NC STATE UNIVERSITY

Animal and Poultry Waste Management Center

Ag ProVision, LLC

Agricultural Waste Solutions

Ajinomoto Heartland, LLC

Alltech, Inc.

Cavanaugh and Associates, P.A.

International Technology Systems, Inc.

Iowa State University

Michigan State University

Mississippi State University

North Carolina Pork Council

North Carolina Poultry Federation

North Carolina's Southeast

North Carolina State University

The Ohio State University

Oklahoma State University

University of Georgia

University of Kentucky

Virginia Polytechnic Institute and State University

ANNUAL REPORT

November 2004

North Carolina State University
College of Agriculture and Life Sciences

Box 7608
Raleigh, NC 27695-7608

WASTE MANAGEMENT PROGRAMS
COLLEGE OF AGRICULTURE & LIFE SCIENCES

Animal and Poultry Waste Management Center (APWMC)
Campus Box 7608
North Carolina State University
Raleigh, NC 27695-7608

Web Site: http://www.cals.ncsu.edu/waste_mgt/

APWMC Director
Mike Williams, North Carolina State University
Email: Mike_Williams@NCSU.EDU
Phone: 919-515-5386
Fax: 919-513-1762

APWMC Associate Director
Leonard Bull, North Carolina State University
Email: Leonard_Bull@NCSU.EDU
Phone: 919-515-6836
Fax: 919-513-1762

APWMC Administrative Manager
Brenda Boykin
Email: Brenda_Boykin@NCSU.EDU
Phone: 919-513-4611
Fax: 919-513-1762

Fifty copies of this public document were printed for $207.50, or $4.15 per copy.

Executive Summary

This report is the eighth in a series of Annual Reports describing annual activities associated with the North Carolina State University (NCSU) Animal and Poultry Waste Management Center (APWMC). The APWMC was established in 1996 and operates per the University of North Carolina system protocol governing Centers, Institutes, and Laboratories. The primary goal of the APWMC is to support research, demonstration, and educational efforts related to environmental impacts of livestock and poultry production agriculture. Focus is on technology development and environmental performance verification of technologies that contribute to sustainable agribusiness in the state and nation.

Since 1996 the APWMC has leveraged state and USDA special grant funding to build research-based partnerships with land-grant universities in the states of Alabama, Georgia, Iowa, Kentucky, Michigan, Mississippi, Missouri, Ohio, Oklahoma, Oregon, and Virginia, as well as with a number of agribusiness companies, environmental groups, and commodity associations in the pork and poultry industries. Examples of sponsored projects include the following:

- Decommissioning anaerobic lagoons,
- Stabilization of manure nutrients in soil,
- Co-combustion of animal manure for energy recovery,
- Development of farm-level odor reduction systems,
- Development of methodologies for the handling of animal mortalities to convert them to value-added feed grade products,
- Assessment of alternative bedding and litter products for use by the poultry industry,
- Commercial scale development and environmental performance standard verification involving emissions of odor, pathogens, emissions of ammonia as well as economic feasibility analysis for approximately 20 experimental animal waste technologies.

The report herein concisely summarizes financials, progress and accomplishments for APWMC currently active sponsored projects. Detailed reports are available in separate documents and may be obtained by contacting the APWMC administrative office located in Scott Hall on the NCSU north campus (phone 919-513-4611). Much of the detailed information is also available on the NCSU College of Agriculture and Life Sciences Waste Management Programs Web site http://www.cals.ncsu.edu/waste_mgt/.

Contents

Animal and Poultry Waste Management Center Funding Information from 1994-2004

	1993/ 1994	1994/ 1995	1995/ 1996	1996/ 1997	1997/ 1998	1998/ 1999	1999/ 2000	2000/ 2001	2001/ 2002	2002/ 2003	2003/ 2004
Memberships[1]				$95,000	$150,000	$160,000	$160,000	$180,000	$185,000	$160,000	$110,000
State[2]			$1,022,799[b]			$735,000[b]				$206,872	$22,327
Federal[3]	$880,000[a]	$806,249[a]		$25,000	$280,432	$75,000	$467,800	$467,750	$1,429,537	$917,108	
Other University Support[4]	$9,000	$154,264		$249,654	$16,820	$219,320	$5,000	$14,000	$12,804		
Industries/Commodities[3]		$133,120	$37,780		$96,492	$148,365	$767,404	$6,000,000[c]	$900,000[d]		$1,013,854
Any Other[4]		$255,000			$24,900		$31,450	$8,997	$1,460	$1,841	$17,460

[1]Includes in-kind Contribution
[2]Contracts and Grants. Does not include APWMC administrative program support
[3]Grants
[4]Resources allocated to other programs in which APWMC director and/or associate director is a collaborator
[a]Primary resource allocation for APWMC Waste Processing Facility infrastructure
[b]Primary resource allocations for innovative animal waste technology development/demonstration program
[c]N.C. Attorney General/Smithfield Foods Agreement allocation for Environmentally Superior Technologies initiative
[d]N.C. Attorney General/Premium Standard Farms Agreement allocation for Environmentally Superior Technologies initiative

Note:
1. USDA grant award for fiscal year 2003-04 was awarded 05-01-03 ($459,716)
2. Department of Transportation Proposal pending for fiscal year 2003-04 ($300,000)

Volatile Emissions from Composting Dairy Manures as Indicators of Bioprocesses and Objectionable Odors

Funding:
$38,000

Funding Source:
membership

SUMMARY REPORT

It is with pleasure that the authors submit this fourth year annual report representing the results of research efforts directed toward a quantitative understanding of bioprocesses that influence the emissions of objectionable odors from fresh, stored, and composting dairy manures. All of the originally proposed objectives of this project were completed by March 31, 2003. Through project efficiencies and the ability to leverage additional funds we completed the original objectives under the allotted APWMC funds. Therefore, we requested and were granted, a no-cost extension in order to conduct additional research relating to odors from livestock manures. The following experiments have been conducted, and data analysis will be completed by the project termination date of December 31, 2004.

Results from the manure aging studies conducted during the first two years of the study provided quantitative information on the rates that the different VFAs, phenolic, and indolic odorants increased in concentration when large batches of manure were sampled at intervals. Whereas, these studies provided the changes in concentrations of each odorant, determinations of the anaerobic mass of manure was impossible. During this period laboratory scale manure aging experiments were conducted to provide better estimates of the mass of the malodorous chemicals produced chronologically with aging.

Many of the experiments originally conducted for this APWMC grant were based on manures collected from two barns; one had animals that were fed high (18.7%) protein and the other low (13%) protein. Ammonia emissions from fresh manure from the animals fed high protein were significantly higher than the low protein fed animals. Concentrations of VFAs, phenols, and indoles were not consistently related to the protein content of the rations fed to these groups of animals. During this period a

Investigators:
Lynn B. Willett, Ohio Agricultural Research and Development Center

David L. Elwell, Ohio Agricultural Research and Development Center

Harold M. Keener, Ohio Agricultural Research and Development Center

Diane C. Borger, Ohio Agricultural Research and Development Center

Volatile Emissions from Composting Dairy Manures as Indicators of Bioprocesses and Objectionable Odors

Latin-square, complete collection, feeding trial experiment was conducted to determine if silage sources and protein concentrations (17.5% vs 14%) influenced the presence of odorants in manure. Valerate was increased ($P<0.01$) and iso-butyrate was decreased ($P<0.04$) by higher protein rations. The other VFAs quantified were not different. Analysis of data relating to phenols and indoles is still in progress.

Results of the original experiments, pilot-scale and full-scale windrows, showed that the odorants studied could be eliminated rapidly by maintaining a minimal aerobic environment. Unfortunately, our results showed that large quantities of ammonia were released when manures were managed aerobically. This agreed with the majority of similar studies that have been published. In order to address environmental and potential regulatory emissions concerns, closed systems of manure management may become necessary. As demonstrated in our original studies, anaerobic aging of manures produced large quantities of odorous compounds, particularly VFAs. The latter are known to be precursors for methane production in anaerobic digesters. To date 13 experiments have been conducted with laboratory-scale anaerobic digesters to monitor the VFA, phenolic, and indolic content of manures and food wastes, before and during anaerobic treatment, along with the production of methane, hydrogen, and carbon dioxide. Preliminary results have shown that changes in the digester feedstock and operating conditions can greatly alter the formation of VFAs and subsequently the formation of methane and/or hydrogen. As of this date many samples must still be analyzed, and statistical analyses have not been conducted.

This project will be formally completed December 31, 2004. Studies in progress at this time will be completed by that date. The support of the APWMC has provided the basis to obtain further continued funding for our manure odor and processing research.

Farm-Level Implementation of the Swine Odor Reduction Bioreactor System (SORBS)

Funding:
$35,000

Funding Source:
membership

SUMMARY REPORT

The pilot SORBS is located on a commercial swine production facility near Pheba, MS. The installation includes: 1) a 5,000 gallon wastewater storage tank; 2) a wastewater distribution system; 3) attached growth bioreactors; 4) a concrete bioreactor pad and wastewater collection sump; 5) pumps for recirculating wastewater in the bioreactor and delivering untreated wastewater to the storage tank; and 6) pump control electronics. Baseline analyses (10/02/02 - 10/29/03) of the anaerobic lagoon effluent being treated by the SORBS showed 4.59 mS/cm, 1,112 mg/l, 271 mg/l, 70 mg/l, 2,640 mg/l, and 450 mg/l for conductivity, COD, ammonia, ortho-P, TS and TSS, respectively. Major construction elements of the Swine Odor Reduction Bioreactor System (SORBS) were completed in November 2003. The first trial run was completed on December 18-19, 2004. Freezing temperatures delayed start-up of the SORBS until March 2004.

Data collected from March through September 1, 2004 showed that the SORBS reduced COD, ammonia, and ortho-P by 15.8, 63.7, and 14.1%, respectively with a throughput of about 4,800 gallons per day. During this same period, nitrate increased by 349%. Dissolved oxygen values of 0.16, 4.3, and 6.3 mg/l were recorded for the lagoon, storage tank, and sump, respectively. The styrofoam beads in the bioreactor did not accumulate appreciable cell mass (TS increased by 1.27%, while TSS decreased by 22.6%). E. Coli counts were reduced by an average of 62% for a testing period from April 28 through May 26, 2004. Fecal streptococci values ranged from a 65% reduction to an increase of over 1,000%.

The Swine Odor Reduction Bioreactor System

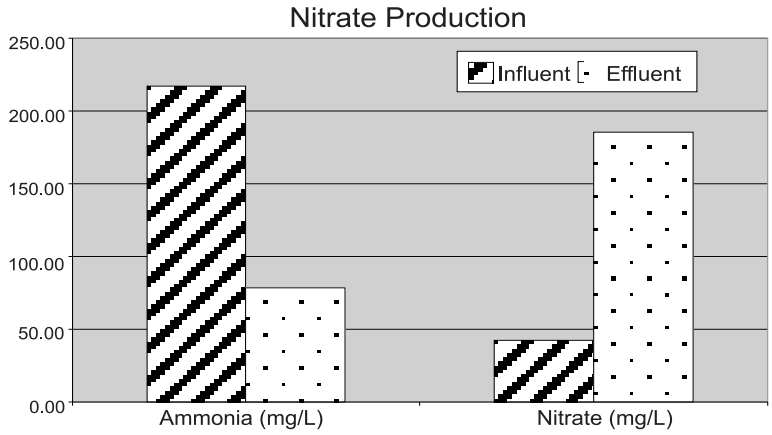
Investigators:
Timothy N. Burcham, University of Tennessee

William R. McCulley, Mississippi State University

Jerry A. Gilbert, Mississippi State University

Farm-Level Implementation of the Swine Odor Reduction Bioreactor System (SORBS)

A Y-filter rectified debris clogging the distribution nozzles. Major mechanical/electrical problems occurred in September 2004. The pump that introduced untreated lagoon effluent into the SORBS seized due to struvite accumulation, while the pump responsible for recirculating wastewater through SORBS had a catastrophic mechanical failure in late October 2004. Testing will resume when this pump is repaired or replaced



Development of an Economically and Environmentally Responsible Technique for Decommissioning Anaerobic Swine Waste Lagoons

Funding:
$18,500

Funding Source:

Animal and Poultry Waste Management Center Phase I: November 2001 to October 2002, $15,000; November 2002 to October 2003, $16,220. The North Carolina Foundation for Soil and Water Conservation provided $12,500 to modify procedures utilized for the large lagoon in closing the smaller lagoon. Current funding from the North Carolina Pork Council is $25,000. The North Carolina Department Environment and Natural Resources, Division of Water Quality, Groundwater Section installed the wells at no cost.

SUMMARY REPORT

An animal waste lagoon closure technique that can serve as an alternative to the currently permitted procedure, which requires removal of all bottom sludge, was evaluated.

This Ecolotree phytoremediation technology has been utilized successfully for landfill closure and contaminated soils. The Ecolotree Cap system employs perennial, fast growing and deep rooting trees to transpire sufficient moisture so that water movement through the lagoon and sludge layer to groundwater is virtually eliminated. An inactive swine waste lagoon 75 ft x 195 ft with about 5 ft of sludge (this lagoon was constructed in 1980 and not loaded with manure during the past 3 to 5 years) was selected. Lagoon liquid was pumped to a new, larger lagoon. Filling of the lagoon with on-site soil was delayed by heavy rains, which began in October 2002. During December 2003, 322 popular trees comprised of rooted and unrooted, 10-12 ft stock were placed on 60 square foot per tree spacing. Following tree planting a combination of grass and winter wheat was planted between tree rows to establish an undercover to reduce erosion. The North Carolina Department of Environment and Natural Resources, Division of Water Quality, Groundwater Division, installed nine 2-inch diameter wells to at least 5 feet below water table to determine groundwater quality changes. Results to date show that nitrate has not increased. The adjacent smaller lagoon, approximately 60 ft x 70 ft x 5 ft, has been drained and was backfilled with soil prior to the Field Day held on August 12, 2004. Tree growth and leaf cover were good at the time of the Field Day, and 15 of the original planted trees that had died were replaced and growing well. The Field Day received excellent media coverage with even an article in USA Today.

Investigators:
Ronald Miner, Oregon State University

Louis A. Licht, Ecolotree, Inc.

Frank Humenik, North Carolina State University

Development of an Economically and Environmentally Responsible Technique for Decommissioning Anaerobic Swine Waste Lagoons

Final Project Activities

Groundwater has been sampled on 4/16/03, 5/27/03 and 6/24/04 for TKN, NH3, NO2 + NO3, TP, Cl, TKN, fecal coliform, total coliform, Mg, Cu, Zn, Na, pH and water level. This sampling program was established by the North Carolina Department of Environment and Natural Resources Division of Water Quality, Groundwater Division to determine if this alternative lagoon closure technique can be permitted. Preliminary analysis is that nitrate concentrations are not building up in groundwater. Tree growth has been the best around the outside perimeter and then diminishes toward the top where some sludge is closer to the soil surface. Cooperative efforts have been developed with the Department of Forestry at NCSU to provide an evaluation of tree growth and causes for tree mortality. Cooperative efforts with North Carolina NRCS, Nash County Cooperative Extension, the North Carolina Department of Environment and Natural Resources Division of Water Quality, Groundwater Division and the North Carolina Pork Council are maintained to continually evaluate groundwater changes and tree growth for both the large and small lagoon. Groundwater sampling will continue as long as possible to provide data to effectively evaluate this procedure as an alternative closure technique.

Planting trees at the Hanor Farms site

Effect of Conventional and Enzymatic Hydrolysis on the Pepsin Digestibility of the Hard Tissues from Mechanically Deboned Spent Laying Hens

Funding:
$11,075

Funding Source:
membershipl

SUMMARY REPORT

The goal of this project was to develop alternative methods utilizing existing technologies for converting mortalities or spent laying hens into quality protein products. Specifically, we have examined several processing techniques for utilizing the bones and feathers to produce a protein source for ruminant diets.

Mechanical deboning was utilized to separate hard tissues (bones and feathers) from soft tissues. The hard tissues were then frozen for storage. Subsequent hydrolysis using both conventional techniques (moist heat and pressure) and enzymatic hydrolysis were employed to improve the digestibility of the final product.

Using the pilot cooker at the Animal and Poultry Waste Management Center Waste Processing Facility, two batches of material were hydrolyzed at 30 psi for 45 min. Samples of the cooked material were removed as it came out of the cooker and before the addition of keratinase enzyme. Keratinase was then added to give a final concentration of 1% enzyme. Samples were removed at 1h, 2h, 4h, and 20h after the addition of the enzyme. All samples were frozen and then freeze dried. Samples of the raw material and of the cooked/enzyme treated material were sent to Woodsen-Tenet Laboratory (Goldston, NC) for 0.02% pepsin digestibility analysis. Additionally, samples from the second batch of hydrolyzed material were sent to Dr. Carl Parsons (University of Illinois, Urbana-Champlain) for determination of true amino acid digestibility.

Crude protein (CP) content of the raw material was 58%, as analyzed in our labs. Pepsin digestibility values are shown in Table 1. While there were some statistically significant differences in the

Investigators:
Sharon Freeman, North Carolina State University

Matthew Poore, North Carolina State University

Peter Ferket, North Carolina A&T State University

Teena Middleton, AgProVisions, LLC

Kenneth Anderson, North Carolina State University

Jason Shih, North Carolina State University

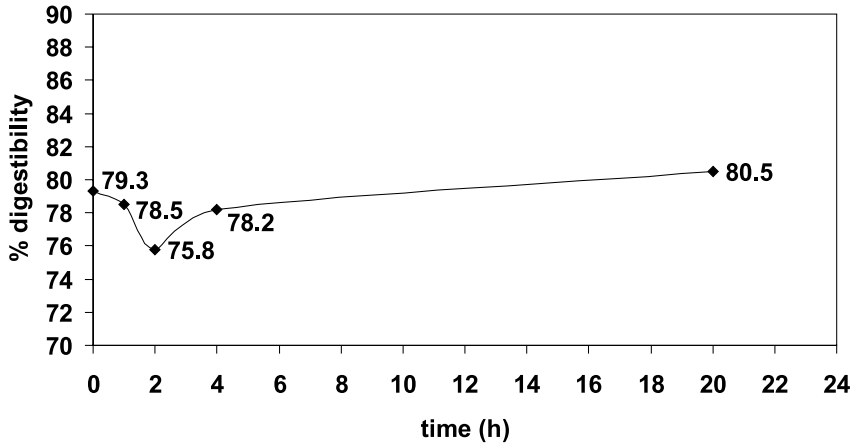
Effect of Conventional and Enzymatic Hydrolysis on the Pepsin Digestibility of the Hard Tissues from Mechanically Deboned Spent Laying Hens

pepsin digestibilities ($P<.05$), these were largely the result of small standard error and are not likely to have biological significance. There were no significant differences among true amino acid digestibility results as a result of exposure to keratinase for varying periods of time ($P>.10$). These data are shown graphically in Figure 1. These data show no advantage to treating conventionally hydrolyzed bones and feathers with keratinase enzyme.

Table 1. Pepsin digestibility of hard tissues with and without keratinase enzyme

Enzyme hydrolysis time (h)	.02% pepsin digestibility (%) (SEM=0.12)
Pre-hydrolysis (raw)	72.5[a]
0	87.2[b]
1	86.3[c,e]
2	87.1[d]
4	84.6[d]
20	86.2[e]

Figure 1. Average true amino acid digestibility of hydrolyzed hard tissues



Compost: An Efficient Nutrient Management Tool for Animal Waste

Funding:
$31,011

Funding Source:
membership

Investigators:
Kenneth R. Baldwin, NC A&T State University

Noah Ranells, North Carolina State University

SUMMARY REPORT

Progress Toward Objectives: *Examine three different composts and evaluate the availability of the organic N in the composts for crop growth, and the relationships of the C:N ratio of the compost and other compost physical characteristics to the mineralization of compost organic N.*

Three composts were donated to the research project from McGill Environmental, the City of Sanford, and Dean Brooks Contractors. NCDA and NCSU laboratories have evaluated these composts for chemical and physical properties, respectively. In the spring of 2003, three composts were top-dressed at 5 different rates (5, 10, 15, 20, and 25 tons/acre) in a randomized, complete block design at the North Carolina A&T State University Farm in Greensboro, NC. Compost was applied to a turf-type fescue in research plots established the previous spring. The composts were reapplied at these same rates in the spring of 2004. Biomass samples were taken monthly from June until October in 2003 and from May until October in 2004. Biomass samples were weighed, dried, and will be evaluated for N concentration. Plots were cored to a depth of 45 cm (in 15-cm segments) in the fall of 2002, October 2003, and in October 2004. These samples have been dried and weighed, and will be analyzed for total N, NH_4-N and NO_3-N concentrations. Data will be used to determine an N budget and for calculating nutrient release curves and compost availability coefficients. Sample analysis is on hold because with the recent project closeout, funds budgeted for laboratory analysis reverted to NC State University. Currently, we are exploring alternative funding for sample analysis.

Similar information has been collected for a rotational series of crops that have received compost applications at similar rates at the Center for Environmental Farming Systems in Goldsboro, NC. That rotation was collards followed by sweet corn, followed by collards. Additional compost was applied prior to transplanting collards in the fall of 2003. Biomass samples of the collards and corn were collected and analyzed for N. Yield data has been collected for both crops, and soil samples were taken prior to planting and at harvest of all crops. N release curves and compost availability coefficients will be determined for compost applied at that site.

All data will be statistically analyzed for the purpose of determining a general N availability regression equation for composts generally, as well as to ascertain compost characteristics that influence N availability.

Technology Determination per Agreements Between the Attorney General of North Carolina and Smithfield Foods, Premium Standard Farms, and Frontline Farmers

SUMMARY REPORT

Funding:
$7,732,000

Funding Source:
Smithfield Foods
Premium Standard Farms
(via North Carolina Attorney General's Office)

Research efforts to identify and implement "Environmentally Superior Technologies" (EST) were initiated in 2000 by the Attorney General of North Carolina by an agreement with Smithfield Foods and its subsidiaries, and a similar agreement with Premium Standard Farms. A third agreement was established between the Attorney General of North Carolina and Frontline Farmers in 2002.[1]

Performance standards defined in the Agreements mandate that successful EST address environmental variables including the discharge of animal waste to surface waters and groundwater; emission of ammonia; emission of odor; release of disease-transmitting vectors and airborne pathogens; and nutrient and heavy metal contamination of soil and groundwater. Comprehensive determinations of economic feasibility are also mandated by the Agreements. Targeted economic variables include projected 10-year annualized cost for each technology; projected revenues from byproduct utilization; available cost-share monies; and the impact that the adoption of the EST may have on the competitiveness of the North Carolina pork industry as compared to the pork industry in other states.

The Super Soils technology

Candidate EST technologies were competitively selected. They include solids separation systems, a covered in-ground anaerobic digester with biological trickling filters and greenhouse vegetable production, mesophilic and thermophilic anaerobic digesters, a sequencing batch reactor, an upflow biological aerated filter system, a gasification system, belt manure removal systems, and wetland systems. In addition to these systems, technologies not

Investigator:
C. M. Williams, North Carolina State University

[1] See Agreements between Attorney General of North Carolina and, SF, PSF, and Frontline Farmers (North Carolina Department of Justice, on file with Ryke Longest, 2000 & 2002). Also available at www.cals.ncsu.edu/waste_mgt/

Technology Determination per Agreements Between the Attorney General of North Carolina and Smithfield Foods, Premium Standard Farms, and Frontline Farmers

funded directly by this initiative but under development by Smithfield Foods in Utah (bio-fuel from manure project), Premium Standard Farms in Missouri (several technologies per a consent decree between Premium Standard Farms and the state of Missouri and USEPA), Sustainable North Carolina and Frontline Farmers (closed loop swine waste management system located in eastern North Carolina) are being followed as potential EST. Detail progress reports describing the EST initiative between the dates of July 25, 2000 and July 25, 2003 have been published.[2] On July 26, 2004 a Technology Determination Report was issued.[3] The Technology Determination Report, as described in the Agreements, comprises "a written determination that contains a finding relative to a technology or combination of technologies candidacy as an Environmentally Superior Technology or Technologies."

ORBIT high-solids anaerobic digester

In brief, the July 26, 2004 report focuses on 8 of the candidate EST that were targeted for an initial (Phase 1) technology determination. Two of the technologies considered in the Phase 1 determinations were shown to be capable of meeting the Agreements technical performance standards that define an Environmentally Superior Technology. Those technologies are: 1) the solids separation/nitrification–denitrification/soluble phosphorus removal system ("Super Soils" technology) and 2) the high solids anaerobic digester system ("ORBIT" technology). The data also indicate that, with technical modifications and/or combination of some of the technology unit processes, additional technologies considered in the Phase 1 determinations may meet the technical performance criteria. Recommended next steps described in the report include:

1. Identify company owned farm(s) for installment and evaluation of a proposed revised cost "Super Soils" technology.
2. Establish a framework such that the "ORBIT" technology

[2] See Development of Environmentally Superior Technologies: One, Two, and Three Year Progress Reports, published by NCSU College of Agriculture and Life Sciences, on file with NCSU Animal and Poultry Waste Management Center (July 25, 2001; 2002; 2003). Also available at www.cals.ncsu.edu/waste_mgt/

[3] See Development of Environmentally Superior Technologies: Phase 1 Technology Determination Report, published by NCSU College of Agriculture and Life Sciences, on file with NCSU Animal and Poultry Waste Management Center (July 26, 2004). Also available at www.cals.ncsu.edu/waste_mgt/

Technology Determination per Agreements Between the Attorney General of North Carolina and Smithfield Foods, Premium Standard Farms, and Frontline Farmers

can operate and process solids from the "Super Soils" or from other candidate technologies generating solids which require further processing of these materials to meet the technical performance criteria.

3. Establish specific criteria to be used in making economic feasibility determinations applicable to the technologies described above, and also for application to the remaining candidate technologies.
4. Conclude the technical performance and economic feasibility analysis for these and all remaining candidate technologies as soon as possible and subsequently identify reasonable modifications, combinations, if required and if possible, for the technologies to be unconditionally "Environmentally Superior.."
5. Identify potential incentives, public policy, and markets related to the sale of byproducts (including energy) generated by the 2 technologies described above as well as the candidate technologies still under evaluation pursuant to the Agreements. Also identify legal and institutional obstacles that must be addressed to maximize the revenue potential of these byproducts.
6. Begin, and if possible complete over the next year, development of state permit conditions as well as proposed National Pollutant Discharge Elimination System (NPDES) permit conditions (if required) for the technologies described above and also for any additional technology under consideration that may meet the Environmentally Superior Technology criteria in the Agreements.

Establish a plan for implementation that describes which farms in North Carolina must adopt Environmentally Superior Technology and over what time profile. The plan should include a mechanism to monitor both environmental and economic performance, a schedule for implementation, and a discussion of how the timing of implementation affects the economic feasibility criteria of candidate EST.

Volatile Emissions from Composting Dairy Manures as Indicators of Bioprocesses and Objectionable Odors

Environmentally Superior Technology Project Status (July 2004)[4]

Technology Candidate	Environmental Performance Data Procurement	Economic Feasibility Determination
Ambient Temperature Anaerobic Digester and Greenhouse for Swine Waste Treatment and Bioresource Recovery at "Barham Farm"	Complete	Complete
"Ekokan" Biofiltration Technology	Complete	Complete
"ReCip" Solids Separation – Reciprocating Wetland	Complete	Complete
"Super Soils" Solids Separation/ Nitrification-Denitrification/Soluble Phosphorus Removal System	Complete	Complete
Belt System for Manure Removal/ Gasification of Solids	Complete (belt component)	Complete
Belt System for Manure Removal/Insect Biomass from Solids	Complete (belt component)	Complete
"ORBIT" High Solids Anaerobic Digester	Complete	Complete
"BEST" Biomass Energy Sustainable Technology	Complete	Complete
Solids separation/constructed wetlands system	In progress	In progress
"ISSUES" Permeable cover/aerobic blanket/ mesophilic digester/microturbine/ water reuse system	In progress	In progress
"ANT" Sequencing batch reactor system	In progress	In progress
"AgriClean" Mesophilic digester and "AgriJet" flush system	In progress	In progress

[4] Environmental performance data and economic feasibility determinations where listed "complete" represent final and / or draft final report submissions by the project investigators in July 2004. "In progress" status represents continued data measurements and procurements for those projects (scheduled to be completed in 2005).

Water Recycling and Use of Recovered Nutrients in Animal Production Systems

Funding:
$459,716

Funding Source:
federal

Investigators:
Leonard S. Bull, North Carolina State University

C. M. Williams, North Carolina State University

John M. Rice, North Carolina State University

Diana G. Rashash, North Carolina State University

SUMMARY REPORT

The objectives of this work are to investigate techniques and technologies for reducing water use, including recycling of water, in animal production systems (primarily swine). In addition, the possibility of using nutrients and other potentially value-added co-products resulting from water recovery and recycling systems is to be investigated.

Waste-water Recovery and Recycling for Animal Consumption:
Waste-water recovered from a comprehensive swine waste treatment system installed on a Smithfield Foods operation in North Carolina as part of the technology evaluations on-going within the agreements between Smithfield Foods, Premium Standard Farms and the North Carolina Attorney General (Innovative Sustainable Systems Using Economic Solutions, ISSUES; www.cals.ncsu.edu/waste_mgt/) is being recycled as drinking water for finishing swine. The water is recovered from a process that includes anaerobic digestion, aerobic digestion, and denitrification, followed by clarification, treatment with polymer, sand bed filtration, reverse osmosis and UV treatment. A second line of investigation will involve a planned collaboration with Premium Standard Farms in which recycled water is being used in swine production. Premium Standard Farms has gained considerable experience in this area, and the work to be undertaken will address some of the critical issues identified in those studies as needing attention. In all cases, animal performance, animal health, product quality (as applicable), water quality and related management data will be gathered. Results will be reported in 2005.

Waste Collection without Water Use:
There have been two projects among the technology verifications noted above that have used belt systems installed under slatted floor swine housing pens to separate urine and feces for subsequent processing (see www.cals.ncsu.edu/waste_mgt/). The purpose of the belt is to eliminate the use of flushing the waste holding areas under the pens with large volumes of water, and to produce separate streams of urine for nitrogen recovery and solids for more economical transport and subsequent processing into value added products without the cost of handling excessive amounts of water. Belt systems have been in use in Europe (successfully) for several years. There is interest in developing the engineering technology to retrofit existing slatted floor flush, pull-plug and pit recharge buildings for installation of belt systems, and to redesign new building plans to allow installation at construction. While there are several technical hurdles to be overcome, the concept is promising and will be further investigated in the future.

Management of Closure or Remediation of Swine Waste Treatment Lagoons (USDA Special Grant)

Funding:
$457,392

Funding Source:
federal

SUMMARY REPORT

Research continues to address the following aspects of nutrient management in active and inactive anaerobic lagoons used for swine waste management: a. improved methods for measurement of sludge depth; b. development of a laboratory-scale simulation of conditions in anaerobic waste treatment lagoons; c. characterization of microbial families in lagoon material (sludge and treatment zone); c. evaluation of biological products and processes for sludge reduction and management in both active and inactive anaerobic swine waste treatment lagoons.

Remote Sludge Depth Measurement using Sonar-based Fish Finders:

Two commercially available, sonar based, fish finders were evaluated as alternative methods for measuring the amount of sludge in lagoons. Initially a relatively inexpensive model was investigated to determine whether the technology had the potential to measure the distance from the lagoon liquid surface to the top of the sludge layer and the lagoon bottom. The sonar unit (fish finder) was consistent with conventional methods at measuring the distance from the liquid surface to the top of the sludge layer but was not reliable at measuring the distance to the lagoon bottom. Therefore, it was concluded that the sonar based fish finder, when operated by an experienced operator, could be an alternative to conventional measurement methods. The next step was to investigate the potential for using a fish finder, with data logging capability, and GPS technology as part of a system assembled from off the shelf components that could reliably measure, record and later down-load data as well as plot a topographical sludge and lagoon map. To this end, a Lowrance Model LCX-18C fish finder was obtained and mounted in a remote controlled boat from Dumas Products. The field experiences and data collected to date indicate that such a system has the potential to take measurements and provide a sludge map for a lagoon although there are still some technical problems to be overcome (performance in lagoons nearly filled with sludge, debris collecting on boat propeller). In

Investigators:
Leonard S. Bull, North Carolina State University

C. M. Williams, North Carolina State University

Frank Humenik, North Carolina State University

Management of Closure or Remediation of Swine Waste Treatment Lagoons (USDA Special Grant)

some cases the amount of sludge and foreign matter it the lagoon make the use of this remote controlled boat impossible. Despite these drawbacks, some integrators have purchased and are using similar equipment.

***Laboratory-Scale Simulation of Anaerobic Waste Treatment Lagoon Conditions**:*

A system based on 120 liter opaque plastic containers with patent closures was developed. Each container was equipped with two ports in the cover to allow air to be introduced or fermentation gases to be collected. Aeration capacity was provided using submersible air dispersion blocks for fine bubbles, powered by a variable-flow compressor. The system was developed with 24 containers and aeration capability using flexible tubing extending through one cover port. A timer allows aeration frequency and duration to be controlled automatically as needed for a specific protocol. This system has been and is used to screen and evaluate biological products for sludge management, reduction or elimination, using replications of treatments or graded treatment levels as appropriate. Samples are easily taken by stirring container contents, resulting in repeatable measures of critical composition (chemical or microbial). To date three sets of trials (length 21-35 days each) have been conducted as part of the development of the system, to both evaluate repeatability of protocols and gather data on biological products. Results to date do not suggest that the products used are significantly effective. A comprehensive sampling and sub-sampling trial was conducted to evaluate repeatability of sampling of material from the source, sub sampling of source material and laboratory analytical repeatability. That trial has been completed and the results are being prepared for publication and distribution.

120-liter opaque plastic containrs were used to simulate anaerobic waste treatment conditions.

During one trail where live organisms were added daily to treatment vessels of fresh swine flush waste, the lack of response was attributed to the fact that the flush material contained on average 1.5 ppm Cu (375ppm DM basis). Data from other laboratories suggest that such concentrations of Cu could be detrimental to organisms that are not specifically selected for high-copper tolerance. More work is needed on this observation in cases where Cu is added to diets at therapeutic levels to enhance growth and performance.

Management of Closure or Remediation of Swine Waste Treatment Lagoons (USDA Special Grant)

In addition, a battery of four 1-liter fermentors has been established to enable conduct of experiments with microbial or chemical treatments intended to enhance biogas production. The fermentor system has capacity to collect biogas volumetrically and also to determine carbon dioxide, moisture and methane content. Several studies have been conducted with this system to evaluate the capacity of proposed lagoon additives for enhancing carbon release and thus sludge and biomass reduction. One tested product that is widely used on swine farms resulted in significant increase in gas production when introduced into the fermentors (rate of biogas production increased 56 percent during 5-day test period). A large number of potential treatment materials are being evaluated using this process and that work continues.

Microbial Families in Anaerobic Swine Waste Treatment Lagoons*:*
Samples of material from a series of the Laboratory-Scale System (above) were gathered according to standard procedures for microbial sampling and analyzed by personnel in the Environmental Microbiology Group, School of Public Health, University of North Carolina at Chapel Hill. A total of five treatment combinations were included plus a control, replicated four times each. Two treatment systems included aeration for 60 minutes twice daily during the 42-day trials. Results of the analyses follow, and indicate that there were no major differences among treatments. The lack of difference due to aeration is surprising, and probably indicates that more extensive aeration duration is needed to create an effect.

Lagoon Simulation Columns:
Two clear, circular polyplastic columns (3m high x 20 cm diameter) were installed in a light-excluded room with ability for heating as needed to simulate the entire lagoon depth. Each column was fitted with 8 sampling ports, spaced equidistant from top to bottom, to enable samples to be taken for microbial and chemical analyses from the entire lagoon column (treatment and sludge zones). In addition, the columns are fitted with caps that can be sealed, and with gas sampling ports to enable gas production to be measured. Initially the columns were filled with lagoon material, and are top-fed weekly with fresh swine barn flush material. One of the columns is being treated with an oxidizing agent, and the other serves as a control. Dissolved oxygen level is monitored weekly. Samples are taken regularly at various levels of the column for microbial analysis using Restriction Fragment Length Polymor-

Management of Closure or Remediation of Swine Waste Treatment Lagoons (USDA Special Grant)

phism. This work is being conducted by faculty and students in the Department of Microbiology at North Carolina State University. Initial results indicate that the treatment imposed resulted in substantially reduced levels of detected pathogenic organisms. Followup work is underway as are numerous additional studies associated with lagoon microbial communities.

Biological Treatment of Sludge in Anaerobic Swine Waste Treatment Lagoons:
Two farm-scale lagoons were selected for monitoring of sludge depth and nutrient content before and during treatment with biological products reported to be effective in sludge reduction. One treatment included aeration of the lagoon and one did not require aeration. Lagoon sludge depth was monitored at 3-month intervals for a year, and samples were gathered (approximately 20 full lagoon content column samples per lagoon acre) for nutrient analysis. Data to date suggest only modest reduction in depth of sludge but some trend in reduced nutrient concentration in the sludge layer is observed in preliminary results. Mechanism of action is being investigated. In another study (under way) the oxidizing agent used in the column studies mentioned above is being applied to several lagoons with untreated controls, to evaluate the impact of this treatment on sludge reduction, odor and ammonia emission and animal health/performance. Early results suggest a reduction in lagoon sludge depth due to treatment, and worker-reported reductions in odors in buildings flushed with treated material.

Effects of Nutrition and Waste Management Technologies on Pathogens in Animal Excreta

Funding:
$962,862 - NC State University
$1,403,138 - The Ohio State University

Funding Source:
USDA (IFAFS)

SUMMARY REPORT

This collaborative project between North Carolina State University and The Ohio State University addresses the relationship of animal nutrition, production and waste management practices / technologies on the fate of pathogenic microorganisms in manure from poultry and swine. During the past 2 years investigators have:

- Characterized populations of microbial pathogens present in commercial poultry and swine operations, including conventional systems and systems utilizing experimental innovative waste treatment technologies,
- Examined nutritional or dietary components potentially affecting the production, frequency and fate of pathogenic microorganisms in excreta,
- Assessed pathogen survival and persistence following waste treatment and land application,
- Developed a prototype on-farm Hazard Analysis and Critical Control Point (HACCP) program for poultry production.

Results to date have shown that of the innovative swine waste treatment systems studied, up to a 3.8-log reduction in *Salmonella* populations have been measured. This compares to an approximate 2.8 log reduction measured for the conventional lagoon spray-field swine waste treatment technology. The study is also examining *Salmonella* incidence in excreta and litter from commercial broiler and turkey farms as a function of bird age and season, as well as the impact of laying-hen production cycle and molting on the incidence and populations of *Salmonella* in fresh excreta. Detail results of these studies as well as an antibiotic susceptibility study will be reported in 2005.

Results for the nutritional studies have shown positive effects of natural feed supplements that modified pathogen gut colonization in broilers and turkeys. Incidence of *S. enteritis* infected broilers and mortality of *Salmonella* positive turkeys were reduced in birds receiving a mannanoligosaccharide (MOS) direct fed substrate. Gut

Investigators:
C. M. Williams[1], North Carolina State University

[1] NCSU project investigators include: B. Sheldon, P. Ferket, X. Li; The Ohio State University project investigators include: Y. Saif, W. Dick, F. Michel, L. Saif, K. Theil, L. Ward, Q. Zang, J. LeJeune.

Effects of Nutrition and Waste Management Technologies on Pathogens in Animal Excreta

health and improved feed conversion was observed in broilers receiving 2 kg MOS/tonne supplement. In separate studies commercially developed exogenous enzymes (Versazyme, NSP Enzymes and Phospholipase) supplementation of corn and wheat/SBM-based diets improved gut histomorphology in broilers and turkeys. Work is in progress to investigate the effect of exogenous enzyme (xylanase) supplementation in wheat-based diets (to replace corn-based diets) on growth performance and *Salmonella* prevalence in turkeys. These and additional nutritional studies including the use of novel supplements in poultry drinking water to increase tolerance to and recovery from enteric diseases will be completed in 2005.

Assessment of Antimicrobial Resistant Bacteria Associated with Swine Operations and their Neighboring Ground and Surface Water Environments

Funding:
$22,327

Funding Source:
North Carolina Department of Health and Human Services

Investigator:
C. M. Williams, North Carolina State University

SUMMARY REPORT

The North Carolina State University (NCSU) Animal and Poultry Waste Management Center (APWMC) is collaborating with the NC Department of Health and Human Service Division of Public Health, UNC-Chapel Hill, and Wake Forest University in this project.

The long term research goals of this project element is to gain knowledge and understanding of the emergence and persistence of antimicrobial resistant bacteria, including potential human pathogens, associated with swine concentrated animal feeding operations (CAFOs) and their neighboring ground and surface water environments.

To date, the APWMC has coordinated with the project investigators to identify appropriate commercial scale CAFO facilities required for the epidemiology study model. In this role the APWMC is structuring a protocol to serve as the field liaison between the CAFO workers and project scientists investigators regarding site identifications, company, worker and community contact, and data collection.

Discussions have been held with the project investigators regarding the current APWMC field activities associated with the Agreements between the Attorney General of North Carolina and Smithfield Foods (SF), Premium Standard Farms (PSF), and Frontline Farmers for the development and performance verification of "Environmentally Superior Technologies" to treat swine waste. This initiative has enabled the APWMC to develop a network of contacts within the swine production companies and farmers, and associated communities. Discussion focus has involved the scope of variability in the various project operations relative to building designs, waste management practices, location in the state and how these variables may impact the experimental design of an epidemiology study.

The proposed experimental design includes 10 farms that are representative of contract grower operations in North Carolina. Ten control farms, comprised of row crop operations only (e.g. – no livestock or poultry production) within the same postal zip code location as the selected swine farms are also targeted. All farms must contain surface water environments. Plans are to finalize site selections and initiate field sampling in early 2005.

Publications and Presentations

Aneja, V.P., D.S. Kim, P. Arya, W. Robarge, L. Todd, D. Dickey, L. Stefansky, M. Williams, H. Arkinson, H. Semunegus, K. Bajwa, I. Rumsey and Z. Holmes. 2003. An evaluation of the emissions of ammonia from four potential environmentaly superior technologies for swine facilities: Barham, Corbett #2, and Howard farms, and Grinnells Laboratory. Proceedings of the North Carolina Animal Waste Management Workshop. Research Triangle Park, NC. October 16-17, 2003. Pgs. 91-101.

Aneja, V.P., D.S. Kim, S.P. Arya, W. Robarge, P. Westerman, M. Williams, D. Dickey, H. Arkinson, H. Semunegus, J. Blunden, M. Sobsey, L. Todd, G. Ko, W. Verkruysse, K. Mottus, C. Likirdopulos, O. Simmons, S. Schiffman, and B. Graham. 2003. An intergraded study of the emissions of ammonia, odor and odorants, and pathogens and related contaminants from potential environmentally superior technologies for swine facilities: Program OPEN (Odor, Pathogens, and Emissions of Nitrogen), Proceedings of the International Symposium on Gaseous and Odors Emissions from Animal Production Facilities@, ISBN 87-88976-66-1,PP. 478-484.

Armstrong, T.A., D.R. Cook, M.M. Ward, C.M. Williams, and J.W. Spears. 2004. Effect of dietary copper source (cupric citrate and cupric sulfate) and concentration on growth performance and fecal copper excretion in weanling pigs. J. Anim. Sci.

Boyd, Garth. 2003. Lower Cape Fear River Program Advisory Board meeting. Wilmington, NC. Technology Update. September 23, 2003.

Boyd, Garth. 2003. North Carolina Pork Council Board of Directors meeting. Raleigh, NC, SF/AG Agreement Technology Update. August 5, 2003.

Boyd, Garth. 2003. Animal Residuals conference. SF/AG Agreement Technology Update. November 3, 2003. Arlington, VA.

Boyd, Garth. 2004. Agricultural Air Quality Task Force meeting. Panel discussion on hog waste treatment technologies. March 10, 2004. RTP, NC.

Bull, L. S. 2003. Critical Components of Animal Waste Management Systems. Proceedings of IX World Conference on Animal Production, p. 245. Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil. WAAP, Rome.

Bull, L. S. 2003. Air, Water and Soil Protection Associated with Animal Production. Proceedings of IX World Conference on Animal Production, p. 245. Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil. WAAP, Rome.

Bull, L. S. and C. M. Williams. 2003. Overview of Innovation in Manure Processing Technologies-Efforts at North Carolina State University funded by the Attorney General Agreements with Smithfield Foods, Premium Standard Farms and Frontline Farmers. Proceedings, University of Illinois Pork Industry Conference, Swine Odor and Manure Management. pp. 183-189.

Bull, Leonard S. and Prince Dugba. 2003. Conversion of Swine Manure Wastewater into Recovered Energy and Reuse Water. Proceedings, North Carolina Animal Waste Management Workshop. October 16-17, 2003. Research Triangle Park, NC. 18p.

Bull, L. S. 2003. Manure Management Technologies. Environmental Quality and Agriculture. November 10-12, 2003. Des Moines, IA. 24p.

Publications and Presentations

Bull, L. S. 2003. Nutrient Management: Balancing Production Goals and Environmental Quality. Environmental Quality and Agriculture. November 10-12, 2003 Des Moines, IA. 18p.

Bull, L. S. 2003. Turning Waste into Watts: The Anaerobic Digester Summit, Session 11, NCSU Virtual Tours. June 2-4, 2004, Raleigh, NC.

Bull, L. S. 2004. A Review on Development of Livestock Systems in North America. WAAP Book of the year – 2003. Editors: A. Rosati, A.Tewolde and C. Mosconi. P13-22. Wageningen Academic Publishers, Wageningen, The Netherlands.

Bull, Leonard S. 2004. Swine: Waste Management. In: Marcel Dekker Encyclopedia of Animal Science. Editors: Wilson G. Pond and Alan W. Bell. 4p. Marcel Dekker, Inc. New York.

Cheng, J., T. E. Shearin, M. M. Peet, and D. H. Willits (In press) Utilization of Treated Swine Wastewater for Greenhouse Tomato Production. Water Sci. Technol.

Cheng, J., T. E. Shearin, M. M. Peet, and D. H. Willits 2003. Utilization of Treated Swine Wastewater for Greenhouse Tomato Production. Proceedings of the 4th International Symposium on Wastewater Reclamation and Reuse. November 12-14, 2003. Mexico City, Mexico.

Cheng, J., M. M. Peet, and D. H. Willits. 2003. Ambient temperature anaerobic digester and greenhouse for swine waste treatment and bioresource recovery at Barham farm. Proceedings of the 2003 North Carolina Animal Waste Management Workshop. October 16-17, 2003. Durham, NC,

Elwell, D. L., D. C. Borger, D. V. Blaho, J. K. Fahrni, H. M. Keener, and L. B. Willett. 2004. Changes in concentrations of malodorous compounds from fresh and aged dairy manure during controlled aeration composting. Compost Sci. & Utilization 12:102-107

Elwell, D. L., D. C. Borger, H. M. Keener, and L. B. Willett. 2004. Concentrations of malodorous, volatile chemicals in composting dairy manure. Transactions of the ASAE, (Submitted)

Harlow, C., M. M. Peet, A. K. Ponce, J. Cheng, D. H. Willits, and M. Casteel. 2003. Utilizing a greenhouse tomato crop to recover bio-resources from swine waste. Proceedings of the ASHS-2003 Centennial Conference. October 3-6, 2003. Providence, RI.

Humenik, Frank J., 2003. Environmentally Superior Technologies being Evaluated in North Carolina. Living with Livestock-Environment and Change Conference Proceedings. October 7, 2003. Winnipeg, Manitoba, Canada. page 31.

Humenik Frank, J.M. Rice, C. Baird, Dianna Rashash, John Classen and S. Liehr. 2003. Emerging Issues and Technologies and for Managing Poultry Waste and Lagoons. National Poultry Waste Management Symposium Proceeding. October 26, 2003. Memphis, Tennessee.

Miner, J.R., F.J. Humenik, J.M. Rice, D.M.C. Rashash, C.M. Williams, W. Robarge, D.B. Harris, and R. Sheffield. 2003. Evaluation of a permeable, 5-cm thick polyethylene foam lagoon cover. *Trans. of the ASAE*. 46(5):1421-1426.

Ponce, K.H., M. M. Peet, J. Cheng, C. Harlow, D.H. Willits. (In press) Preliminary assessment of swine waste bioremediation using greenhouse tomatoes. Acta Horticulturae.

Publications and Presentations

Thibodeau M.S, M.H. Poore, W.M. Hagler Jr, and G.M. Rogers. 2004. Effect of fermentation on sweetpotato (Ipomoea batatas) toxicity in mice. J Agric Food Chem. 52: 380-384.

Shearin, T. E., J. Cheng, M. M. Peet, and D. H. Willits. 2003. Utilization of nutrients in anaerobically-pretreated swine wastewater for greenhouse tomato production. Proceedings of the Ninth International Symposium on Animal, Agricultural and Food Processing Wastes (ISAAFPW), October 12-15, 2003, Durham, NC, USA.

Schiffman, S., Graham, B., McLaughlin, B., Fitzpatrick, D., Katul, G., Nagle, T., and Williams, C.M. 2003. Predicting odor dispersion at five swine facilities using a Eulerian-Lagrangian model. Proceedings North Carolina Animal waste Management Workshop. October 16-17, 2003. Research Triangle Park, NC. Edited by G.B. Havenstein. Published by College of Agriculture and Life Sciences, NCSU, Raleigh, NC. Pages 102-111.

Schiffman, S.S. and C.M. Williams. Science of odor as a potential health issue. J. Envir. Qual. (in press).

Vanotti, M., P. Hunt, A. Szogi, F. Humenik, P. Millner, and A. Ellison. 2003. Solids separation, nitrification-denitrification, soluble phosphorus removal, solids processing system. Proceedings North Carolina Animal Waste Management Workshop, October 16-17, 2003. Raleigh, NC. pp. 30-35. (CD-ROM)

Westerman, P. W. and J. Arogo. 2003. Performance of the IESS biokinetic air waste treatment system on a swine farm. In: Proceedings of the 9th International Symposium on Animal, Agricultural and Food Processing Wastes. October 12-15, 2003. Research Triangle Park, NC. ASAE, St. Joseph, MI. p. 153-163.

Westerman, P. W. and J. Arogo. 2003. Ekokan upflow biofiltration treatment system. In: Proceedings of the North Carolina Animal Waste Management Workshop. October 16-17, Research Triangle Park, NC. p. 26-29.

Westerman, P. W., J. Arogo, G. Boyd and K. Elmer. 2003. Evaluation of "BEST" system – Solids/liquid separation and solids combustion. In: Proceedings of the North Carolina Animal Waste Management Workshop. October 16-17, 2003. Research Triangle Park, NC. p. 54-61.

Westerman, P. W., J. Arogo, A. Kantardjieff and P. Kantardjieff. 2003. Evaluation of Ekokan biofiltration treatment system on a swine farm. ASAE Paper No. 03-4125. 2003 ASAE Annual International Meeting, Las Vegas, Nevada, July 27-30, 2003. 16 pg. ASAE, St. Joseph, MI.

Williams, C.M. 2003. Performance verification of candidate environmentally superior technologies. Poultry Science Annual Meeting, Madison, WI, July 6-9, 2003. Abstract No 241 pg 58.

Williams, C.M. 2003. Development of Environmentally Superior Technologies: NC Agreements - Progress Report. Public Meeting (mandated by Agreements) held in Clinton, NC, July 22, 2003.

Williams, C.M. 2003. Swine Production: Environmental Issues and Development of New Waste Treatment Technology-Future Perspective (Invited presentation). Proceedings International Conference and Exhibition on Pig Production. Bejing, China. September 9-12, 2003. 2 pgs.

Williams, C.M. 2003. Development of Environmentally Superior Technologies – Progress Report NC Attorney General Agreements. Pfizer Animal Health Customer Appreciation Meeting, Myrtle Beach, SC, October 4, 2003.

Williams, C.M. 2003. Development of Environmentally Superior Technologies – Progress Report NC Attorney General Agreement. American Society Agricultural Engineers Meeting, Research Triangle Park, NC, October 12, 2003.

Publications and Presentations

Williams, C.M. 2003. Invited panel member - Potash Corp. Phosphorus Cycle Symposium, Research Triangle Park, NC. October 15, 2003.

Williams, C.M. 2003. Status of the Smithfield Foods and Premium Standard Farms Projects to Identify " Environmentally Superior Technology" per NC Attorney General Agreements. 2003 North Carolina Animal Waste Management Workshop. Research Triangle Park, NC. October 16-17, 2003.

Williams, C.M. 2003. Value-Added Products from Animal Waste. Value-Added Agriculture for NC Agricultural Leaders Meeting. Raleigh, NC, October 27, 2003.

Williams, C.M. and L. S. Bull. 2004. Alternative uses and value added processing of animal waste products. Paper 704. Federation of Animal Science Societies Annual Meeting, St. Louis, MO.

Williams, C.M, and F.J. Humenik (presentation by FJH). 2003. Innovation in Manure Management Technologies. The Fertilizer Industry Round Table Program, Winston-Salem, NC. October 27, 2003.

Williams, C.M. 2003. Development of Environmentally Superior Technologies: NC Agreements, NC Irrigation Society Annual Conference, Raleigh, NC, November 4, 2003.

Williams, C.M., and L.S. Bull (presentation by LSB). 2003. Nutrient Management: Balancing Product Goals and Environmental Quality. EQA, Environmental Quality & Agriculture-Coexisting in the 21st Century. Des Moines, IA. November 10-12, 2003. Williams, C.M. 2003.

Williams, C.M. 2003. Development of Environmentally Superior Technologies: NC Agreements - Progress Report. Frontline Farmers Annual Meeting, Kenansville, NC, November 13, 2003.

Williams, C.M. 2003. Development of Environmentally Superior Technologies: NC Agreements - Progress Report. Kinston Regional Pork Conference. Kinston, NC. November 20, 2003.

Williams, C.M., and L.S. Bull (presentation by LSB) 2003. Overview of Innovation in Manure Processing Technologies-Efforts at NCSU funded by the Attorney General Agreements with Smithfield foods, Premium Standard Farms and Frontline Farmers. UI Pork Industry Conference on Swine Odor and Waste Management. Urbana, IL. December 11-12, 2003. 11 pgs.

Williams, C.M. 2004. Development of Environmentally Superior Technologies-Status Report. South Carolina Pork Board. Columbia, SC. January 28-30, 2004.

Williams, C.M. 2004. Development of "Environmentally Superior Technologies" for Animal Waste Management in North Carolina. North Carolina State University. Raleigh, NC. February 18, 2004.

Williams, C.M. 2004. Biomass Sources of Energy: Animal Waste. Efficient NC: Leading by Example. NCSU-McKimmon Center. Raleigh, NC. March 4, 2004.

Williams, C.M. 2004. Panel Discussion on the Smithfield Settlement Agreement. USDA-Agricultural Air Quality Task Force. Research Triangle Park, NC. March 11, 2004.

Williams, C.M. 2004. Pork Production: Trends, Environmental Issues, New Technology for Waste Treatment and Future Perspective. Key note address. Pan Pacific Pork Expo. Brisbane, Australia. March 18, 2004.

Publications and Presentations

Williams, C.M. 2004. Development of Environmentally Superior Technologies-Status Report. Environmental Commission Committee Meeting, Raleigh, NC. March 25, 2004.

Williams, C.M. 2004. Sponsored Projects, Progress, and Future Directions. NCSU-Animal Science Department. April 26, 2004.

Willits, D. H., J. M. Marbis, J. Cheng, M. M. Peet, and T. Shearin. 2003. Waste heat utilization in a greenhouse used for the removal of nutrients from a swine waste stream. Proceedings of the ASAE Annual International Meeting, July 27- 30 2003, Las Vegas, Nevada, USA. (Paper No. 034043)