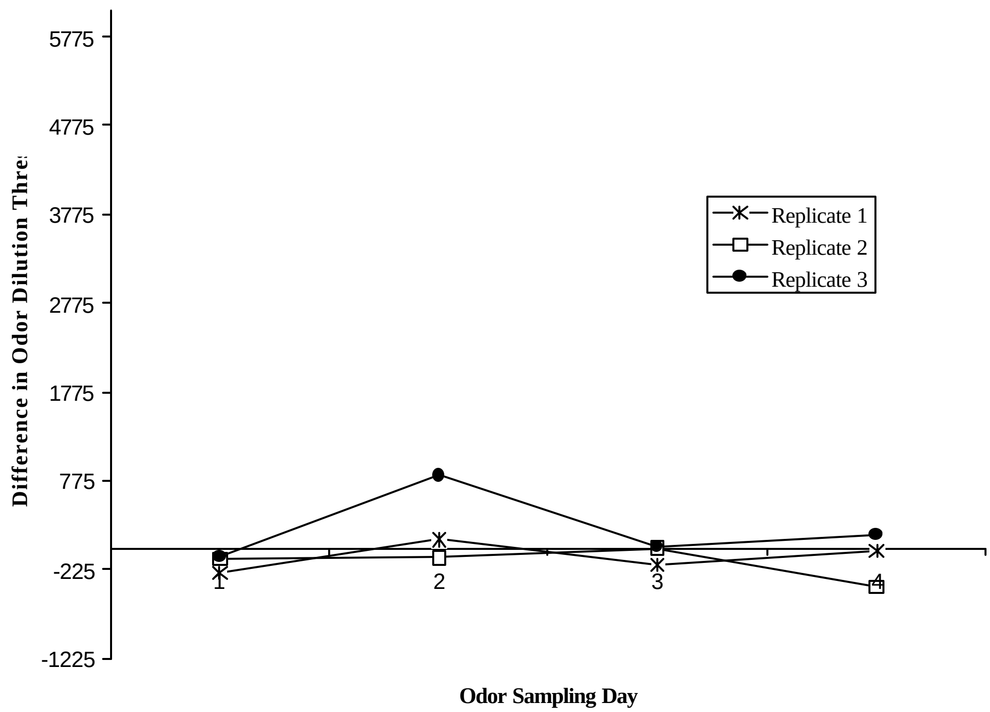
95% Certainty
AIRSPACE -increase in odor intensity, and hydrogen sulfide concentration

75% Certainty
MANURE -increase in acetic acid, propionic acid, and skatole concentrations
-decrease in isovaleric acid and indole concentrations

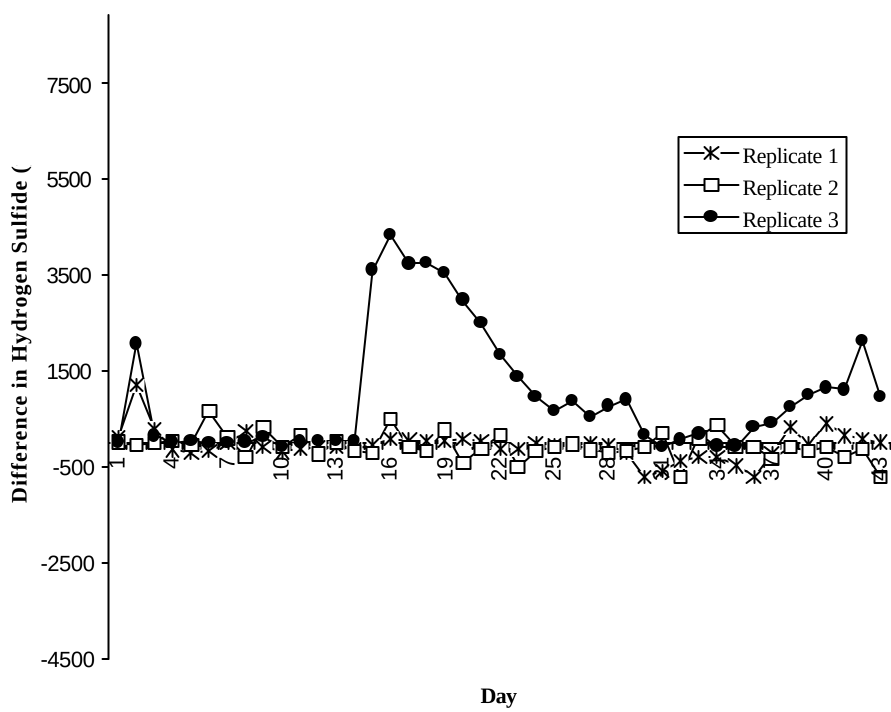
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **MICROBE-LIFT**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	702 ± 144	none	none
Odor Intensity		3.8 ± 0.2	**19% increase**	**95%**
Odor Offensiveness		-5.8 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1410 ± 113	**27% increase**	**95%**
Ammonia (ppm)		104.7 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8384 ± 403	none	none
Ammonia (ppm)		6846 ± 149	none	none
Phosphorus (ppm)	Manure	2034 ± 59	none	none
Potassium (ppm)		2796 ± 98	none	none
Chemical Oxygen Demand (g/L)		99.5 ± 10	none	none
Acetic Acid (mM/L)		193.7 ± 10.7	**12% increase**	**75%**
Propionic Acid (mM/L)		50.3 ± 1.7	**5% increase**	**75%**
Isobutyric Acid (mM/L)	Manure	15.5 ± 0.5	none	none
Butyric Acid (mM/L)		51.5 ± 1.7	none	none
Isovaleric Acid (mM/L)		22.3 ± 8.0	**34% decrease**	**75%**
Valeric Acid (mM/L)		2.8 ± 0.2	none	none
Phenol (g/L)		0.06 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.08 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.03 ± 0.01	**50% increase**	**75%**

Differences in **Odor Dilution Threshold** between **MICROBE-LIFT** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **MICROBE-LIFT** and Untreated Columns by Replicate



MUNOX®

Osprey Biotechnics
1833-A 57th Street
Sarasota, FL 34243
941/351-2700 phone
941/351-0026 fax

TECHNOLOGY DESCRIPTION: Bacteria

Munox® is a product comprised of non-pathogenic pseudomonads that have been isolated from various soil and water samples throughout the U.S. These bacteria are grown as single strains and then blended with other single pure culture strains after passing quality assurance.

PRODUCT APPLICATION RATE:

2.5 gallons of product per 7,500 gallons of manure added weekly. Frequency of application may vary.

LIST PRICE (Year 2001):

$23.40 per 2.5 gallons

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration

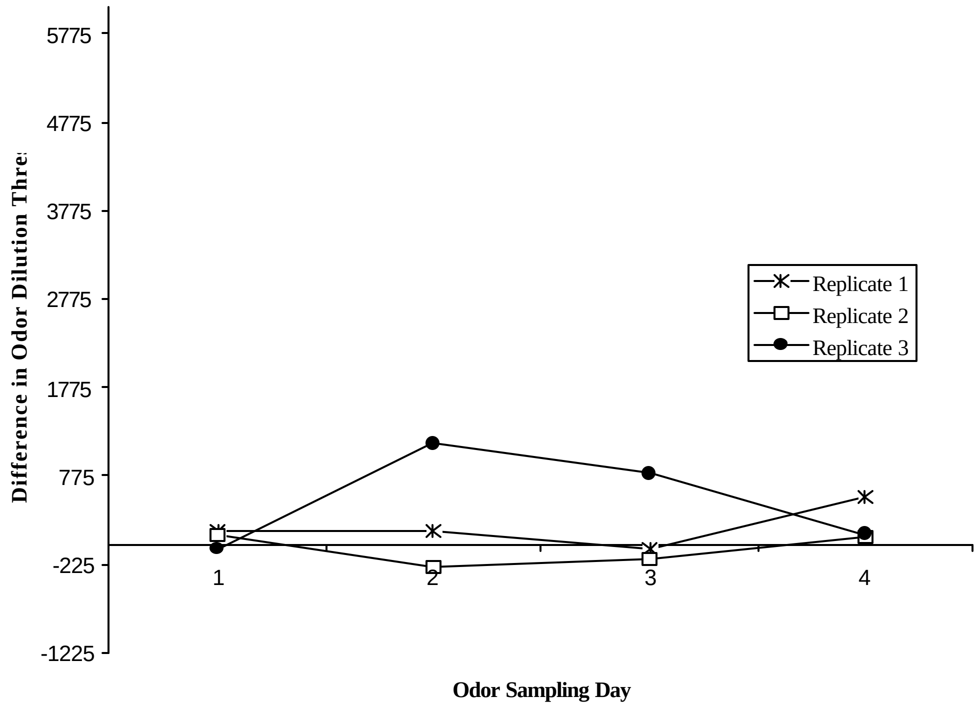
75% Certainty

AIRSPACE	-increase in odor dilution threshold
MANURE	-increase in acetic acid, isobutyric acid, and valeric acid concentrations -decrease in total nitrogen content, chemical oxygen demand, and indole concentration

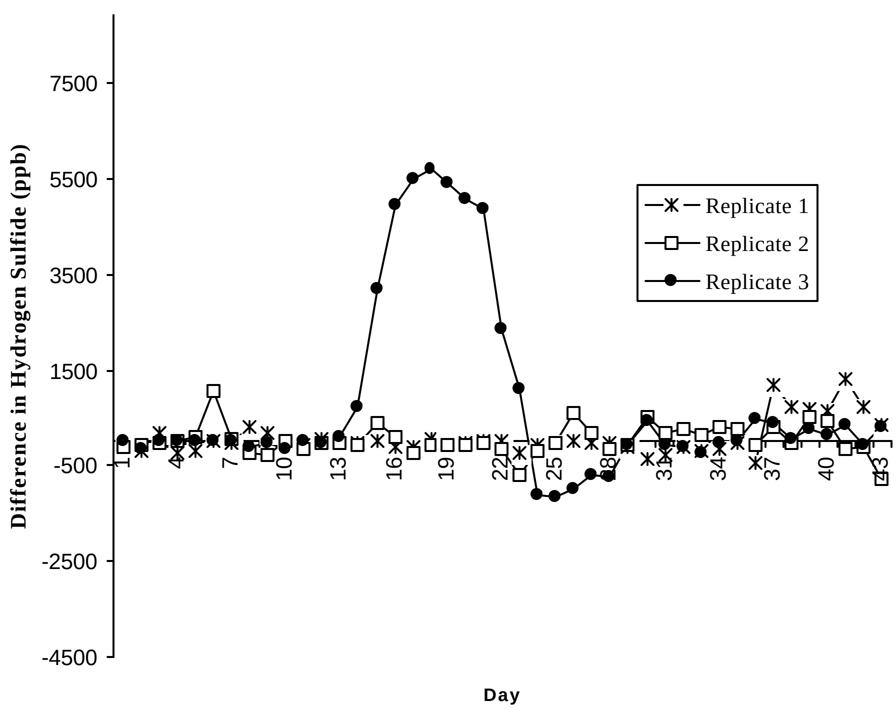
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Munox®**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	987 ± 144	**28% increase**	**75%**
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.6 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1428 ± 113	**29% increase**	**95%**
Ammonia (ppm)		104.1 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		1.9 ± 0.03	none	none
Total Nitrogen (ppm)		7314 ± 403	**9% decrease**	**75%**
Ammonia (ppm)		6576 ± 149	none	none
Phosphorus (ppm)	Manure	1918 ± 59	none	none
Potassium (ppm)		2975 ± 98	none	none
Chemical Oxygen Demand (g/L)		86 ± 10	**17% decrease**	**75%**
Acetic Acid (mM/L)		186.9 ± 10.7	**8% increase**	**75%**
Propionic Acid (mM/L)		49.0 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	15.7 ± 0.5	**5% increase**	**75%**
Butyric Acid (mM/L)		51.6 ± 1.7	none	none
Isovaleric Acid (mM/L)		30.5 ± 8.0	none	none
Valeric Acid (mM/L)		2.9 ± 0.2	**7% increase**	**75%**
Phenol (g/L)		0.06 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.10 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Munox**^{R} and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Munox**^{R}and Untreated Columns by Replicate



M_2 Acid Buffer / M_2 Microbial Activator

BIO-SURGE, Inc.
1003-1009 South Lincoln Avenue
NE Corner 11th and So. Lincoln
Amarillo, TX 79101-3639
806/374-3586 phone
806/373-5683 fax

TECHNOLOGY DESCRIPTION: Bacteria, chemical and enzyme

In contrast to the current general practices of diluting manure in an attempt to reduce odors, our technology is based on preparing the waste by physical or chemical means to optimize bioremediation. The reason why waste lagoons and short-term storage pits smell and are not liquefied is that there are insufficient and not appropriate microorganisms present to metabolize the organic material present. Our process is unique in that we stimulate appropriate microorganisms into very high biomasses, according to the stage of degradation. The principal formulations are proprietary, trademarked, and currently being processed for patent.

We do need to know of any special feeding additives that may be bacteriocidic and of bacteriocidic cleaners, particularly phenolics, being used.

PRODUCT APPLICATION RATE:

The prescribed rate of application is 1-2 gallons of M_2 Microbial Activator preceded by 2 gallons of M_2 Acid Buffer (25%) per million gallons of liquid slurry, weekly.

RETAIL PRICE (Year 1999):

M_2 Microbial Activator $85.00 per gallon
M_2 Acid Buffer $25.00 per gallon.

RESEARCH RESULTS

95% Certainty

AIRSPACE	-decrease in odor offensiveness

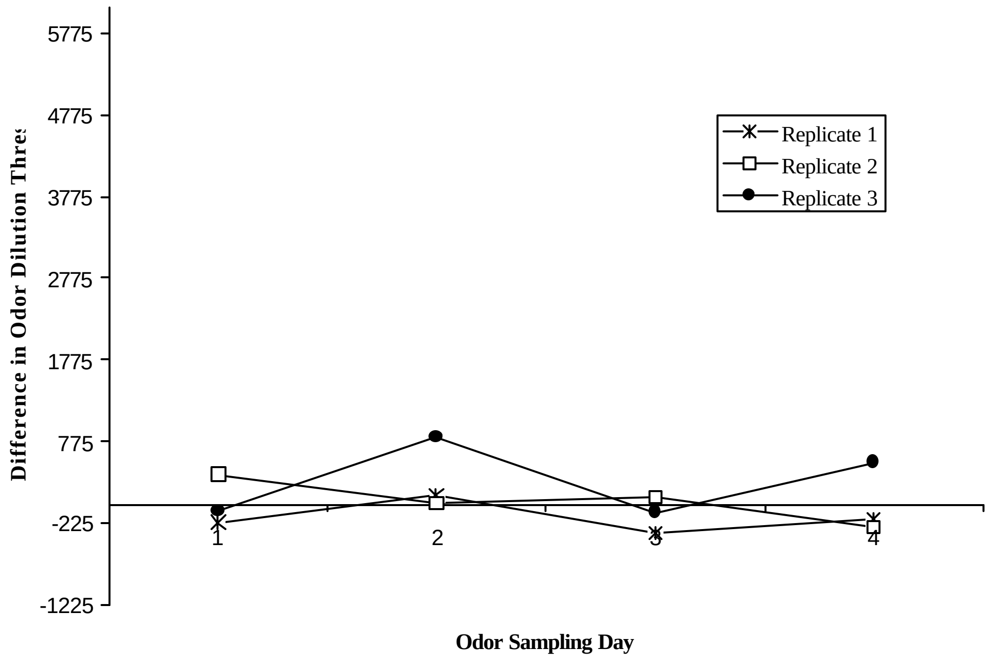
75% Certainty

AIRSPACE	-decrease in odor intensity
MANURE	-increase in ash content, and isovaleric acid concentration
	-decrease in chemical oxygen demand

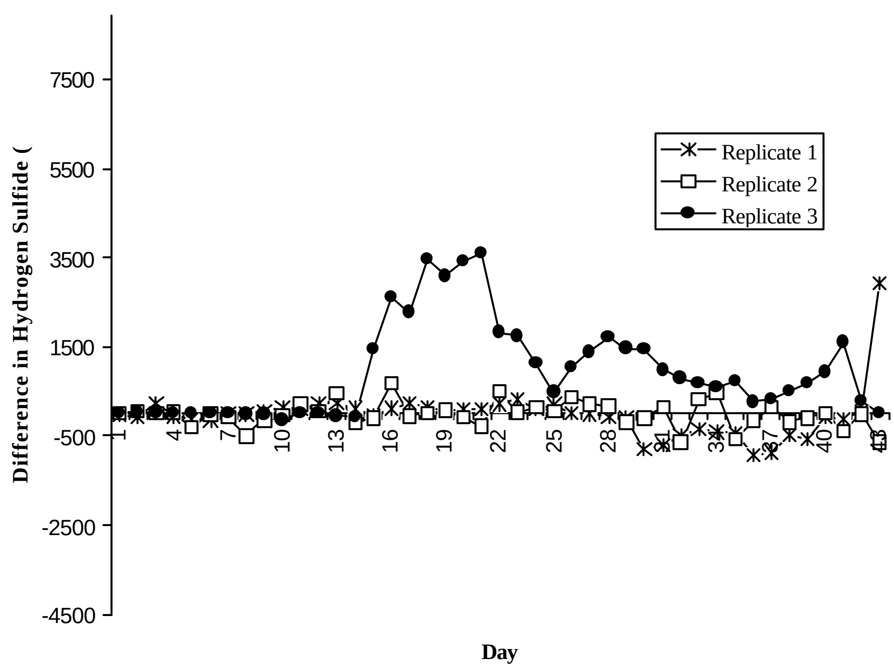
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **M_2 Acid Buffer & M_2 Microbial Activator**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	720 ± 144	none	none
Odor Intensity		2.7 ± 0.2	**16% decrease**	**75%**
Odor Offensiveness		-4.9 ± 0.3	**13% decrease**	**95%**
Hydrogen Sulfide (ppb)		1209 ± 113	none	none
Ammonia (ppm)		103.7 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.6 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8407 ± 403	none	none
Ammonia (ppm)		6543 ± 149	none	none
Phosphorus (ppm)	Manure	1977 ± 59	none	none
Potassium (ppm)		3067 ± 98	none	none
Chemical Oxygen Demand (g/L)		90 ± 10	**13% decrease**	**75%**
Acetic Acid (mM/L)		183.4 ± 10.7	none	none
Propionic Acid (mM/L)		49.1 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.8 ± 0.5	none	none
Butyric Acid (mM/L)		48.3 ± 1.7	none	none
Isovaleric Acid (mM/L)		48.7 ± 8.0	**45% increase**	**75%**
Valeric Acid (mM/L)		2.9 ± 0.2	none	none
Phenol (g/L)		0.04 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.08 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **M_2 Acid Buffer & M_2 Microbial Activator** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **M_2 Acid Buffer & M_2 Microbial Activator** and Untreated Columns by Replicate



Nature's Key Pit & Lagoon Treatment™

American Eco-Systems, Inc.
The Nature's Key Co.
PO Box 109
125 9th Ave.
Wellman, IA 52356
800/433-2999 toll free
319/646-2843 fax

TECHNOLOGY DESCRIPTION: Bacteria and enzyme

Nature's Key Pit & Lagoon Treatment™ is an advanced bio-technical product which contains a synergized blend of eight bacteria strains. P&L is formulated with buffers, surfactants and stabilized enzymes to enhance degradation capabilities of heavy organic deposits.

The liquid product is poured directly into pugs once per week, with no mixing or dilution required. P&L is non-toxic and non-caustic requiring no specialized equipment or apparel for application.

PRODUCT APPLICATION RATE:

One gallon of product should be applied to 100,000 gallons of manure for the initial application, there after one gallon to 1,000,000 gallons of manure monthly.

RETAIL PRICE (Year 2001):

$20.00 per gallon

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration
MANURE	-increase in isobutyric acid concentration
	-decrease in chemical oxygen demand

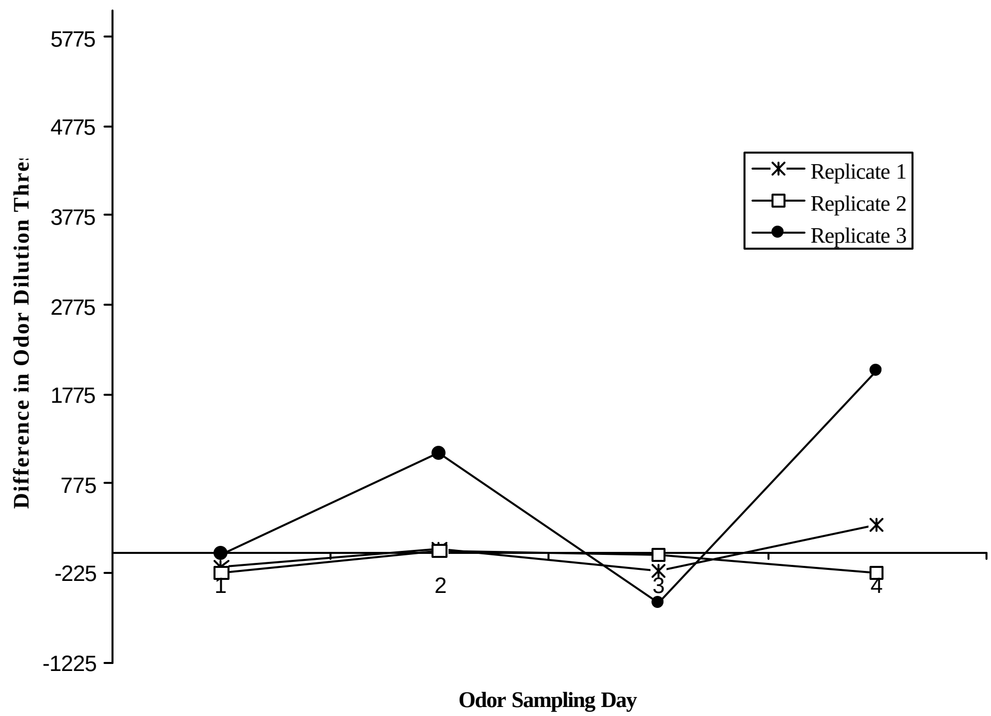
75% Certainty

AIRSPACE	-increase in odor dilution threshold
MANURE	-increase in acetic acid and para-cresol concentrations
	-decrease in indole concentration

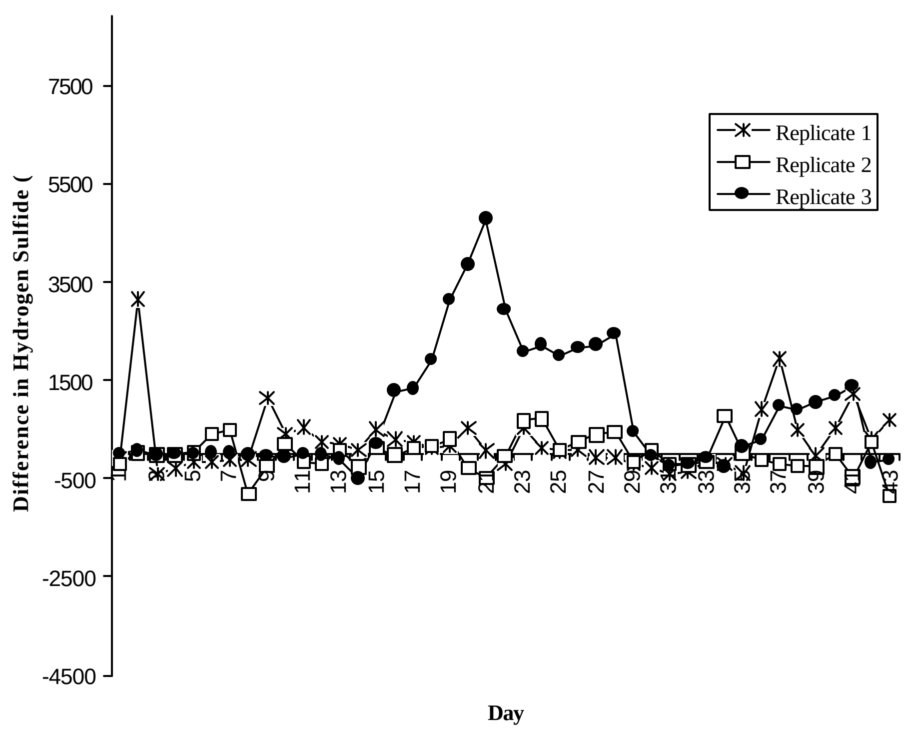
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Nature's Key Pit Treatment**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	990 ± 144	**28% increase**	**75%**
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.9 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1431 ± 113	**29% increase**	**95%**
Ammonia (ppm)		104.3 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7915 ± 403	none	none
Ammonia (ppm)		6582 ± 149	none	none
Phosphorus (ppm)	Manure	1953 ± 59	none	none
Potassium (ppm)		3058 ± 98	none	none
Chemical Oxygen Demand (g/L)		80 ± 10	**22% decrease**	**95%**
Acetic Acid (mM/L)		191.2 ± 10.7	**11% increase**	**75%**
Propionic Acid (mM/L)		49.5 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	16.1 ± 0.5	**7% increase**	**95%**
Butyric Acid (mM/L)		50.3 ± 1.7	none	none
Isovaleric Acid (mM/L)		36.1 ± 8.0	none	none
Valeric Acid (mM/L)		2.9 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.11 ± 0.02	**43% increase**	**75%**
Indole (g/L)		0.01 ± 0.02	**75% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Nature's Key** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Nature's Key** and Untreated Columns by Replicate



N-P 50

NEO PRODUCTS
448 E. Oliver St
Corunna, MI 48817
888/977-4848 toll free
517/743-8240 fax

TECHNOLOGY DESCRIPTION: Enzyme

N-P 50 is a Yucca Schidigera plant extract. The use of N-P 50 Does not directly act on the odor causing compounds, but rather acts to promote bacterial efficiency such that the production of the odor causing compounds is reduced or minimized.

PRODUCT APPLICATION RATE:

N-P 50 should be applied to a manure storage pit every three days for 15 days and once a week there after. The recommended application rate is 3.3 ounces per 1000 gallons of manure storage volume.

RETAIL PRICE (Year 2001):

$1036.00 per 55 gallon drum ($18.84 per gallon).

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration

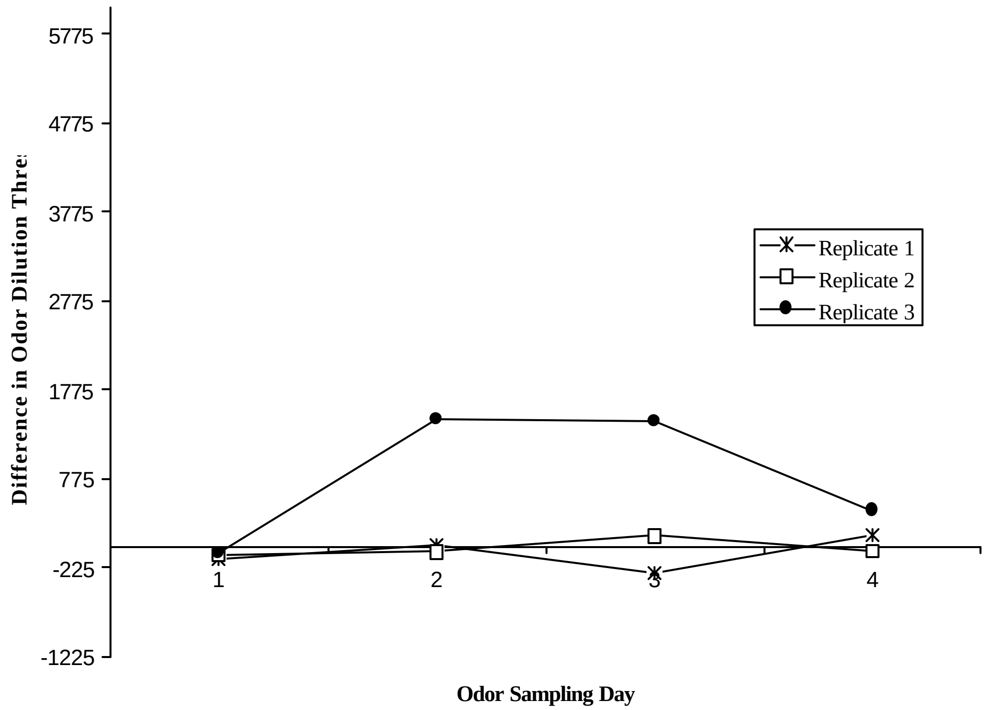
75% Certainty

AIRSPACE	-increase in odor dilution threshold, and acetic acid, phenol, para-cresol, and skatole concentrations -decrease in ammonia concentration
MANURE	-decrease in total nitrogen content, and chemical oxygen demand

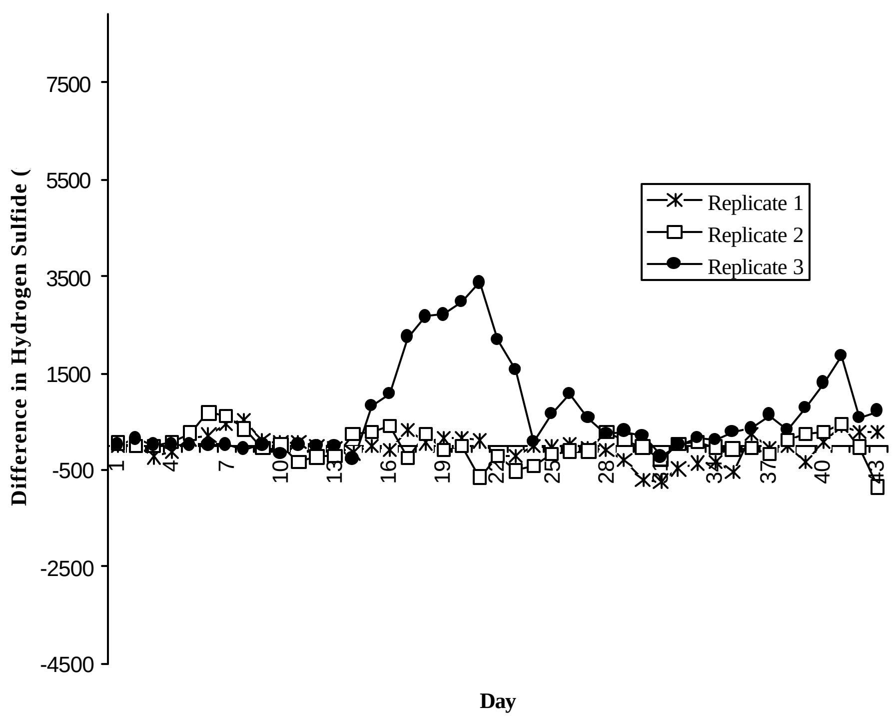
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **N-P 50**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	1065 ± 144	**38% increase**	**75%**
Odor Intensity		3.0 ± 0.2	none	none
Odor Offensiveness		-5.5 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1437 ± 113	**30% increase**	**95%**
Ammonia (ppm)		102.2 ± 1.6	**3% decrease**	**75%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7352 ± 403	**8% decrease**	**75%**
Ammonia (ppm)		6606 ± 149	none	none
Phosphorus (ppm)	Manure	192 ± 59	none	none
Potassium (ppm)		2978 ± 98	none	none
Chemical Oxygen Demand (g/L)		85 ± 10	**17% decrease**	**75%**
Acetic Acid (mM/L)		187.4 ± 10.7	**8% increase**	**75%**
Propionic Acid (mM/L)		49.9 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.7 ± 0.5	none	none
Butyric Acid (mM/L)		50.1 ± 1.7	none	none
Isovaleric Acid (mM/L)		29.0 ± 8.0	none	none
Valeric Acid (mM/L)		2.8 ± 0.2	none	none
Phenol (g/L)		0.07 ± 0.01	**40% increase**	**75%**
para-Cresol (g/L)	Manure	0.12 ± 0.02	**71% increase**	**75%**
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.03 ± 0.01	**50% increase**	**75%**

Differences in **Odor Dilution Threshold** between **N-P 50** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **N-P 50** and Untreated Columns by Replicate



OdorKlenz BMT

Aqualogy BioRemedics
4331 E. Western Star Blvd.
Phoenix, AZ 85044-1007
602/893-9234 phone
602/244-0522 fax

TECHNOLOGY DESCRIPTION: Bacteria

OdorKlenz BMT incorporates the action of stable, highly active microbial cultures specifically selected for rapid uptake of ammonia ions with non-toxic ingredients that capture typical animal manure odors such as ammonia, amines, hydrogen sulfide and mercaptans. A proprietary biological metabolic enhancer and nutrients are added to increase the rate of activity for both naturally occurring and bioaugmented microbes to biologically degrade the manure.

PRODUCT APPLICATION RATE:

For application of OdorKlenz BMT, dilute (10% solution) and spray directly on solid manure. One gallon of OdorKlenz BMT should be used per 1000 hogs, monthly.

RETAIL PRICE (Year 2001):

$69.00 per gallon

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration

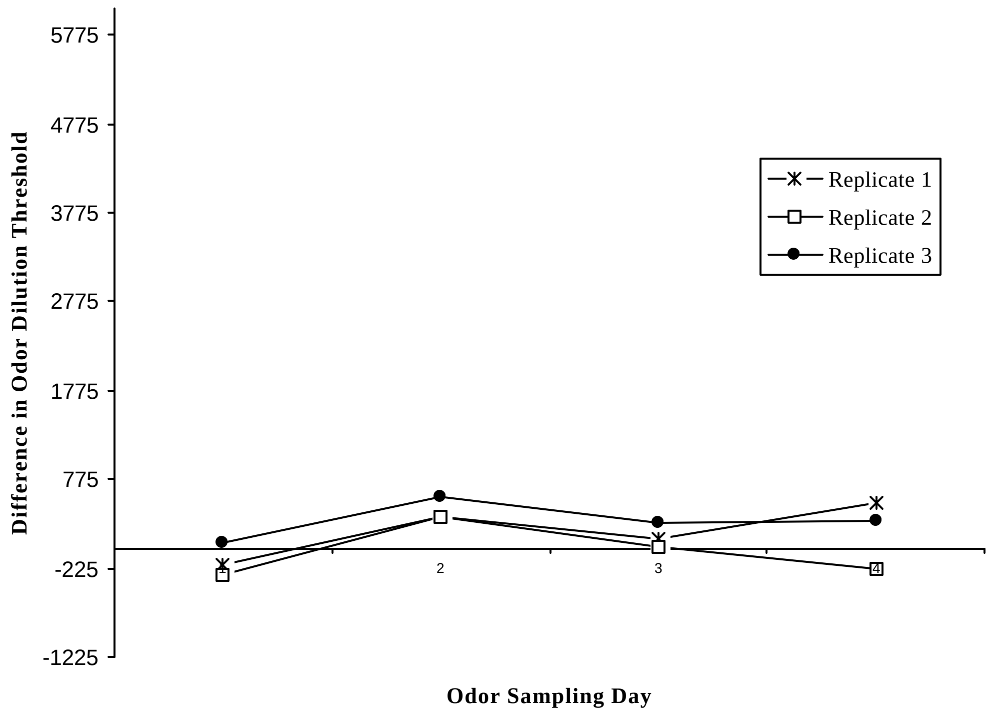
75% Certainty

MANURE	-decrease in chemical oxygen demand, and indole concentration

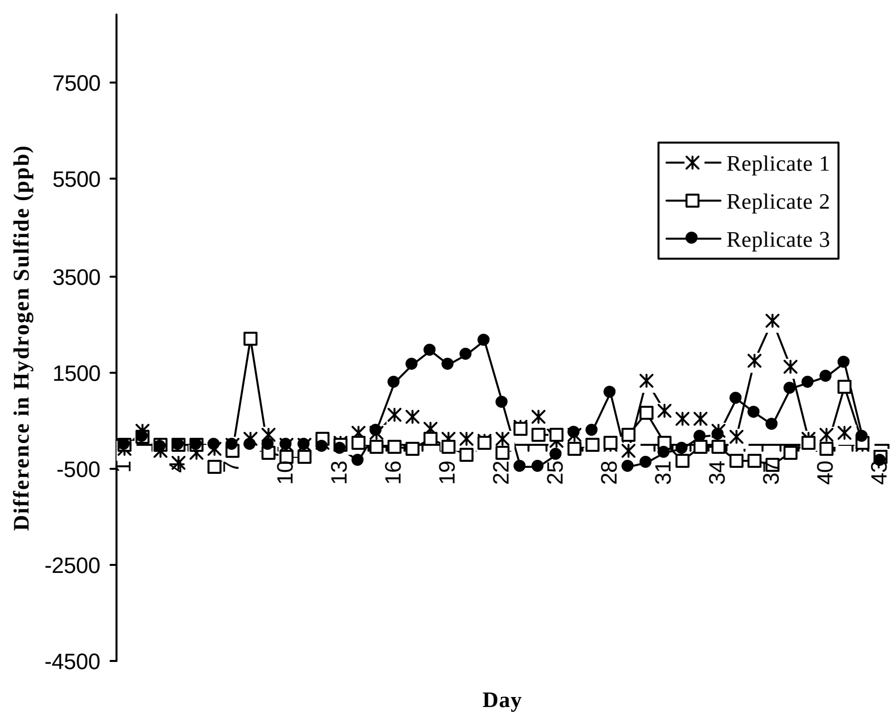
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **OdorKlenz BMT**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	937 ± 144	none	none
Odor Intensity		2.9 ± 0.2	none	none
Odor Offensiveness		-5.7 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1636 ± 113	**48% increase**	**95%**
Ammonia (ppm)		104.3 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8185 ± 403	none	none
Ammonia (ppm)		6653 ± 149	none	none
Phosphorus (ppm)	Manure	1943 ± 59	none	none
Potassium (ppm)		3027 ± 98	none	none
Chemical Oxygen Demand (g/L)		84 ± 10	**18% decrease**	**75%**
Acetic Acid (mM/L)		181.5 ± 10.7	none	none
Propionic Acid (mM/L)		48.9 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.9 ± 0.5	none	none
Butyric Acid (mM/L)		50.0 ± 1.7	none	none
Isovaleric Acid (mM/L)		35.7 ± 8.0	none	none
Valeric Acid (mM/L)		2.8 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.08 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **OdorKlenz BMT** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **OdorKlenz BMT** and Untreated Columns by Replicate



Peroxy Odor Control

Kennedy Enterprises
508 3rd Avenue NE
Belmond, IA 50421
515/444-3736 phone

Randy Navratil
327 Hillcrest Drive
Story City, IA 50248
515/733-5053 phone
515/733-4722 fax

TECHNOLOGY DESCRIPTION: 35% Hydrogen Peroxide

Hydrogen Peroxide is water plus an extra atom of oxygen. When Hydrogen Peroxide comes in contact with an organic material it gives up the extra oxygen to the environment for aerobic activity.

PRODUCT APPLICATION RATE:

Apply the hydrogen peroxide at a rate of one gallon of 35% Hydrogen Peroxide to 5,000 gallons of hog manure prior to agitation for manure storage pump out.

RETAIL PRICE (Year 1999):

$6.50 per gallon

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration -decrease in ammonia concentration

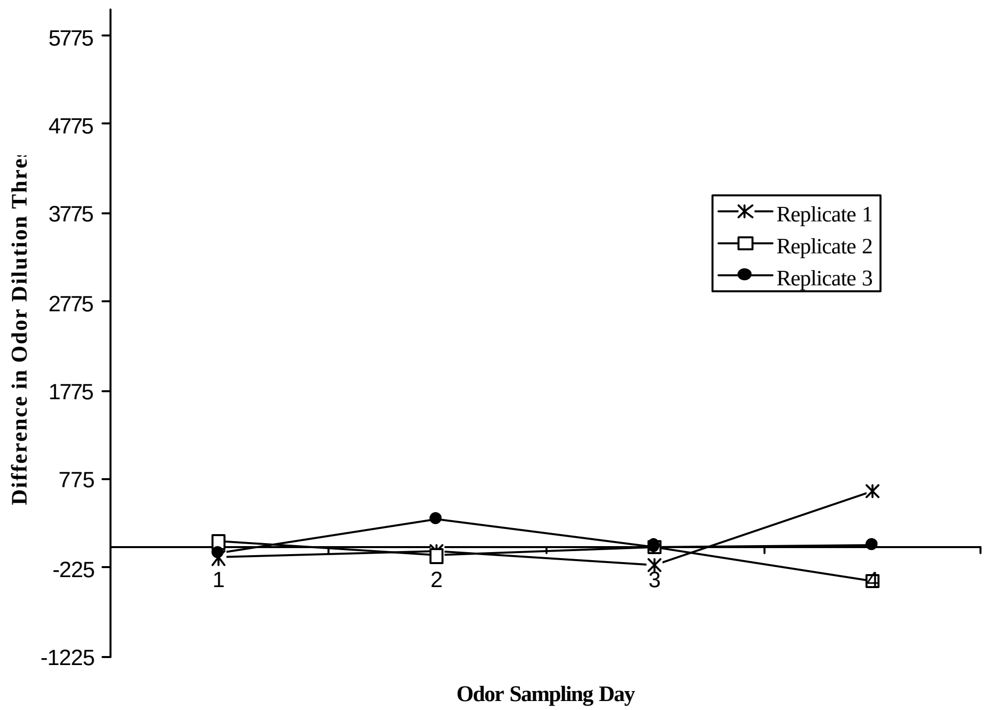
75% Certainty

MANURE	-decrease in isobutyric acid and indole concentrations

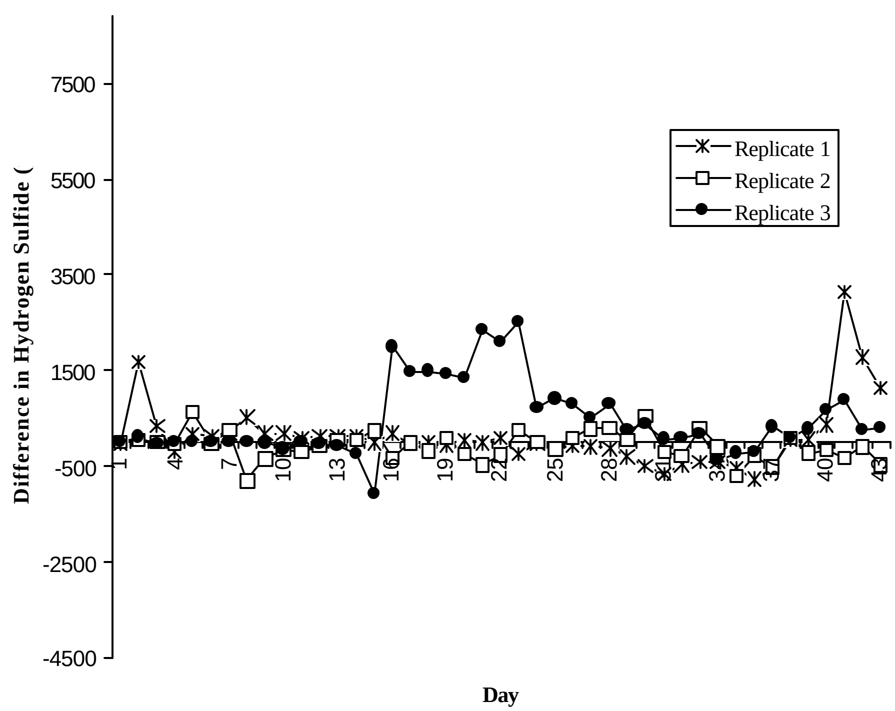
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Peroxy Odor Control**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	790 ± 144	none	none
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.7 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1402 ± 113	**27% increase**	**95%**
Ammonia (ppm)		101.8 ± 1.6	**3% decrease**	**95%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.1 ± 0.03	none	none
Total Nitrogen (ppm)		8069 ± 403	none	none
Ammonia (ppm)		6596 ± 149	none	none
Phosphorus (ppm)	Manure	1906 ± 59	none	none
Potassium (ppm)		3149 ± 98	none	none
Chemical Oxygen Demand (g/L)		95 ± 10	none	none
Acetic Acid (mM/L)		179.8 ± 10.7	none	none
Propionic Acid (mM/L)		49.2 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.2 ± 0.5	**5% decrease**	**75%**
Butyric Acid (mM/L)		50.4 ± 1.7	none	none
Isovaleric Acid (mM/L)		34.4 ± 8.0	none	none
Valeric Acid (mM/L)		2.9 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.05 ± 0.03	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.03 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Peroxy Odor Control** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Peroxy Odor Control** and Untreated Columns by Replicate



Pit Remedy

Al Larson Distributing
13105 Hamilton St.
Omaha, NE 68154
888/231-1002 toll free
402/493-0455 phone
402/498-0268 fax

TECHNOLOGY DESCRIPTION: Bacteria

Pit Remedy is a safe, all natural, biological product. The formulation of the product is proprietary. A generic analysis of the product describes a combination of aerobic and anaerobic bacteria that have been specifically designed for livestock waste management purposes.

In the field of bioremediation, we help augment natural biological processes. Pit Remedy is simply a concentration of organisms that grow naturally in the environment to improve and enhance reduction of animal waste into non-polluting products with nutrient value.

PRODUCT APPLICATION RATE:

Recommended application rates are listed below.

- Gestation/Farrowing unit = 1 quart per 250 sows monthly
- Nursery = 1 gallon per 500 pigs per turn
- Finishing = 1 gallon per 1,000 hogs monthly

RETAIL PRICE (Year 2001):

$50.00 per gallon

RESEARCH RESULTS

95% Certainty

MANURE	-increase in valeric acid concentration
	-decrease in total nitrogen content

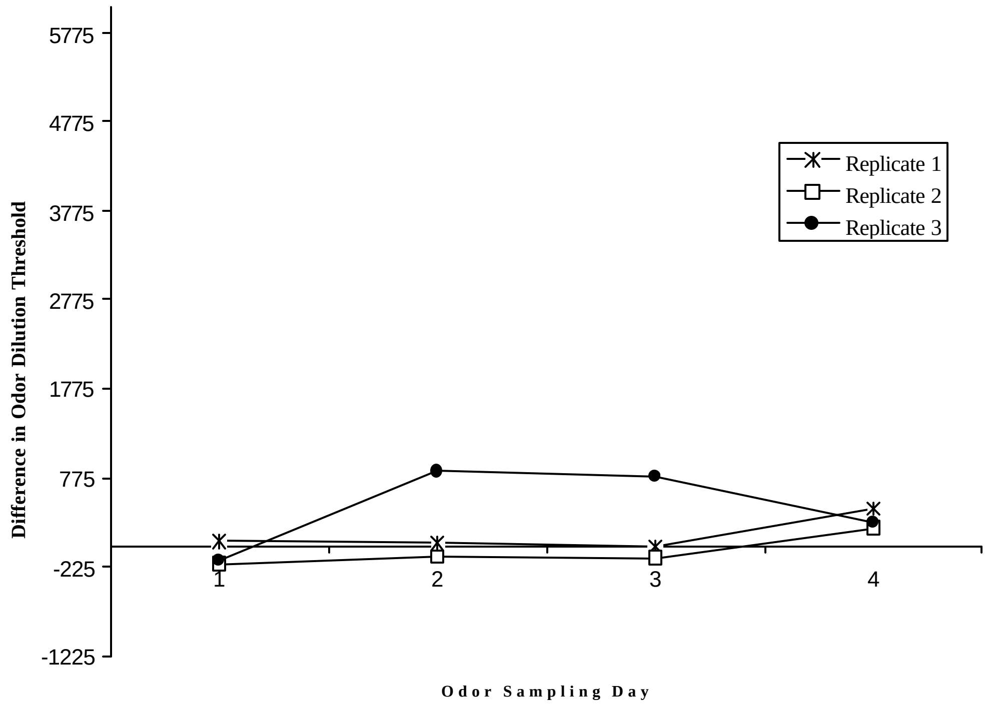
75% Certainty

AIRSPACE	-increase in odor dilution threshold
MANURE	-increase in isobutyric acid concentration

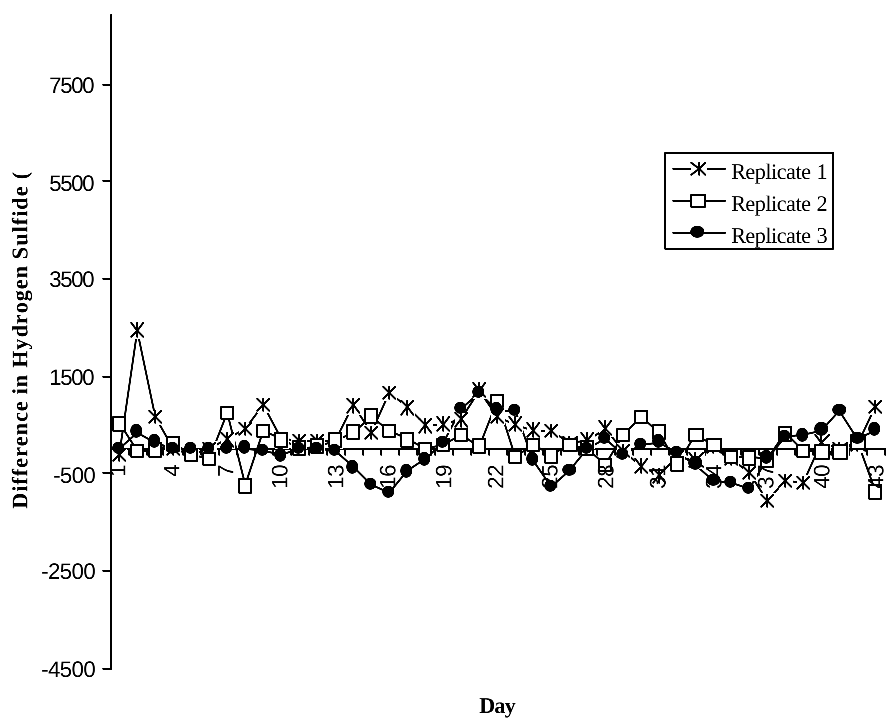
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Pit Remedy**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	1035 ± 144	**34% increase**	**75%**
Odor Intensity		3.3 ± 0.2	none	none
Odor Offensiveness		-5.7 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1112 ± 113	none	none
Ammonia (ppm)		103.4 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		6302 ± 403	**21% decrease**	**95%**
Ammonia (ppm)		6707 ± 149	none	none
Phosphorus (ppm)	Manure	1930 ± 59	none	none
Potassium (ppm)		3056 ± 98	none	none
Chemical Oxygen Demand (g/L)		110 ± 10	none	none
Acetic Acid (mM/L)		180.4 ± 10.7	none	none
Propionic Acid (mM/L)		47.2 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	15.7 ± 0.5	**5% increase**	**75%**
Butyric Acid (mM/L)		50.5 ± 1.7	none	none
Isovaleric Acid (mM/L)		43.1 ± 8.0	none	none
Valeric Acid (mM/L)		3.1 ± 0.2	**15% increase**	**95%**
Phenol (g/L)		0.04 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.06 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Pit Remedy** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Pit Remedy** and Untreated Columns by Replicate



PS1

A.D. Associates, LLC (ADA)
752 Gapter Rd.
Boulder, CO 80303
303/499-3133 phone
303/402-5305 fax

TECHNOLOGY DESCRIPTION: Chemical

The ADA waste treatment system, similar to the Earth Balance system, utilizes a proprietary, non-toxic, non-hazardous chemical technology.

PS1 is an aqueous solution containing about 3% organic matter which acts as a catalytic reagent, enabling reactions that normally would not take place except under extreme conditions to take place at ambient temperature and pressure.

The reactions do not require the presence of oxygen (dissolved oxygen). The treatment chemical does not contain any volatile compounds and does not produce any volatile products of gases as a result of reaction.

PRODUCT APPLICATION RATE:

One gallon of product should be applied per 10,000 gallons of hog manure as storage volume increases. The rate and frequency may vary depending upon the percent solids of the manure being treated.

RETAIL PRICE (Year 2001):

$30.00 per gallon

RESEARCH RESULTS

95% Certainty

MANURE	-decrease in isobutyric acid concentration

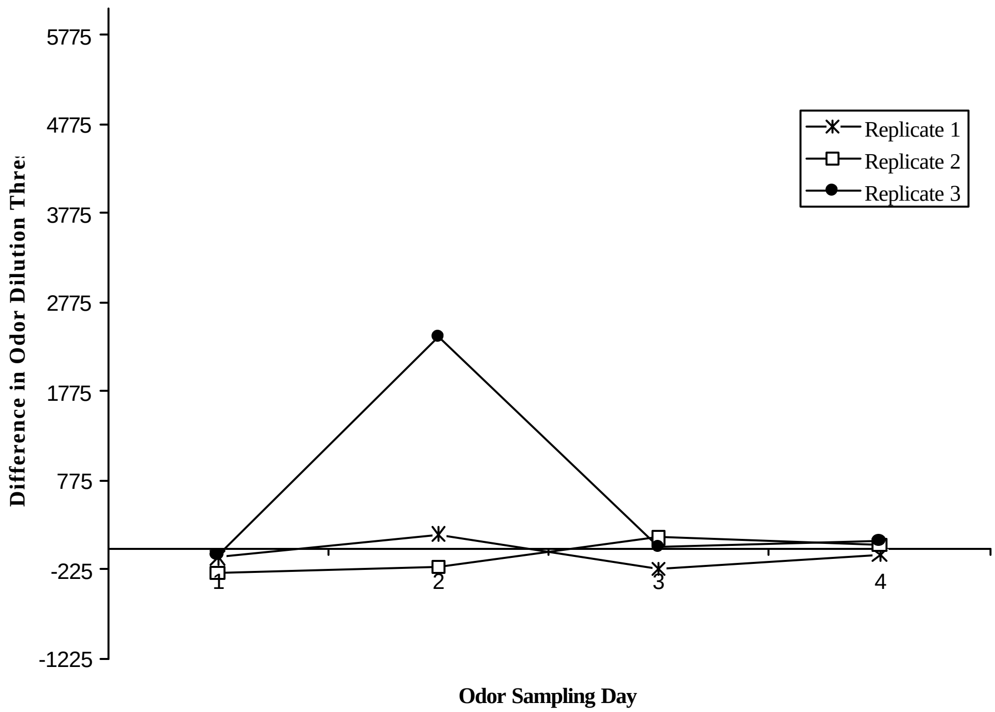
75% Certainty

AIRSPACE	-decrease in hydrogen sulfide concentration
MANURE	-increase in pH, ash content, and skatole concentration
	-decrease in manure ammonia content, and phenol concentration

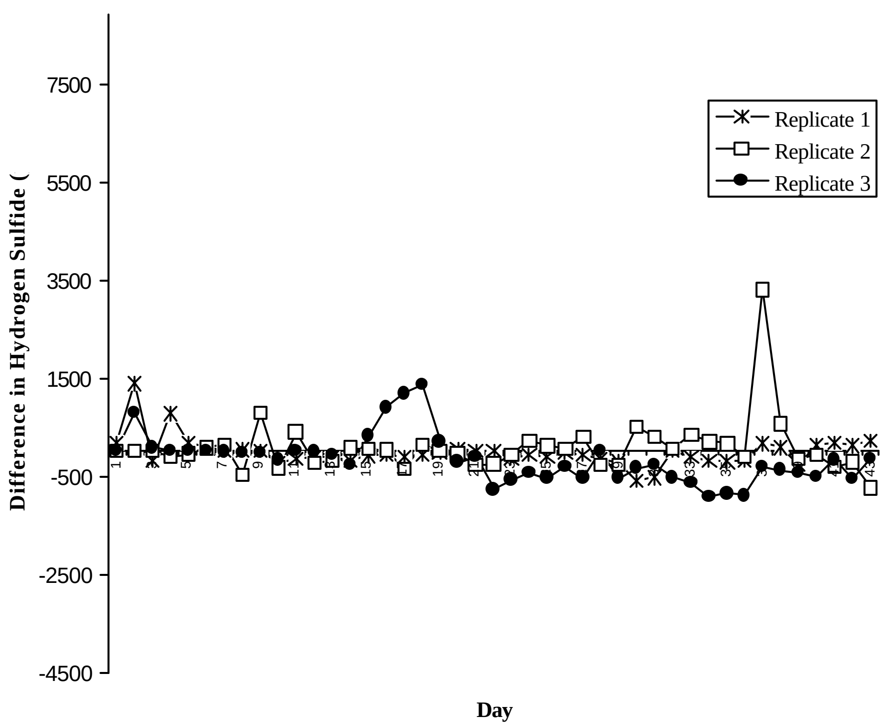
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **PS1**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	769 ± 144	none	none
Odor Intensity		3.3 ± 0.2	none	none
Odor Offensiveness		-5.8 ± 0.3	none	none
Hydrogen Sulfide (ppb)		950 ± 113	**14% decrease**	**75%**
Ammonia (ppm)		103.3 ± 1.6	none	none
pH	Manure	7.2 ± 0.04	**1% increase**	**75%**
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.1 ± 0.03	none	none
Total Nitrogen (ppm)		7518 ± 403	none	none
Ammonia (ppm)		6416 ± 149	**6% decrease**	**75%**
Phosphorus (ppm)	Manure	1915 ± 59	none	none
Potassium (ppm)		2944 ± 98	none	none
Chemical Oxygen Demand (g/L)		115 ± 10	none	none
Acetic Acid (mM/L)		172.1 ± 10.7	none	none
Propionic Acid (mM/L)		46.6 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	13.8 ± 0.5	**8% decrease**	**95%**
Butyric Acid (mM/L)		48.2 ± 1.7	none	none
Isovaleric Acid (mM/L)		37.9 ± 8.0	none	none
Valeric Acid (mM/L)		2.5 ± 0.2	none	none
Phenol (g/L)		0.04 ± 0.01	**20% decrease**	**75%**
para-Cresol (g/L)	Manure	0.09 ± 0.03	none	none
Indole (g/L)		0.03 ± 0.02	none	none
Skatole (g/L)		0.03 ± 0.01	**50% increase**	**75%**

Differences in **Odor Dilution Threshold** between **PS1** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **PS1** and Untreated Columns by Replicate



Roebic Manure Liquefier (RML)

ROEBIC Laboratories, Inc.
25 Connair Rd.
P.O. Box 927
Orange, CT 06477
203/795-1283 phone

Bob Beer
4920 Jule Drive
Panora, IA 50216
641/755-2996 phone
641/755-2642 fax

TECHNOLOGY DESCRIPTION: Bacteria

This product is a mixture of nonpathogenic anaerobic, aerobic, and facultative bacteria.

PRODUCT APPLICATION RATE:

Apply 1 gallon per 10,000 gallon storage capacity, monthly.

RETAIL PRICE (Year 2001):

$34.24 per gallon

RESEARCH RESULTS

95% Certainty

MANURE	-increase in acetic acid concentration

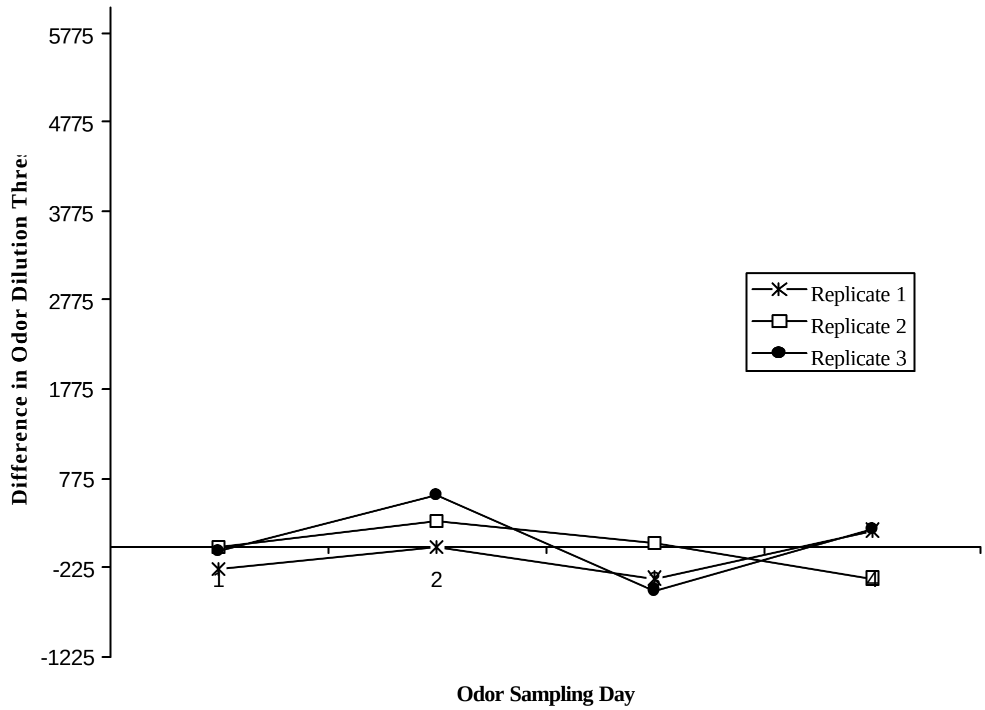
75% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration
MANURE	-increase in propionic acid, butyric acid, and valeric acid concentrations

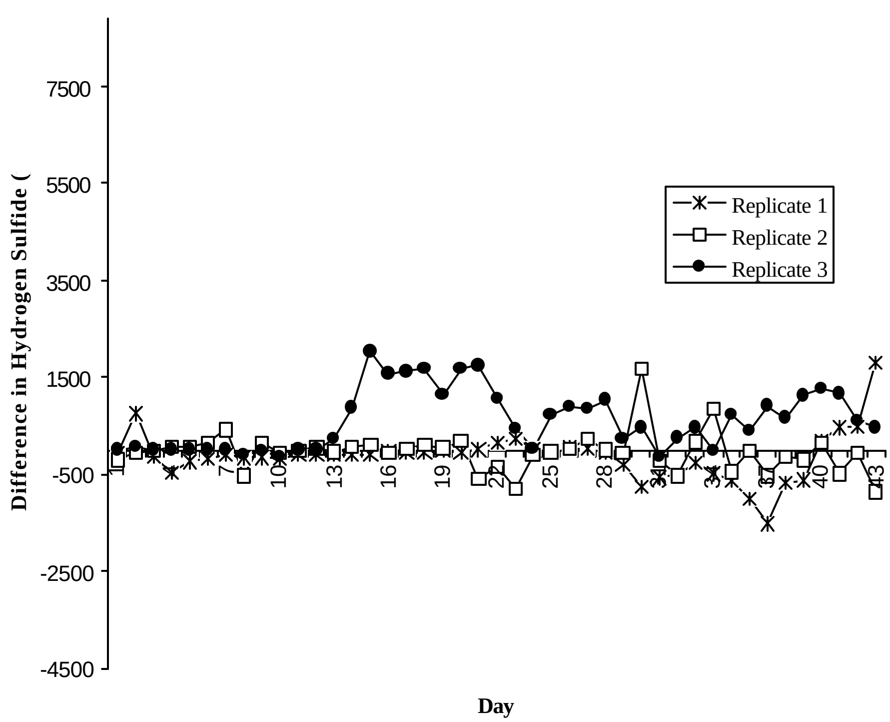
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Roebic Manure Liquefier**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	648 ± 144	none	none
Odor Intensity		3.0 ± 0.2	none	none
Odor Offensiveness		-5.4 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1306 ± 113	**18% increase**	**75%**
Ammonia (ppm)		104.9 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7962 ± 403	none	none
Ammonia (ppm)		6657 ± 149	none	none
Phosphorus (ppm)	Manure	1987 ± 59	none	none
Potassium (ppm)		3158 ± 98	none	none
Chemical Oxygen Demand (g/L)		99 ± 10	none	none
Acetic Acid (mM/L)		199.2 ± 10.7	**15% increase**	**95%**
Propionic Acid (mM/L)		50.8 ± 1.7	**6% increase**	**75%**
Isobutyric Acid (mM/L)	Manure	15.0 ± 0.5	none	none
Butyric Acid (mM/L)		53.5 ± 1.7	**7% increase**	**75%**
Isovaleric Acid (mM/L)		30.2 ± 8.0	none	none
Valeric Acid (mM/L)		2.9 ± 0.2	**7% increase**	**75%**
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.05 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Roebic Manure Liquefier** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Roebic Manure Liquefier** and Untreated Columns by Replicate



Roebic Odor Eliminator (ROE)

ROEBIC Laboratories, Inc.
25 Connair Rd.
P.O. Box 927
Orange, CT 06477
203/795-1283 phone

Bob Beer
4920 Jule Drive
Panora, IA 50216
641/755-2996 phone
641/755-2642 fax

TECHNOLOGY DESCRIPTION: Enzyme

This product is a mixture of enzymes derived from plant material. ROE is safe, non-toxic, and biodegradable.

PRODUCT APPLICATION RATE:

Dilute 1:100 – 1:500 product to water depending on odor type and intensity. Apply as fine mist or direct spray on odor source, monthly.

RETAIL PRICE (Year 2001):

$42.00 per gallon

RESEARCH RESULTS

95% Certainty

AIRSPACE	-increase in ammonia concentration
	-decrease in hydrogen sulfide concentration

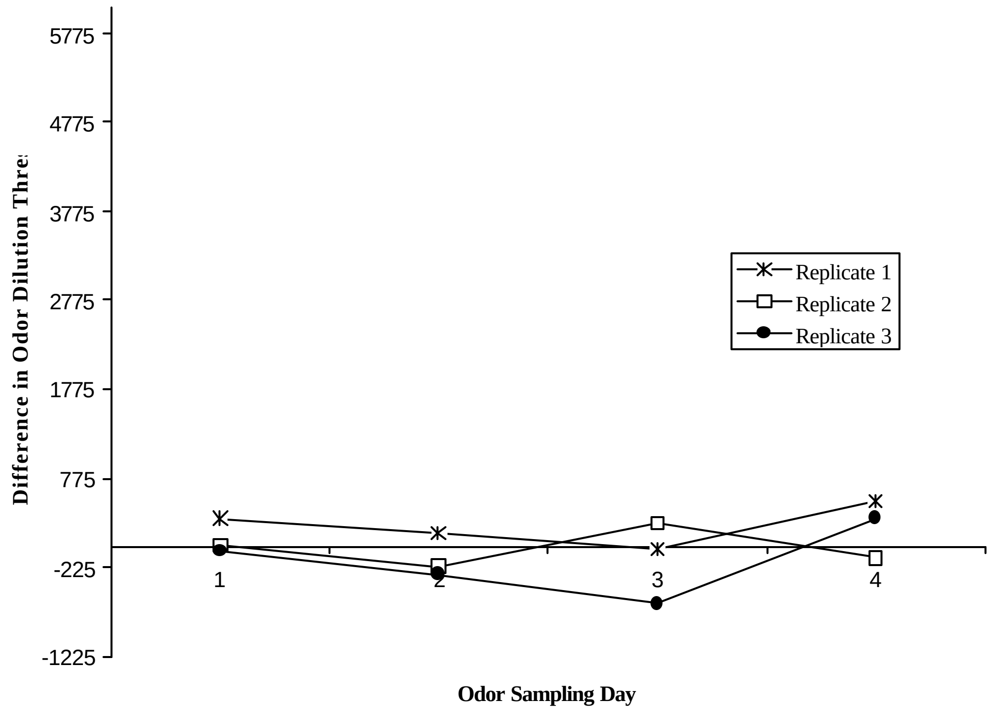
75% Certainty

MANURE	-increase in butyric acid
	-decrease in chemical oxygen demand

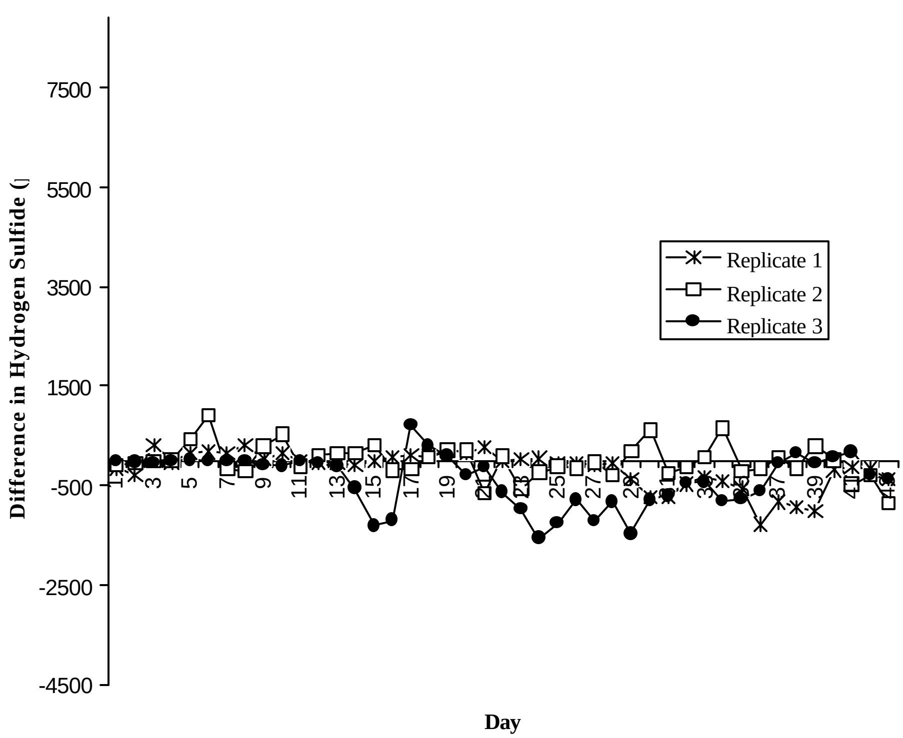
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Roebic Odor Eliminator**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	827 ± 144	none	none
Odor Intensity		3.2 ± 0.2	none	none
Odor Offensiveness		-5.7 ± 0.3	none	none
Hydrogen Sulfide (ppb)		854 ± 113	**23% decrease**	**95%**
Ammonia (ppm)		114.8 ± 1.6	**9% increase**	**95%**
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		7.0 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		7706 ± 403	none	none
Ammonia (ppm)		6748 ± 149	none	none
Phosphorus (ppm)	Manure	1882 ± 59	none	none
Potassium (ppm)		3164 ± 98	none	none
Chemical Oxygen Demand (g/L)		84 ± 10	**18% decrease**	**75%**
Acetic Acid (mM/L)		185.2 ± 10.7	none	none
Propionic Acid (mM/L)		47.9 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	15.6 ± 0.5	none	none
Butyric Acid (mM/L)		53.2 ± 1.7	**7% increase**	**75%**
Isovaleric Acid (mM/L)		36.1 ± 8.0	none	none
Valeric Acid (mM/L)		2.8 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.08 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Roebic Odor Eliminator** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Roebic Odor Eliminator** and Untreated Columns by Replicate



SEPTI-SOL

Kennedy Enterprises
Dave Kennedy
508 3rd Avenue NE
Belmond, IA 50421
515/444-3736 phone

Randy Navratil
327 Hillcrest Drive
Story City, IA 50248
515/733-5053 phone
515/733-4722 fax

TECHNOLOGY DESCRIPTION: Enzyme

SEPTI-SOL is a liquid product that adds enzymes, amino acids, trace minerals and oxygen to the existing manure. It is easily applied to shallow pits or deep pits by 1) medicating the soaker system, by 2) putting the SEPTI-SOL through the soap dispenser of a high-pressure sprayer, or 3) using a siphon mixer that puts the SEPTI-SOL in the pit or lagoon through a garden hose.

PRODUCT APPLICATION RATE:

SEPTI-SOL should be applied at a rate of one gallon product to 40,000 gallons of manure, monthly.

RETAIL PRICE (Year 2001):

$80.00 per gallon

RESEARCH RESULTS

95% Certainty

MANURE	-increase in acetic acid concentration

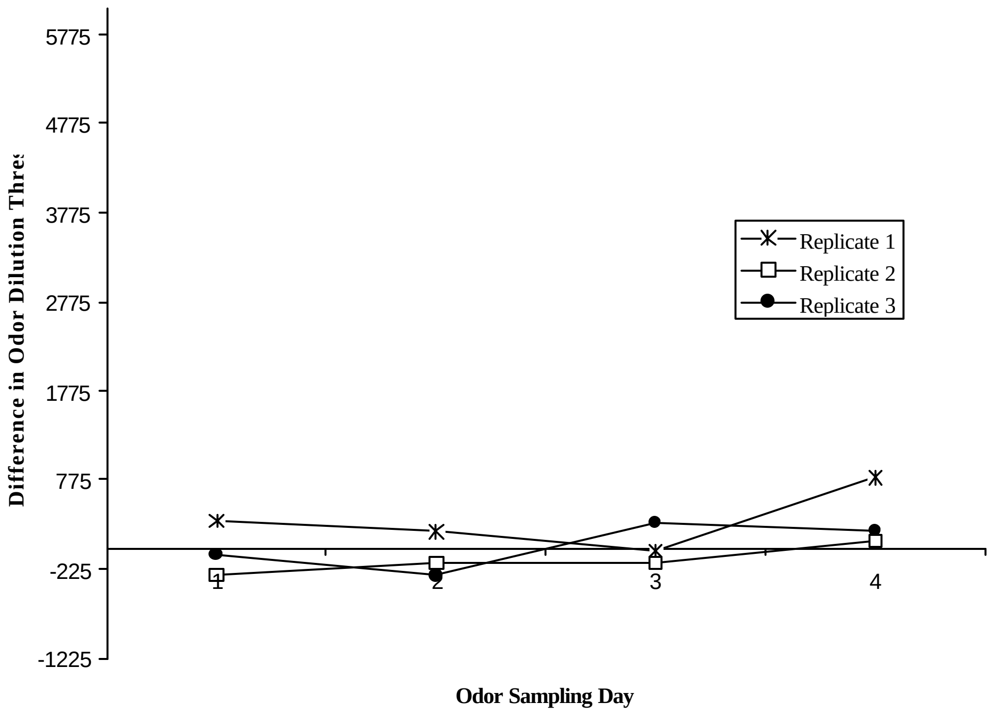
75% Certainty

AIRSPACE	-increase in odor dilution threshold
MANURE	-increase in propionic acid and skatole concentrations
	-decrease in chemical oxygen demand

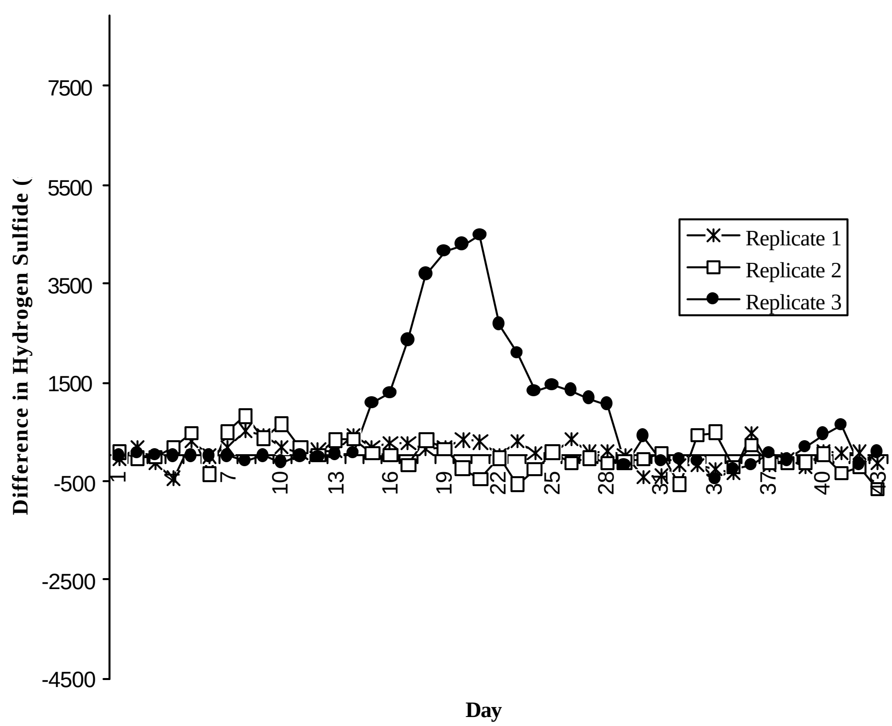
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **SEPTI-SOL**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	971 ± 144	**26% increase**	**75%**
Odor Intensity		3.1 ± 0.2	none	none
Odor Offensiveness		-5.8 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1073 ± 113	none	none
Ammonia (ppm)		106.5 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8119 ± 403	none	none
Ammonia (ppm)		6714 ± 149	none	none
Phosphorus (ppm)	Manure	2047 ± 59	none	none
Potassium (ppm)		3082 ± 98	none	none
Chemical Oxygen Demand (g/L)		85 ± 10	**17% decrease**	**75%**
Acetic Acid (mM/L)		196.3 ± 10.7	**14% increase**	**95%**
Propionic Acid (mM/L)		51.2 ± 1.7	**7% increase**	**75%**
Isobutyric Acid (mM/L)	Manure	15.4 ± 0.5	none	none
Butyric Acid (mM/L)		50.5 ± 1.7	none	none
Isovaleric Acid (mM/L)		29.9 ± 8.0	none	none
Valeric Acid (mM/L)		2.9 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.07 ± 0.02	none	none
Indole (g/L)		0.03 ± 0.02	none	none
Skatole (g/L)		0.03 ± 0.01	**50% increase**	**75%**

Differences in **Odor Dilution Threshold** between **SEPTI-SOL** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **SEPTI-SOL** and Untreated Columns by Replicate



Solmar AW-509

Micro-Link, LLC
110 Surrey Run
Williamsville, NY 14221
716/633-5678 phone
716/633-6614 fax

e-mail address: microbelink@worldnet.att.net

TECHNOLOGY DESCRIPTION: Bacteria

Micro-Link products are preventative, not curative; cannot harm any person, animal, plant or aquatic plant, fish or frogs.

PRODUCT APPLICATION RATE:

RETAIL PRICE (Year 2001):

$11.95 per pound

RESEARCH RESULTS

95% Certainty

MANURE	-increase in valeric acid concentration

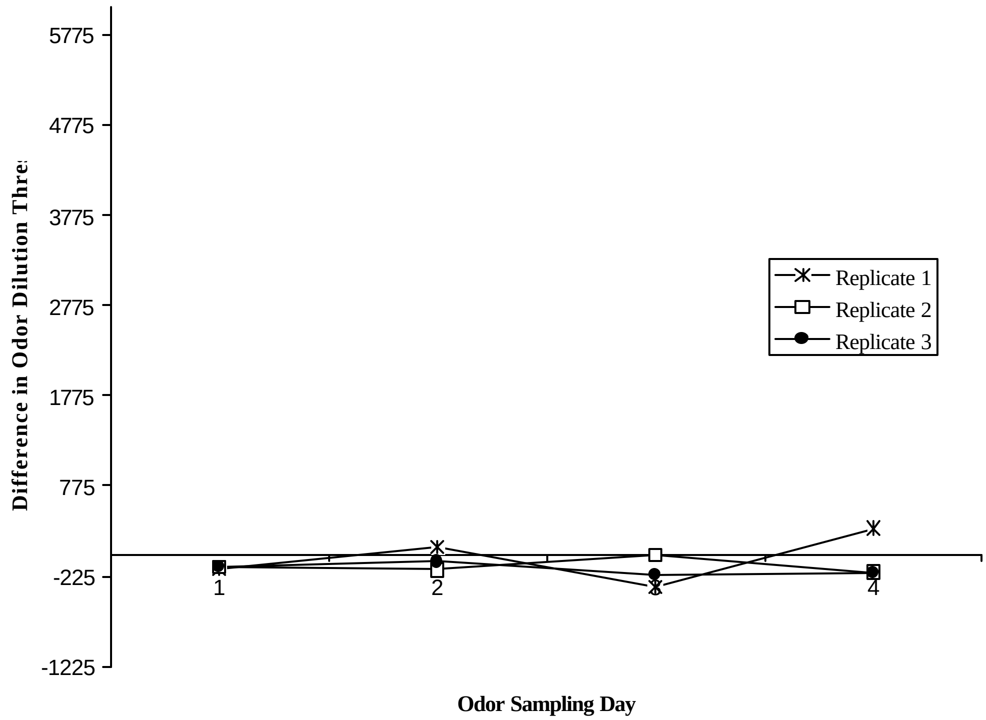
75% Certainty

AIRSPACE	-increase in odor intensity
MANURE	-increase in propionic acid concentration
	-decrease in chemical oxygen demand, and indole concentration

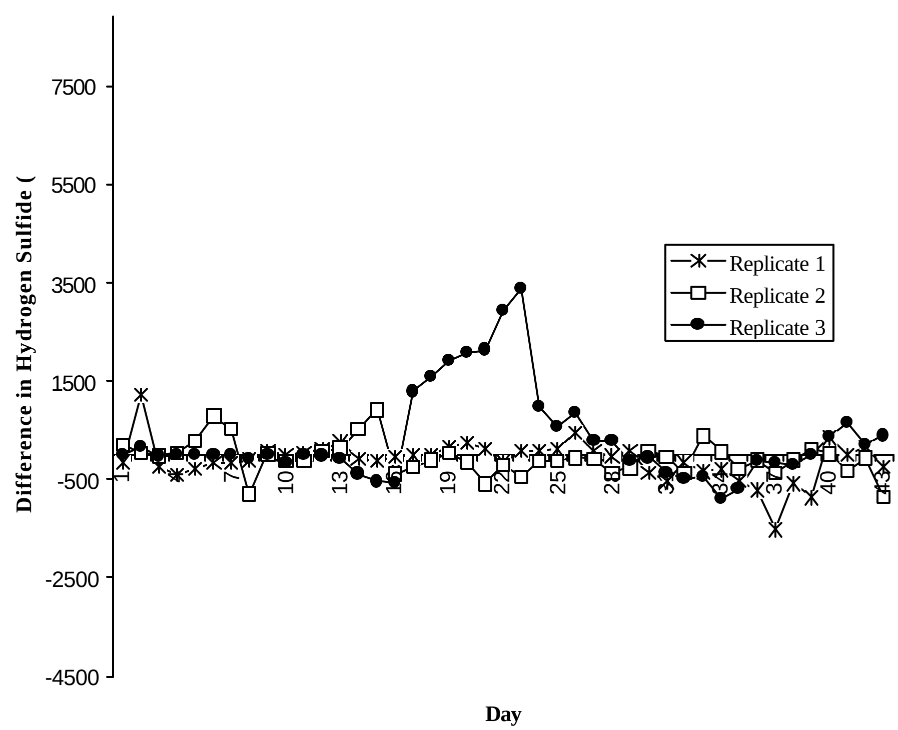
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **Solmar AW-509**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	669 ± 144	none	none
Odor Intensity		3.4 ± 0.2	**6% increase**	**75%**
Odor Offensiveness		-6.0 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1008 ± 113	none	none
Ammonia (ppm)		103.3 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8490 ± 403	none	none
Ammonia (ppm)		6713 ± 149	none	none
Phosphorus (ppm)	Manure	1893 ± 59	none	none
Potassium (ppm)		3036 ± 98	none	none
Chemical Oxygen Demand (g/L)		85 ± 10	**17% decrease**	**75%**
Acetic Acid (mM/L)		180.8 ± 10.7	none	none
Propionic Acid (mM/L)		51.4 ± 1.7	**7% increase**	**75%**
Isobutyric Acid (mM/L)	Manure	15.5 ± 0.5	none	none
Butyric Acid (mM/L)		51.1 ± 1.7	none	none
Isovaleric Acid (mM/L)		31.1 ± 8.0	none	none
Valeric Acid (mM/L)		3.2 ± 0.2	**19% increase**	**95%**
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.07 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **Solmar AW-509** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **Solmar AW-509** and Untreated Columns by Replicate



Super Microbial Odor Control (SMOC)

SMSI, Inc.
6610 Rockledge Drive, Suite 168
Bethesda, MD 20817
301/581-9577 phone
301/897-4092 fax

website: www.supermicrobe.com

TECHNOLOGY DESCRIPTION: Bacteria

SMOC is composed of natural non-harmful elements that carry super microbes, which have been associated to the production of many organic beneficial effects.

PRODUCT APPLICATION RATE:

1. Impact phase – Apply 1 bag (25 kg) of SMOC per 10,000 gallons of manure once a week for 3 weeks.

2. Maintenance phase – After the impact phase, use ½ bag (12.5 kg) of SMOC per 10,000 gallons of manure once a week or 1 bag (25kg) of SMOC every other week.

** Amounts may be adjusted, lower or higher, according to the manure pit or lagoon conditions.

RETAIL PRICE (Year 2001):

$25.00 per bag (25 kg)

RESEARCH RESULTS

95% Certainty

AIRSPACE	-decrease in hydrogen sulfide concentration
MANURE	-increase in ash content, and valeric acid concentration

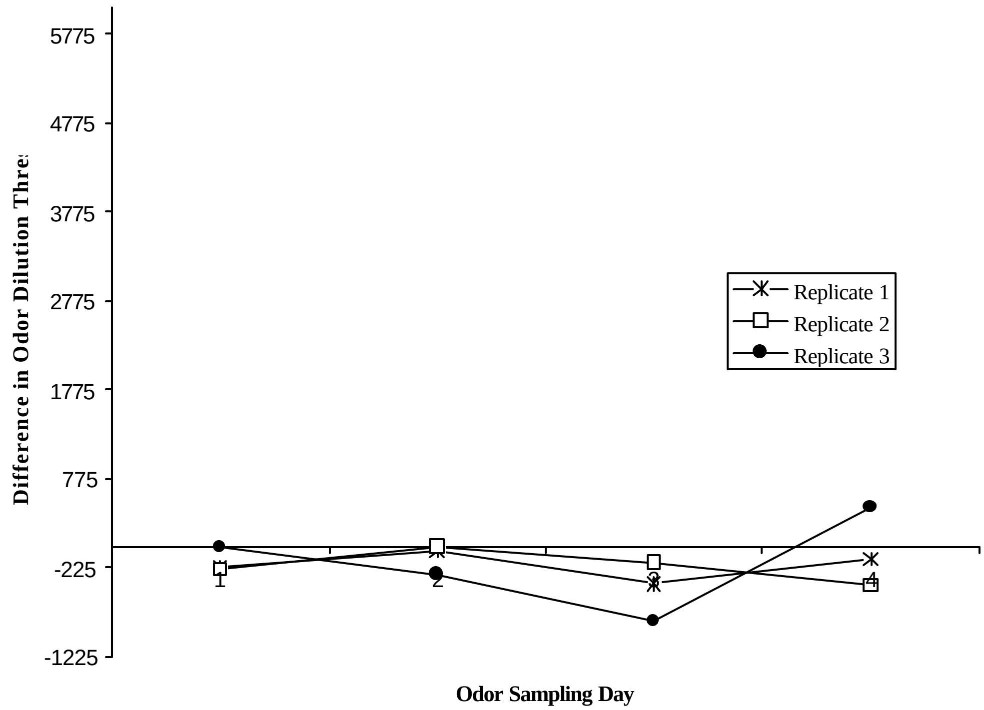
75% Certainty

AIRSPACE	-decrease in odor dilution threshold
MANURE	-increase in chemical oxygen demand
	-decrease in acetic acid and indole concentrations

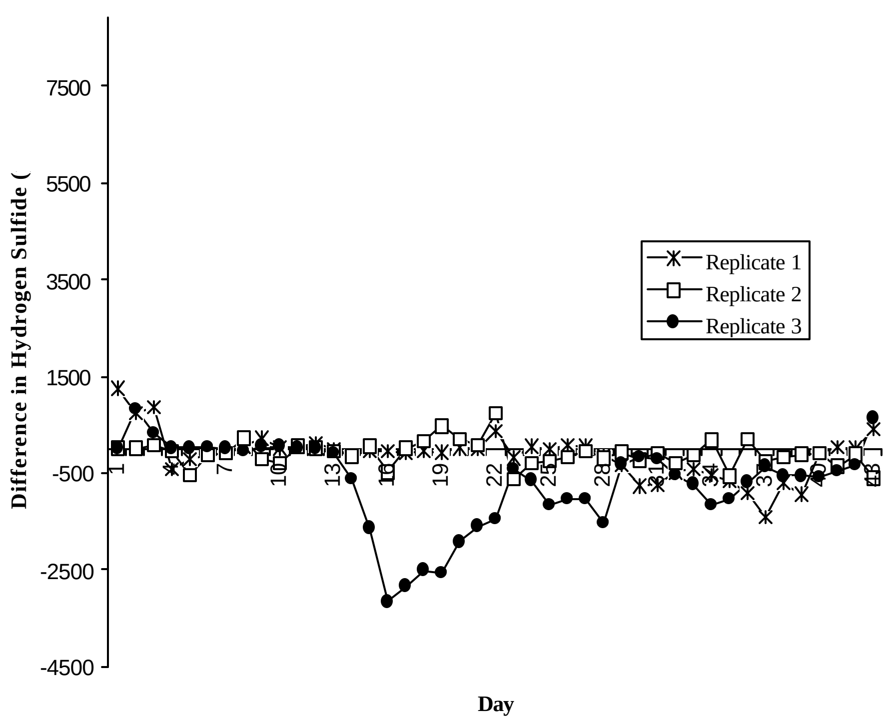
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **SMOC**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	521 ± 144	**32% decrease**	**75%**
Odor Intensity		3.3 ± 0.2	none	none
Odor Offensiveness		-5.8 ± 0.3	none	none
Hydrogen Sulfide (ppb)		699 ± 113	**37% decrease**	**95%**
Ammonia (ppm)		106.3 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.9 ± 0.2	none	none
Ash (%)		2.2 ± 0.03	none	none
Total Nitrogen (ppm)		8173 ± 403	none	none
Ammonia (ppm)		6581 ± 149	none	none
Phosphorus (ppm)	Manure	1917 ± 59	none	none
Potassium (ppm)		3027 ± 98	none	none
Chemical Oxygen Demand (g/L)		116 ± 10	**13% increase**	**75%**
Acetic Acid (mM/L)		154.6 ± 10.7	**11% decrease**	**75%**
Propionic Acid (mM/L)		49.0 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	15.3 ± 0.5	none	none
Butyric Acid (mM/L)		50.6 ± 1.7	none	none
Isovaleric Acid (mM/L)		26.5 ± 8.0	none	none
Valeric Acid (mM/L)		3.4 ± 0.2	**26% increase**	**95%**
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.06 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **SMOC** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **SMOC** and Untreated Columns by Replicate



UC-40™ Microbe Formula

UCI Bioaugmentation Research and Technology
P.O. Box 548
Klamath Falls, OR 97601
541/851-8311 phone
541/851-8312 fax

TECHNOLOGY DESCRIPTION: Bacteria

UC-40™ Microbe Formulas are intentionally selected for their high metabolism, rapid reproduction and ability to consume a wide range of hydrocarbons. They are naturally occurring, saprophytic bacteria, cultured from various locations in nature and will not cause or transmit disease in higher life forms or metabolize living organisms. Strict quality control insures that these formulas remain free of pathogens and contamination throughout the culture, collection, and packaging process.

PRODUCT APPLICATION RATE:

One pound of product per 15-20,000 gallons of lagoon capacity, weekly.

RETAIL PRICE (Year 2001):

$18.00 per pound

RESEARCH RESULTS

95% Certainty

MANURE	-decrease in chemical oxygen demand

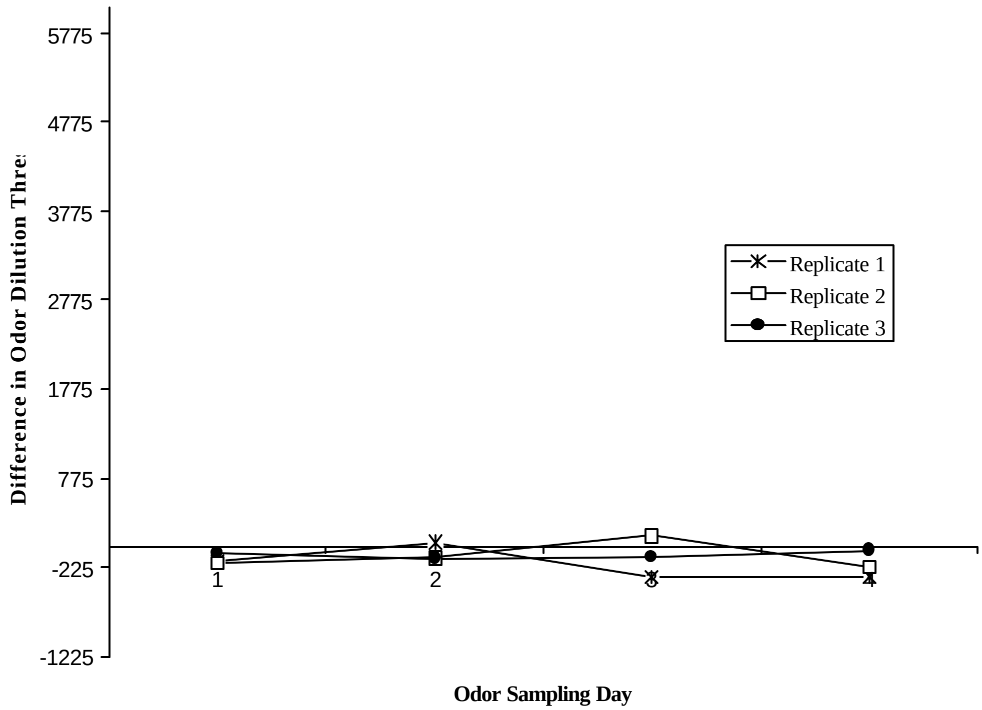
75% Certainty

AIRSPACE	-decrease in hydrogen sulfide concentration
MANURE	-increase in acetic acid and butyric acid concentrations
	-decrease in phenol and indole concentrations

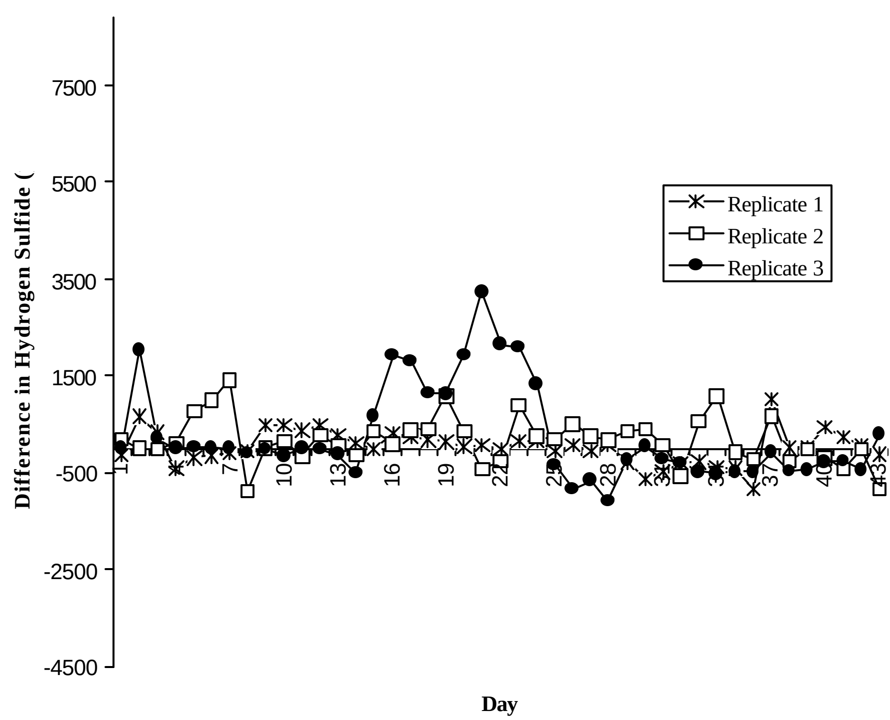
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **UC-40™ Microbe Formula**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	623 ± 144	none	none
Odor Intensity		3.2 ± 0.2	none	none
Odor Offensiveness		-5.6 ± 0.3	none	none
Hydrogen Sulfide (ppb)		941 ± 113	**15% decrease**	**75%**
Ammonia (ppm)		104.1 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.6 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8007 ± 403	none	none
Ammonia (ppm)		6658 ± 149	none	none
Phosphorus (ppm)	Manure	1869 ± 59	none	none
Potassium (ppm)		2891 ± 98	none	none
Chemical Oxygen Demand (g/L)		75 ± 10	**27% decrease**	**95%**
Acetic Acid (mM/L)		193.5 ± 10.7	**12% increase**	**75%**
Propionic Acid (mM/L)		50.0 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.6 ± 0.5	none	none
Butyric Acid (mM/L)		52.4 ± 1.7	**5% increase**	**75%**
Isovaleric Acid (mM/L)		25.7 ± 8.0	none	none
Valeric Acid (mM/L)		2.8 ± 0.2	none	none
Phenol (g/L)		0.04 ± 0.01	**20% decrease**	**75%**
para-Cresol (g/L)	Manure	0.06 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **UC-40 Microbe Formula** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **UC-40 Microbe Formula** and Untreated Columns by Replicate



X12

Earth Balance Technologies, Ltd.
752 Gapter Rd.
Boulder, CO 80303
303/499-3133 phone
303/402-5305 fax

TECHNOLOGY DESCRIPTION: Chemical

Earth Balance X12 is a non-toxic, non-hazardous proprietary treatment chemical. The chemical acts as a catalytic reagent.

PRODUCT APPLICATION RATE:

One gallon of product should be applied per every 10,000 gallons of hog manure as storage volume increases. The rate and frequency may vary depending upon the percent solids of the manure being treated.

RETAIL PRICE (Year 2001):

$80.00 per gallon

RESEARCH RESULTS

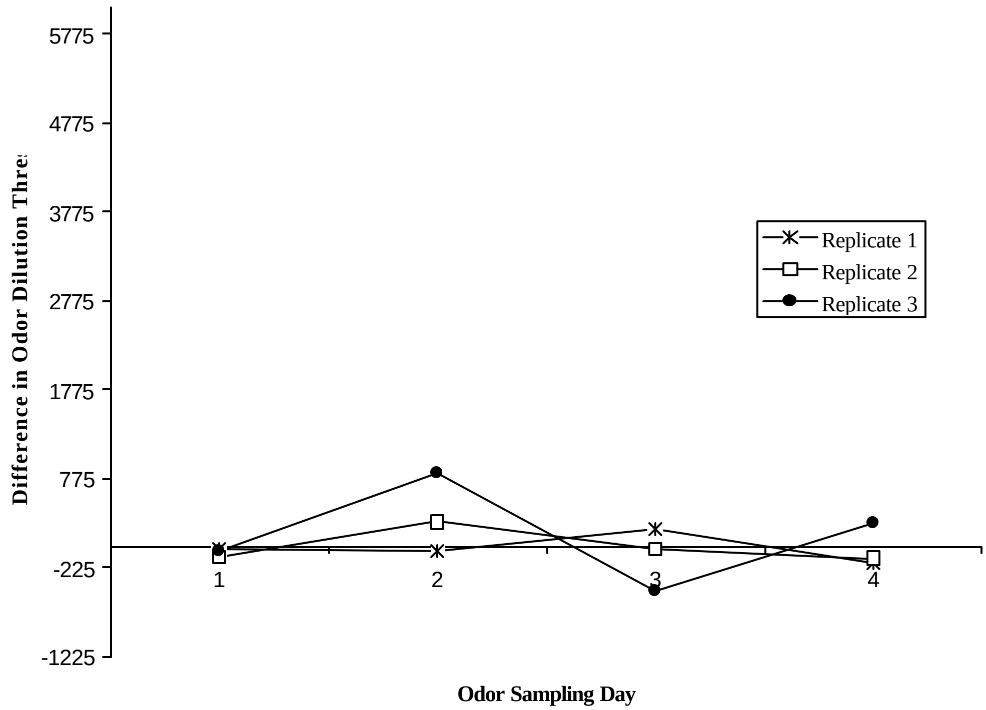
75% Certainty

AIRSPACE	-increase in hydrogen sulfide concentration
MANURE	-increase in acetic acid concentration
	-decrease in indole concentration

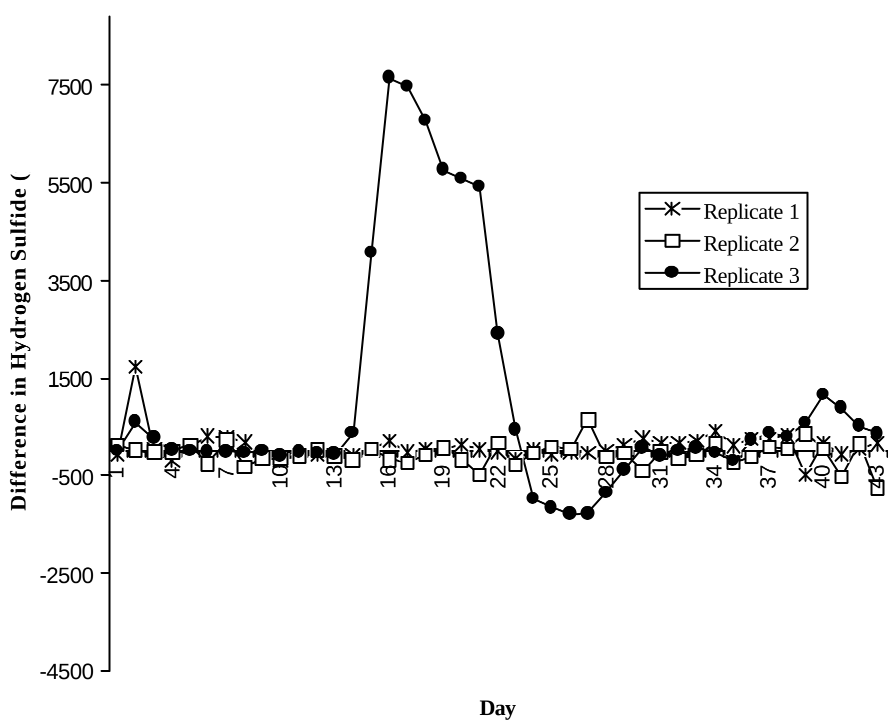
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **X12**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	713 ± 144	none	none
Odor Intensity		3.4 ± 0.2	none	none
Odor Offensiveness		-5.9 ± 0.3	none	none
Hydrogen Sulfide (ppb)		1284 ± 113	**16% increase**	**75%**
Ammonia (ppm)		104.4 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8008 ± 403	none	none
Ammonia (ppm)		6753 ± 149	none	none
Phosphorus (ppm)	Manure	2140 ± 59	none	none
Potassium (ppm)		2931 ± 98	none	none
Chemical Oxygen Demand (g/L)		93 ± 10	none	none
Acetic Acid (mM/L)		187.5 ± 10.7	**8% increase**	**75%**
Propionic Acid (mM/L)		48.3 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	14.4 ± 0.5	none	none
Butyric Acid (mM/L)		52.0 ± 1.7	none	none
Isovaleric Acid (mM/L)		35.3 ± 8.0	none	none
Valeric Acid (mM/L)		2.8 ± 0.2	none	none
Phenol (g/L)		0.05 ± 0.01	none	none
para-Cresol (g/L)	Manure	0.06 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	**50% decrease**	**75%**
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **X12** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **X12** and Untreated Columns by Replicate



ZymPlex

World Wide Enzymes, Inc.
Odor Research Division
Department 40
P.O. Box 025216
Miami, FL 33102
011 506/228-5853 phone
011 506/228-5850 fax

e-mail address: zymplex@costarica.net

TECHNOLOGY DESCRIPTION: Enzyme

ZymPlex is a 100% organic multi enzyme produced through a fermentation process.

PRODUCT APPLICATION RATE:

The product is applied four to six times a day (depending on population density) by an automatic spraying system that would be installed. Sixty-six gallons of Zymplex will treat the fattening (5-6 months) of 3500 pigs. As a pit additive the prescribed rate of application would be one gallon diluted with water 120:1.

RETAIL PRICE (Year 2001):

$45.00 per gallon

RESEARCH RESULTS

95% Certainty

AIRSPACE	-decrease in hydrogen sulfide concentration

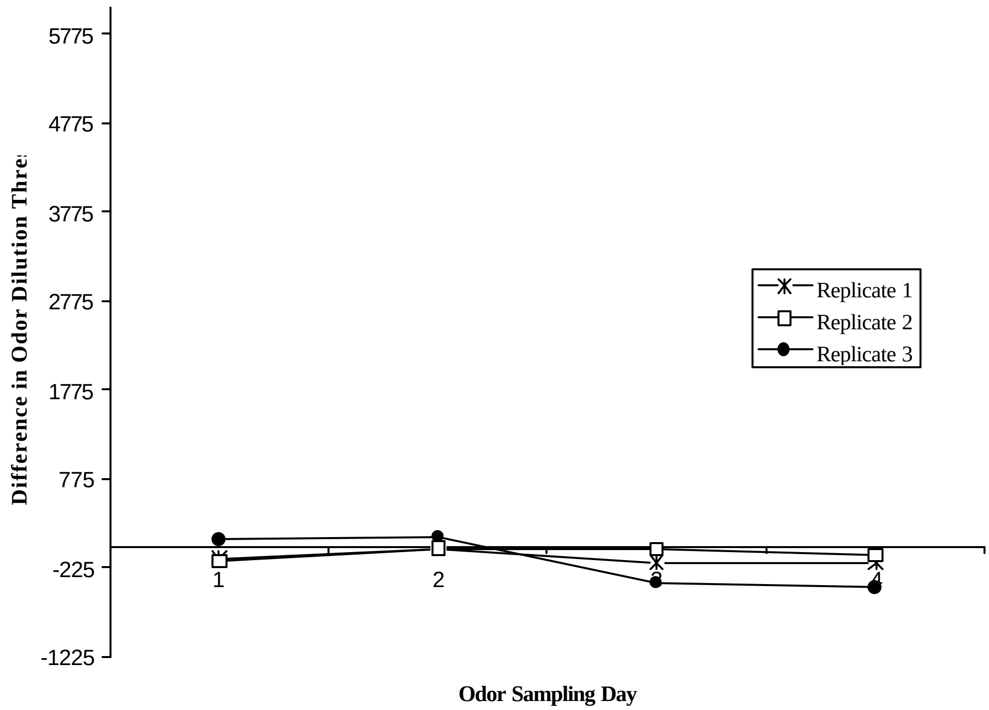
75% Certainty

AIRSPACE	-increase in odor intensity
	-decrease in odor dilution threshold
MANURE	-increase in isovaleric acid and valeric acid concentrations
	-decrease in phenol concentration.

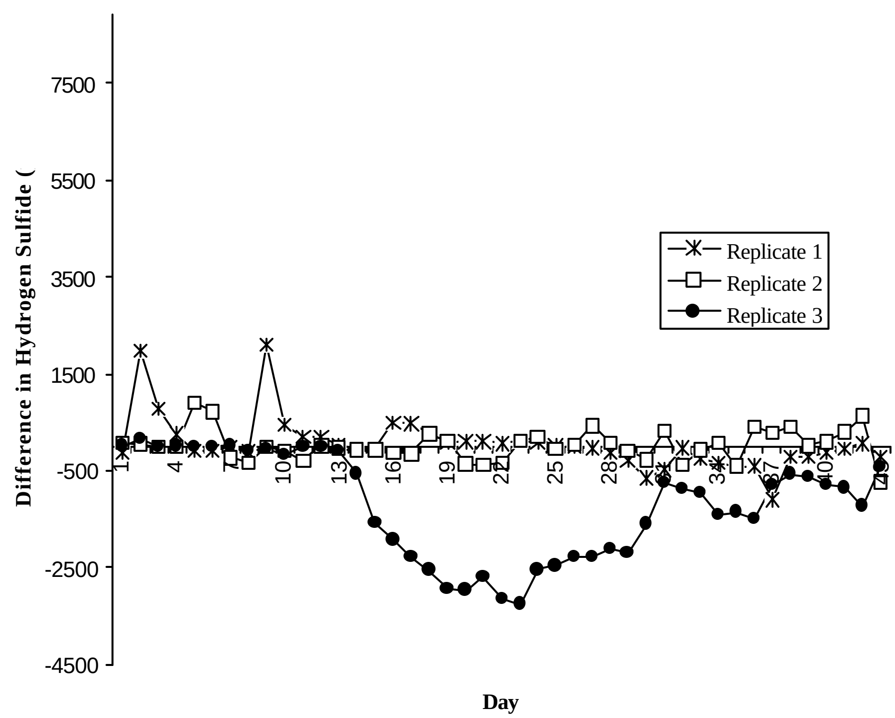
Final Odor, Gas Concentrations, and Manure Characteristic Measures for **ZymPlex**

Measure	Location	Least Squares Mean and Standard Error	Treatment Effect	Effect Certainty
Odor Dilution Threshold	Airspace	552 ± 144	**28% decrease**	**75%**
Odor Intensity		3.5 ± 0.2	**9% increase**	**75%**
Odor Offensiveness		-5.5 ± 0.3	none	none
Hydrogen Sulfide (ppb)		809 ± 113	**27% decrease**	**95%**
Ammonia (ppm)		106.4 ± 1.6	none	none
pH	Manure	7.1 ± 0.04	none	none
Dry Matter (%)		6.7 ± 0.2	none	none
Ash (%)		2.0 ± 0.03	none	none
Total Nitrogen (ppm)		8106 ± 403	none	none
Ammonia (ppm)		6532 ± 149	none	none
Phosphorus (ppm)	Manure	2030 ± 59	none	none
Potassium (ppm)		3008 ± 98	none	none
Chemical Oxygen Demand (g/L)		99 ± 10	none	none
Acetic Acid (mM/L)		184.3 ± 10.7	none	none
Propionic Acid (mM/L)		49.9 ± 1.7	none	none
Isobutyric Acid (mM/L)	Manure	15.3 ± 0.5	none	none
Butyric Acid (mM/L)		50.9 ± 1.7	none	none
Isovaleric Acid (mM/L)		45.8 ± 8.0	**36% increase**	**75%**
Valeric Acid (mM/L)		3.0 ± 0.2	**11% increase**	**75%**
Phenol (g/L)		0.04 ± 0.01	**20% decrease**	**75%**
para-Cresol (g/L)	Manure	0.05 ± 0.02	none	none
Indole (g/L)		0.02 ± 0.02	none	none
Skatole (g/L)		0.02 ± 0.01	none	none

Differences in **Odor Dilution Threshold** between **ZymPlex** and Untreated Columns by Replicate



Differences in **Hydrogen Sulfide** between **ZymPlex** and Untreated Columns by Replicate



Appendix A NPPC Product Testing Protocol
TESTING OF MANURE ADDITIVES FOR ODOR CONTROL

National Pork Producers Council
Odor Solutions Initiative

INTRODUCTION

Modern livestock production facilities are becoming larger with a greater concentration of animals in a given area. Public scrutiny and regulation of these livestock operations is increasing. Many complaints associated with hog confinement operations have been based upon odors. It is thought by many, that reduction in odors would increase the public acceptance of pork production operations. Reduction in odor emission has been proposed through the use of additives. These additives reportedly combat odors and/or odor production, reduce ammonia and hydrogen sulfide emissions, break down solids, and increase the availability of the manure nutrients. Additives come in a variety of forms including chemicals, enzymes, masking agents, bacterial, and biological, or a combination of these.

This protocol was developed for testing the effectiveness of additives in treating swine manure to achieve reduction in odor, ammonia, hydrogen sulfide, VOCs, solids, etc.

MANURE

All manure will be collected from a single liquid manure system and characterized. Any stored manure will be stored at a temperature of 68°F (20°C) ± 2°F for no longer than one (1) day. Pigs shall be fed a standard corn-soybean grow-finish diet and the manure system will not include any type of feed additive or change in diet in an effort to affect the basic qualities of the manure. The manure source could be one of the following so long as the same source is used throughout each trial: scrape, or shallow pit flush type system. The manure should be in barn/pit storage for no less than five (5) days and not more than seven (7) days. The manure supply will not come from a source that may contain disinfectants customarily used in cleaning these facilities.

TESTING CONDITIONS

There will be a distinct operating temperature to be maintained throughout all testing periods. Prior to the start of any trial the room temperatures will be at the designated temperature of 68°F

(20°C) $\pm$ 2°F. Thermometers will be placed around the room containing the reactors, using high/low thermometers which will be read and reset daily.

PERCENT SOLIDS

The percent solids content will be tested for every manure addition. A range of percent solids will be used for testing and therefore a percent solids range will need to be specified for products prescribing based upon percent solids content.

EXPERIMENTAL DESIGN

The experimental design will be an incomplete block design with an untreated control in each block. The number of reactors will dictate the size and number of blocks, dependent upon the lab. The experimental unit will consist of fifteen (15) inch diameter by forty-eight (48) inch sealed reactors.

REACTOR DESIGN AND MANAGEMENT

The reactors will be made of hard plastic with an inner Tedlar lining in the air space. Following each 42-day testing period, the test reactors will be thoroughly cleaned and disinfected prior to the next trial. Each product will be tested in triplicate. There will be randomized product placement within each block. The prescribed quantity and frequency of the manure additive product will be added to the manure in the reactors according to the method and rate recommended by the product manufacturer. The reactors will be loaded to a maximum level of thirty-six (36) inches throughout the test to allow twelve (12) inches of headspace. Within the reactors there must be some mechanism to agitate the reactor prior to the completion of the testing period. This mechanism does not need to be stationary in the reactor, therefore, a single mixer could be used for many reactors when cleaned between each use. This will provide for the agitation and air monitoring of the headspace at the end of the trial. All fixtures and air tubes of the testing reactor will be made of inert materials.

REACTOR LOADING

The test will run for a total of 42 days. Manure will be stirred within the manure source bulk tank prior to and during manure additions to the reactors to ensure homogeneity. Twenty-four inches of manure will be added to each reactor on day zero. Additional manure will be added as follows:

Day	Quantity (inches)	Quantity in reactors (inches)
0	26	26
7	2	28
14	2	30
21	2	32
28	2	34
35	2	36

Two inches of manure equates to 5.76 liters of manure. Each addition will be based upon the volume of manure. Manure additions will be made after scheduled air monitoring, and sampling has been completed on the sampling day. Manure shall be added from a discharge height not to exceed 3” above the manure surface on that day. The ventilation port shall be withdrawn or raised during the addition of manure in order to prevent deposition of manure on the port. Following the addition of manure to a reactor, the loading tube shall be mechanically purged with a tight-fitting, sanitized plunger to ensure that essentially all of the manure loaded through the tube actually enters the test reactor. Following visual inspection of the purged loading tube, the tube shall be withdrawn, cleaned and sanitized. The reactors will not be mixed during scheduled manure additions; the only disturbances during the testing period will be the additions of manure, the additive, and the final day 42 agitation.

MANURE ADDITIVE

Manufacturer’s additives will be added as described by the manufacturer. No special manure conditioning (e.g., pH adjustments or agitation) will be performed for products being tested. Some products may require adding only once at the beginning of the test while others may require more frequent loading. The rates at which the vendors should plan on prescribing should be based upon the amounts prescribed to producers in the field. The analysis of the manure source will not be known prior to the start-up testing. Manufacturers will be informed of the approximate analysis of the source manure prior to testing.

VENTILATION AIR

The airflow through the headspace of the reactors will be continuous at a flow rate of 0.5cfm. The source air will be compressed air treated to remove oils and then filtered through a carbon filter. The source air will come directly from the testing room to ensure that the air temperature is consistent with the treatment temperature. Temperature and relative humidity will be monitored in the ventilation air flowing through the reactors. An inline flow meter will be used prior to each reactor to ensure uniform flow. Air will be exhausted from each reactor headspace at a constant rate equal to the jet momentum number of J=7.5E-05. The air inlet size will need to be adjustable, as well as, telescoping to allow the inlet to be within six (6) inches of the manure surface.

AIR SAMPLES

Monitoring the headspace air will be done during a four (4) hour period each week collecting at least four (4) to six (6) thirty (30) second samples. The equipment to be used for sampling ammonia and hydrogen sulfide will have a minimum accuracy of $\pm$1ppm and $\pm$0.03ppm, respectively and have potential for use in continuous monitoring. The olfactometry samples will be taken midway through the four (4) hour period for direct olfactometry analysis or to fill a 10 liter tedlar bag for analysis by another lab. The bag samples will be shipped to the contracting laboratory for analysis. The bag samples must be analyzed within 24 hours of sampling. Odor threshold will be evaluated in an olfactometry laboratory using an appropriate number of panelists. Odor threshold is defined as the dilution of odorous air with clean air at which the panelist can just sense the odor. The olfactometer will be built in accordance with ASTM standards to evaluate the odor threshold using the forced choice ascending concentration series method. The panelist choices will be recorded electronically. The trained panelists are continually monitored under the QA/QC plan of the lab.

LIQUID SAMPLES

The liquid samples taken on day zero (0) will be in triplicate of the manure source only, not every reactor. The analysis of each reactor to start the experiment is assumed to be similar to the day zero (0) analysis. All tests will be performed in accordance with United States Environmental Protection Agency (USEPA) and/or AWWA Standard Methods for Analysis of Water and Wastewater.

DATA COLLECTION

Data collection will include evaluations of the headspace air and manure within the reactors. The following table shows the frequency of sampling for each parameter.

Time of Data Collection

	Day 0	5	7	12	14	19	21	26	28	33	35	40
Air Samples												
Ammonia(NH3)			CONTINUOUS									
Hydrogen Sulfide(H2S)			CONTINUOUS									
Odor Threshold		♦				♦				♦		♦
VFA/VOC												
Acetic acid		♦				♦				♦		♦
Propionic acid		♦				♦				♦		♦
Butyric acid		♦				♦				♦		♦
cresols		♦				♦				♦		♦
disulfides		♦				♦				♦		♦
trisulfides		♦				♦				♦		♦
phenols		♦				♦				♦		♦
indole		♦				♦				♦		♦
skatole		♦				♦				♦		♦
methylamines		♦				♦				♦		♦
Liquid Samples												
Total Solids(TS)	♦		♦		♦		♦		♦		♦	♦
Volatile Solids(VS)	♦											♦
COD	♦											♦
BOD	♦											♦
pH	♦		♦		♦		♦		♦		♦	♦
Total Phosphorus	♦											♦
ortho-Phosphorus	♦											♦
Total Potassium	♦											♦
Ammonia	♦											♦
Organic nitrogen	♦											♦
TKN	♦											♦
Copper (Cu)	♦											♦
Zinc (Zn)	♦											♦

Time of Data Collection

	Day											
	0	5	7	12	14	19	21	26	28	33	35	40
Electric conductivity (EC)	♦											♦
Chloride (Cl)	♦											♦
Sulfate	♦											♦
Total dissolved sulfide	♦											♦
Calcium (Ca)	♦											♦
Magnesium (Mg)	♦											♦
VFA	♦											♦
Acetic acid	♦											♦
Propionic acid	♦											♦
iso-butyric acid	♦											♦
n-butyric acid	♦											♦
2-methyl butyric acid	♦											♦
3-methyl butyric acid	♦											♦
n-valeric acid	♦											♦
isovaleric acid	♦											♦
VOC												
p-cresol	♦											♦
m-cresol	♦											♦

The sampling and analysis procedures to be use on day 42 require vigorous agitation of the manure without opening the reactors. During and following agitation, air quality will be monitored for a minimum of one (1) hour and sampled for olfactometry analysis. The manure samples will be taken upon emptying the reactors. Mixing manure prior to liquid sampling will be done to ensure the retrieval of a representative sample. All labs doing analysis will be certified labs or will be operating based upon ASTM Standards. Every lab will be required to have QA/QC plans, which will be monitored by a third-party verifier.

SOLIDS CHARACTERIZATION

Solids characterization testing will be done using a glass column. The following measurements will be taken at minimum:

Time to settle

Depth of solid layers

Total solids (average)

Volatile solids (average)

Total Suspended solids (average)

Solids density (average)

These measurements of the manure collected on a weekly basis will be taken prior to use in the product testing.

REQUIREMENT FROM MANUFACTURER

Prior to testing each product a disclosure of the ingredients in the product and potential end products, but not the recipe, is required to insure the safety of laboratory personnel. If a Material Safety Data Sheet (MSDS) is not available, one must be applied for due to the potential health risks posed to the producers, animals, and consumers. If a product does not have a safety sheet, it will not be tested. All bacterial products must supply the bacterial count in the product, the approximate number of strains and give a general description of the bacteria present. The total cost of the product to the producers must be reported. The product to be used in the testing must come directly from the manufacturer in a sealed container, just as the producer would receive the product. A sample of every product, with container, will be held and stored by NPPC. Testing is limited to those products which vendors proposed and are currently on the market. Any further testing of other products may be available at a cost.

LAB REPORTING

The contracted lab must supply developed SOP, GLP, and QA/QC documentation of the protocol. Laboratory standards will be included with every assay, and these results will be included with the reports to NPPC. The data supplied to NPPC will be in spreadsheet computer form.

REPORTING

Test labs will confidentially report results to NPPC staff. Data results will be reported to the manufacturers by NPPC. The final public industry report will be a summary of the overall testing period. In the final report will be the comparisons of all the results for the products tested. Each product will be rated high, average, or low for the performance parameters measured including cost to the producer per pig. Also reported will be the actual prescribed rate of product and calculations, the method and frequency of product addition, and the cost of the product quoted to NPPC. The ratings of each product will be based upon comparison or the untreated control and the product results. The results of this testing can not be compared to or used in conjunction with any other testing. The NPPC OSI committee will do final classification of products. A final public industry report will be prepared and published by NPPC.

COST OF ANALYSIS

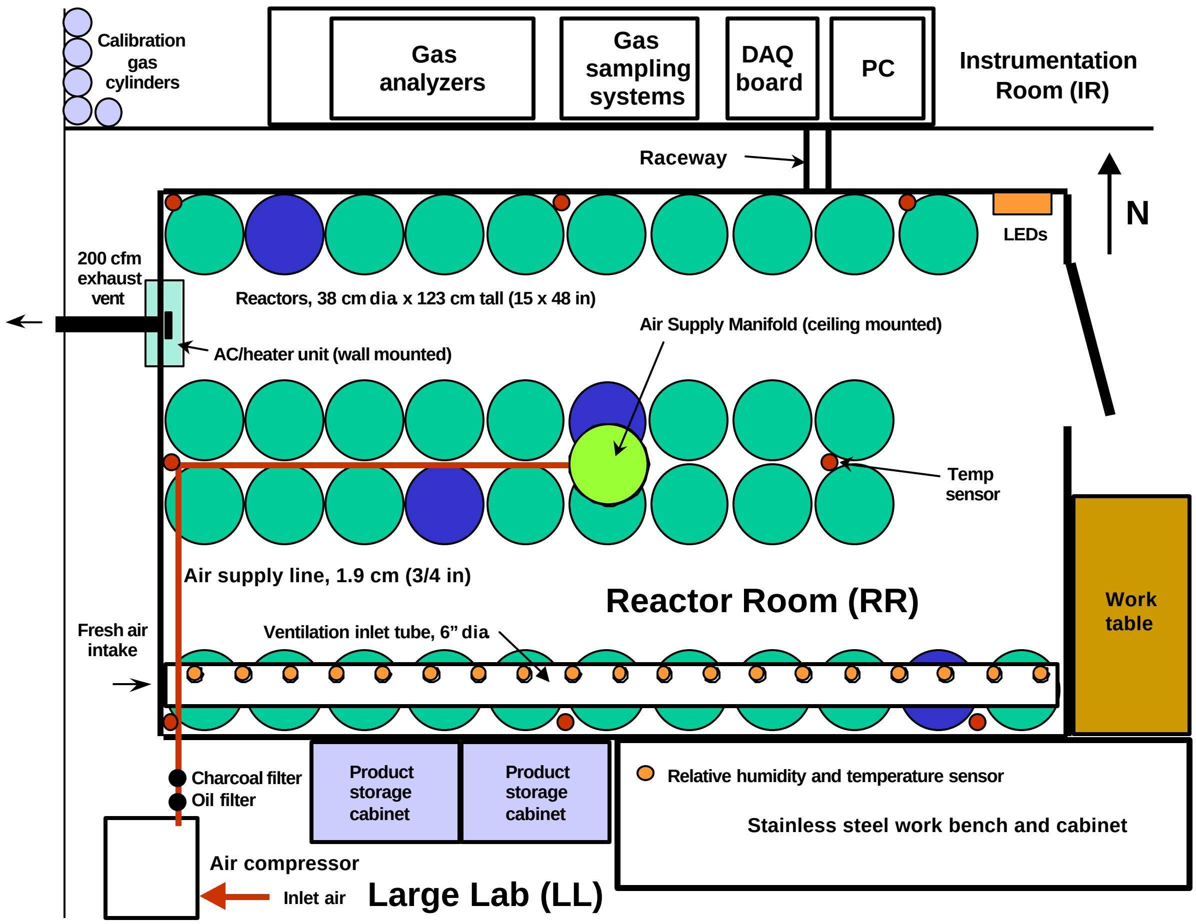
There will be no cost to the product supplier for this testing in conjunction with the NPPC Odor Solutions Initiative. The OSI committee asks for full cooperation with regard to disclosure of information on the product, its application and assistance as needed from the contracted laboratory.

FURTHER TESTING OF ODOR CONTROL PRODUCTS/PROCESSES

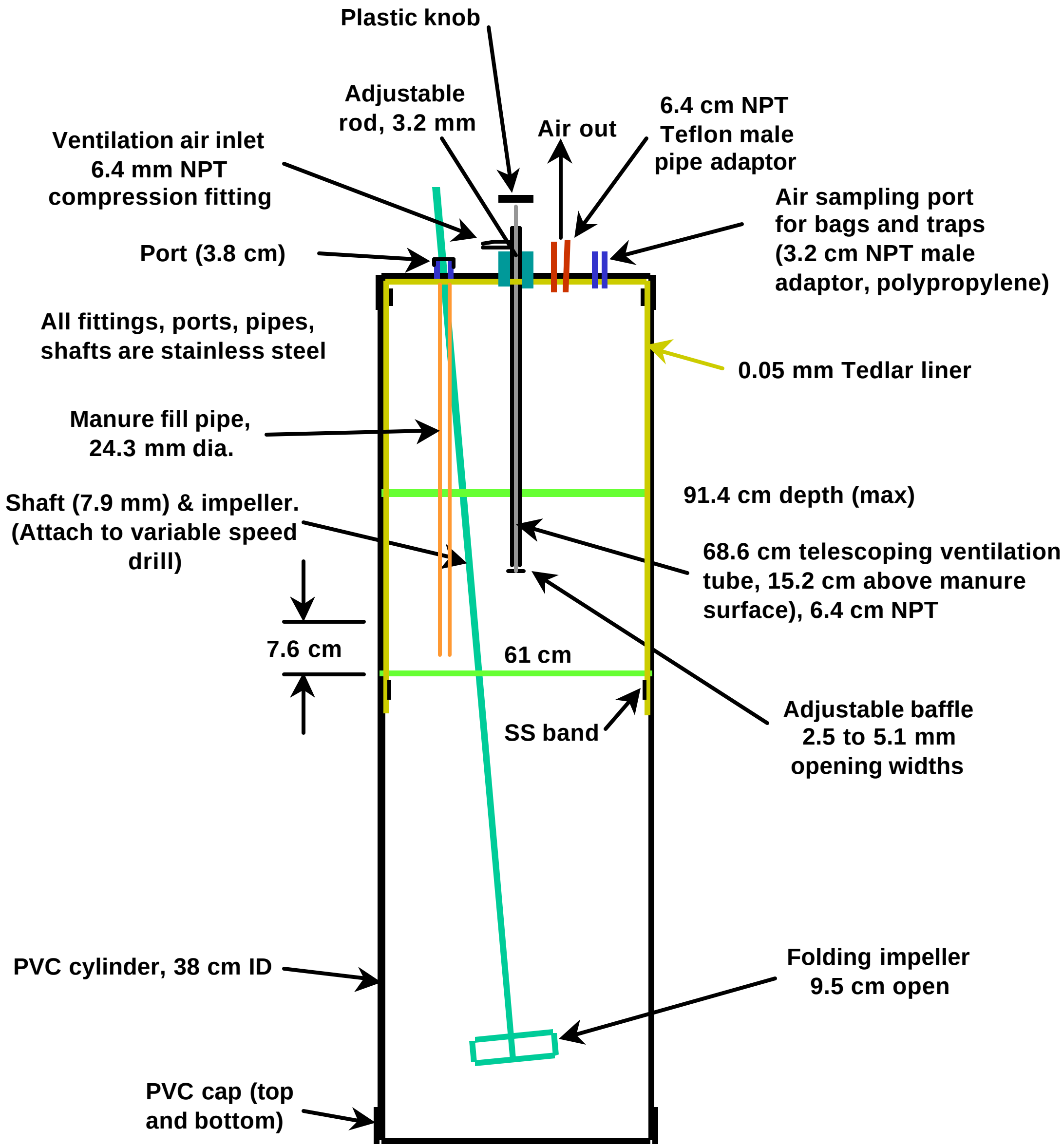
The testing described in this protocol is specifically for the products identified in the title, manure additives. Testing of any other type of product/process will not be included under this protocol.

Appendix B Diagrams and Photographs

Layout of Test Facility



Schematic of Reactor (test reactor)



Weekly Manure Addition

Odor Measurement with a Dynamic Dilution Forced-Choice Olfactometer

Glossary of Terms

acetic acid (C2)

CH_3COOH – clear, colorless, liquid with a pungent odor; mixable with water or alcohol

airspace

see "headspace"

ammonia (NH_3)

colorless, alkaline gas; dissolves easily in water; has a characteristic pungent odor; lighter than air; formed during decomposition of most nitrogenous organic material

ash, %

incombustible matter remaining after a substance has been incinerated; consists of minerals such as phosphorus, potassium, calcium, and magnesium

bacteria

extremely small, simple, one-celled microorganisms

n-butyric acid (C4)

$CH_3CH_2CH_2COOH$ – colorless, combustible liquid; dissolves in water, alcohol, and ether; used in synthesis of flavors, in pharmaceuticals, and in emulsifying agents

chemical oxygen demand (COD)

a measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test.

p-cresol (4-methylphenol)

$CH_3C_6H_4OH$ – poisonous, colorless compound; used in production of phenolic resin, tricresyl phosphate, disinfectants, and solvents

column

see “reactor”

dry basis (db)

data expressed on a 100% dry matter basis

dry matter (DM)

same as total solids; the residue remaining when water is evaporated away from a sample of water, slurry, wastewater, other liquids or semi-solid masses of material and the residue is then dried at a specific temperature and time; usually expressed as percentage or mg/L

enzyme

catalytic proteins produced by living cells; mediate and promote chemical processes without being altered or destroyed

Flame Ionization Detector (FID)

device in which the measured change in conductivity of a standard flame (usually hydrogen) due to the insertion of another gas or vapor is used to detect the gas or vapor

Flame Photometric Detector (FPD)

instrument used in flame photometry, in which a solution of the chemical being analyzed is vaporized; the spectral lines resulting from the light source going through the vapors enters a monochromator that selects the bands of interest

headspace

air-occupied airspace in the reactor between the manure surface and the top of the reactor

hydrogen sulfide (H_2S)

flammable, toxic, colorless gas with offensive odor of rotten eggs; dissolves in water and alcohol; used as an analytical reagent, a sulfur source, and for purification of hydrochloric and sulfuric acids

iso-butyric acid (iC4)

$(CH_3)_2CHCOOH$ – colorless liquid; dissolves in water, alcohol, and ether; used as a chemical intermediate and disinfectant, in flavor and perfume bases, and for treating leather

iso-valeric acid (iC5)

$(CH_3)_2CHCH_2COOH$ - colorless liquid with disagreeable aroma; dissolves in alcohol and ether; found in valeriana, hop, tobacco, and other plants; used in flavors, perfumes, and medicines

indole

$C_6H_4(CHNH)CH$ – product of the decomposition of the amino acid tryptophan; formed in the intestine during putrefaction and by certain bacteria; has a characteristic fecal odor

odor detection threshold (ODT)

number of dilutions of sample air with odor-free air required for an odor to be just detected by 50% of odor evaluation panel members

phenol (carbolic acid)

C_6H_5OH – white, poisonous, corrosive crystals with sharp, burning odor; soluble in alcohol, water, ether, carbon disulfide, and other solvents; used to make resins and weed killers, and as a solvent and chemical intermediate

pH

term used to describe the hydrogen-ion activity of a system; a solution of pH 0 to 7 is acid, pH of 7 is neutral, pH 7 to 14 is alkaline/basic

phosphorus (P)

atomic number 15, atomic weight 31; a nonmetallic element of the nitrogen family that occurs widely, especially as phosphates

potassium (K)

atomic number 19, atomic weight 39; a silver-white soft light low-melting univalent metallic element of the alkali metal group that occurs abundantly in nature especially combined in minerals

propionic acid (C3)

CH_3CH_2COOH – water- and alcohol-soluble, clear, colorless liquid with pungent aroma

reactor

testing apparatus used for evaluation of individual manure pit additives; an enclosed vessel with ventilation inlets and outlets. A simulated manure pit

settled solids, % (SS)

suspended solids heavy enough to settle

skatole

C_9H_9N white, crystalline compound; dissolves in hot water; has an unpleasant fecal odor

total Kjeldahl nitrogen (TKN)

analytical procedure to determine total nitrogen content of water, wastewater, slurry, other liquids, semi-solid and solid materials through acid digestion and alkaline distillation

total solids (TS)

total content of both suspended and dissolved solids

total suspended solids (TSS)

fraction of total solids that are not dissolved and can be filtered

n-valeric acid (C5)$CH_3(CH_2)_3COOH$ – combustible, toxic, colorless liquid with a penetrating aroma; soluble in water, alcohol, and ether; used to make flavors, perfumes, lubricants, plasticizers, and pharmaceuticals.

volatile solids (VS)

solids that are removed (volatilized) when manure is heated in a furnace at 500-600 °C; includes carbon, oxygen, hydrogen, and nitrogen

wet basis (wb)

data expressed on an "as is" basis; concentrations in substances as sampled

COMMON CONVERSION FACTORS

Multiply	By	To Get
cubic ft. (H_2O)	7.48	gallons
cubic ft. (H_2O)	62.4	pounds
gallons (H_2O)	8.34	pounds
parts per million (ppm)	0.00834	lb./1,000 gal.
percent	83.4	lb./1,000 gal
P (phosphorus)	2.27	P_2O_5
K (potassium)	1.20	K_2O